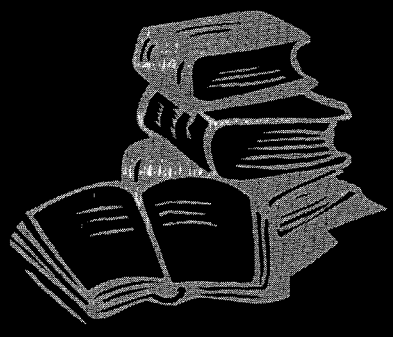
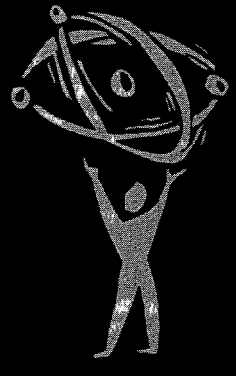


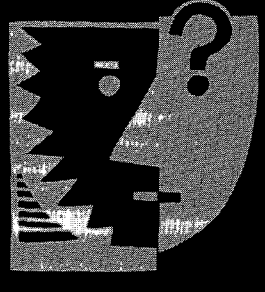
SECONDARY EDUCATION SERIES

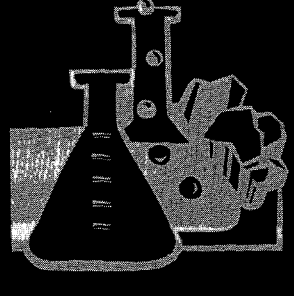
19659
August 1999

SCIENCE AND ENVIRONMENT EDUCATION VIEWS FROM DEVELOPING COUNTIRES

Sylvia A. Ware, editor







EDUCATION
THE WORLD BANK

World Bank, Human Development Network
Secondary Education Series

Science and Environment Education Views from Developing Countries

Sylvia A. Ware, Editor

The World Bank
Washington, D.C.

Contents

Foreword

Welcome to the Human Development Network–Education Group's Secondary Education Series.

The World Bank has been helping developing countries reform their secondary education systems since it started making loans for education more than 35 years ago. Now, the World Bank is facing increasing demands from its clients for more attention to the secondary phase. There are many expectations for this phase:

- To provide education for the increasing number of students who are completing basic education as a result of the successful expansion of educational opportunity.
- To cope with the often low quality of education experienced by students in the primary phase.
- To give students the *higher* levels of *new* skills needed in the rapid-changing, global economy.
- To ensure lifelong learning. The necessary attitudes and aptitudes need to be acquired before students exit secondary education (those same attitudes and aptitudes will more likely ensure that fewer students drop out of secondary education).
- To teach students of various ages—those who have progressed smoothly through primary education, those who have repeated one or more years, and those older students returning to education. This requires new, different, flexible forms of and opportunities for learning.
- To emphasize the importance of secondary education in promoting active citizens.

This series will address a wide range of topics within secondary education that reflect these challenges.

A central requirement for any successful reform of secondary education is an understanding of good (and poor) practice in different countries around the world. This Secondary Education Series is part of the World Bank's contribution to developing that understanding.

This volume, *Science and Environment Education: Views from Developing Countries*, is the first in the Secondary Education Series. But it is also unusual in another respect: it sets out specifically to bring to a wider audience the views and experiences of those working in the World Bank's client countries. The authors are coping with the daily reality and complexity of science and environment education reform. By publishing these experiences, we hope to open a channel of communication for those engaged in reform activities. We invite readers' comments on the value of these essays and this approach. Given a positive response to this experiment, we intend to continue to publish the views of practitioners on a variety of secondary education topics, alongside other more traditional papers. This paper is the result of a collaboration between the Human Development Network Education Team and the Human Development Sector Unit of the Latin American and Caribbean Region.

Toby Linden
World Bank
May 1999

Avant-propos

Bienvenue sur le réseau Développement humain — Série de l'enseignement secondaire du Groupe de l'éducation.

La Banque mondiale aide les pays en développement à réformer leurs systèmes d'enseignement secondaire depuis qu'elle a commencé à accorder des prêts à l'éducation, il y a plus de 35 ans. Elle s'efforce maintenant de répondre aux demandes de ses clients de plus en plus soucieux de consacrer davantage d'attention à l'enseignement secondaire, qui suscite de nombreuses attentes :

- Dispenser un enseignement au nombre croissant d'élèves à avoir reçu une éducation de base du fait que l'on est parvenu à ouvrir plus largement les portes de l'enseignement.
- Faire face au problème que pose le niveau souvent insuffisant de l'enseignement dispensé aux élèves dans le primaire.
- Permettre aux élèves d'atteindre des niveaux *plus élevés* et d'acquérir les compétences *nouvelles* rendues nécessaires par une économie mondialisée et en pleine évolution.
- Assurer une formation continue. Les attitudes et aptitudes nécessaires doivent être acquises avant que les élèves ne quittent l'enseignement secondaire (ces mêmes attitudes et aptitudes limiteront en fait le risque de rupture de scolarité chez les élèves du secondaire).
- Enseigner à des élèves d'âge différent : ceux qui ont avancé régulièrement dans le primaire, ceux qui ont redoublé une ou deux classes et les élèves plus âgés qui reprennent leurs études. Cela implique des formes et possibilités d'apprentissage nouvelles, différentes et flexibles.
- L'importance de l'enseignement secondaire pour permettre aux élèves de devenir plus tard des citoyens responsables.

Cette série traitera d'une vaste gamme de questions en rapport avec l'enseignement secondaire en abordant ces multiples problèmes.

Pour qu'une réforme de l'enseignement secondaire quelle qu'elle soit puisse être couronnée de succès, il est indispensable de comprendre les bonnes (et mauvaises) pratiques suivies dans différents pays du monde. Cette série sur l'enseignement secondaire fait partie de la contribution de la Banque mondiale à cet effort de compréhension.

La présente étude — *L'enseignement scientifique et environnemental : points de vue des pays en développement* — est la première de la série sur l'enseignement secondaire, mais elle est inhabituelle également en ce sens qu'elle se donne pour objectif de faire connaître à un plus large public les points de vue et expériences de ceux qui travaillent dans les pays clients de la Banque mondiale. Ses auteurs sont confrontés à la réalité quotidienne et à la complexité d'une réforme de l'enseignement scientifique et environnemental. En faisant connaître ces expériences, nous espérons faciliter la communication avec ceux qui entreprennent des réformes. Nous invitons les lecteurs à nous communiquer leurs observations sur l'intérêt que présentent ces essais et cette approche. Si cette expérience suscite une réaction positive, nous avons l'intention de continuer à publier les points de vue des praticiens sur diverses questions relatives à l'enseignement secondaire, parallèlement à d'autres publications plus traditionnelles. Le présent document est le fruit d'une collaboration entre le HDNED et le LCHSD.

Toby Linden
Banque mondiale
Mai 1999

Prólogo

Bienvenidos a la Red de Desarrollo Humano – Serie para la Educación Secundaria del Grupo Educacional.

El Banco Mundial ha prestado su asistencia a los países en desarrollo en la reforma de sus sistemas de educación secundaria desde que comenzó a otorgar préstamos para la educación hace más de treinta y cinco años. En la actualidad, el Banco se ve enfrentado a crecientes demandas de sus clientes para prestar una mayor atención a la fase de la educación secundaria. Esta fase enfrenta muchas expectativas:

- Proporcionar educación al creciente número de estudiantes que se gradúan en la enseñanza básica debido a la exitosa expansión de las oportunidades educacionales.
- Enfrentarse con la baja calidad de la educación que a menudo experimentan los estudiantes en la primera fase.
- Proporcionar a los estudiantes los *máximos* niveles de *nuevas técnicas* necesarias en la economía global sujeta a rápidos cambios.
- Asegurar un aprendizaje para toda la vida. Los estudiantes deben adquirir las actitudes y aptitudes necesarias antes de egresar de la educación secundaria (de hecho, estas mismas actitudes y aptitudes probablemente también permitirán que el número de estudiantes que desertan de la educación secundaria disminuya).
- Enseñar a estudiantes de diversas edades: a aquellos que han avanzado sin tropiezos por la educación primaria, a los que han repetido uno ó más años y a los estudiantes de más edad que se reinsertan en la educación. Para ello, se requieren formas y oportunidades flexibles de aprendizaje, a la vez nuevas y diferentes.
- La importancia de la educación secundaria en promover ciudadanos activos.

En esta serie se abordará un amplio espectro de materias dentro de la educación secundaria, que hace eco de estos múltiples desafíos.

Cualquier reforma exitosa de la educación secundaria requiere principalmente de una amplia comprensión de las buenas (y malas) prácticas de los distintos países alrededor del mundo. La presente Serie para la Educación Secundaria forma parte del aporte del Banco Mundial para lograr este entendimiento.

Este estudio, *Educación de Ciencias y Medio Ambiente: Perspectivas de los Países en Desarrollo,* es el primero de la Serie para la Educación Secundaria. Pero también es excepcional en otro aspecto: con él se propone específicamente divulgar hacia un público más amplio, los puntos de vista y experiencias de quienes trabajan en países clientes del Banco Mundial. Los autores se enfrentan a la realidad y complejidad diaria de la reforma en la educación de las ciencias y el medio ambiente. Al publicar estas experiencias, esperamos abrir un canal de comunicación entre todos los que se dedican a las actividades de reforma. Agradeceremos los comentarios de los lectores acerca del valor de estos ensayos y este planteamiento. En caso de una respuesta positiva a este experimento, nuestro propósito es seguir publicando puntos de vista de profesionales acerca de una variedad de materias relacionadas con la educación secundaria,

junto con otros estudios más tradicionales. El presente documento es el resultado de la colaboración entre HDNED y LCHSD.

Toby Linden
Banco Mundial
Mayo de 1999

Preface

Currently, there is an increasing understanding that teaching and learning good school science may produce extensive contributions to economic development. The importance of scientifically literate citizens and workers is likely to increase further in the coming decades as a result of the fast replacement of traditional technologies by new, efficient, science-based technologies. In all developing and industrial countries there is an increasing drive to make citizens "science and environmentally literate." These articles, written by science educators from various countries, give an overview of some of the current best practices in school science and environment education.

In spite of agreement on the goal there is considerable disagreement on the means. It is not easy to secure high-quality science education in any country. In most countries traditional methods have failed to produce the necessary outcomes. As a result, many school science reforms were initiated in the 1990s. Many countries are implementing reforms, especially in secondary education, many of which have a profound impact on the ways and means by which science and the environment education is integrated in the curricula. The rapid revolution in Information and Communication Technologies in the 1990s plays an important part in education system changes and how schools are made more effective. Information on many of the reforms introduced in industrial countries have been made available to a global audience (Black and Atkin, eds., *Changing the Subject,* 1996). Information on new developments in school science in developing countries is much less common. In addition bilateral and multilateral donors that are active in education reform have relied heavily on the resources of experts from industrial countries (even from countries that do not excel in school science).

One of the main purposes of this book is to demonstrate that valuable information is available in developing countries, several of which have attempted to implement significant science education reforms in recent years. These reforms have often taken place in a setting quite different from that in industrial countries, and they have produced many valuable ideas and relevant experiences. It is hoped that this publication, by providing insight into some of the activities, will be able to support those engaged in the monumental task of modernizing school science and environmental education in developing countries. Many more good stories and valuable practices are out there, and we hope that teachers, educators, and scientists will continue to send their contributions. If possible, we would like to make this an annual publication, to keep us informed about the special needs and successes in science and environmental education among World Bank clients.

Erik W. Thulstrup and Jacob Bregman
World Bank

Préface

Il est maintenant de plus en plus reconnu qu'un bon enseignement scientifique peut contribuer très utilement au développement économique. Dans les décennies à venir, il sera probablement de plus en plus important que les citoyens et les travailleurs aient des compétences scientifiques du fait que les technologies traditionnelles seront remplacées rapidement par des technologies nouvelles et efficaces fondées sur la science. Dans tous les pays aussi bien en développement qu'industrialisés, on s'efforce de plus en plus de permettre à la population d'acquérir un certain niveau de connaissances scientifiques et environnementales. Ces articles, rédigés par des responsables de l'enseignement scientifique de divers pays, passent en revue certaines des meilleures pratiques suivies actuellement dans le domaine de l'enseignement scientifique et environnemental.

Bien que l'on soit d'accord sur l'objectif poursuivi, les moyens à mettre en oeuvre sont encore loin de faire l'unanimité. Il n'est pas facile de dispenser un enseignement scientifique de haute qualité dans un pays quel qu'il soit. Dans la plupart des pays, les méthodes traditionnelles n'ont pas donné les résultats voulus et, par conséquent, de nombreuses réformes de l'enseignement scientifique ont été entreprises dans les années 90. Dans l'enseignement secondaire en particulier, de nombreux pays entreprennent des réformes qui ont souvent un profond impact sur la façon dont l'enseignement scientifique et environnemental est intégré dans les programmes. La révolution rapide des technologies de l'information et de la communication dans les années 90 joue un rôle important dans les changements touchant le système éducatif et la façon d'améliorer l'efficacité des établissements scolaires. Des informations sur un grand nombre des réformes entreprises dans les pays industrialisés ont été rendues publiques (voir, par exemple, Black et Atkin, directeurs de publication, *Changing the Subject*, OCDE, 1996). Les informations sur les nouvelles évolutions de l'enseignement scientifique dans les pays en développement sont beaucoup moins courantes. De plus, les bailleurs de fonds bilatéraux ou multilatéraux qui interviennent dans la réforme de l'enseignement font très largement appel à des experts des pays industrialisés (et même de pays qui ne brillent pas particulièrement dans l'enseignement des sciences).

L'un des nombreux objectifs du présent ouvrage est de démontrer que de précieuses informations sont disponibles dans les pays en développement, dont plusieurs se sont efforcés sérieusement de réformer l'enseignement des sciences au cours des dernières années. Ces réformes se sont souvent déroulées dans un cadre très différent de celui des pays industrialisés, et elles sont à l'origine d'une multitude d'idées et d'expériences intéressantes. Nous espérons qu'en permettant d'y voir plus clair en ce qui concerne certaines de ces activités, le présent ouvrage pourra aider ceux qui se sont attelés à la tâche formidable consistant à moderniser l'enseignement scientifique et environnemental dans les pays en développement. On y trouve beaucoup d'informations et de pratiques valables et nous espérons que les enseignants, les éducateurs et les scientifiques continueront à nous apporter leurs contributions. Nous souhaiterions si possible faire de cette étude une publication annuelle pour nous tenir informés des besoins particuliers des clients de la Banque mondiale et des succès qu'ils obtiennent en matière d'enseignement scientifique et environnemental.

Erik W. Thulstrup et Jacob Bregman
Banque mondiale

Prefacio

Cada vez hay más certeza respecto a que un buen aprendizaje de las ciencias en las escuelas puede contribuir de manera significativa al desarrollo económico. Es probable que la importancia de ciudadanos y trabajadores con sólidos conocimientos científicos aumente aún más en las siguientes décadas, como consecuencia de la rápida sustitución de las tecnologías tradicionales por nuevas y eficientes tecnologías basadas en las ciencias. En todos los países en desarrollo e industrializados se nota una creciente tendencia por transformar a sus ciudadanos en "letrados científica y ambientalmente". En estos artículos, redactados por educadores de ciencias de diversos países, se ofrece una visión general de algunas de las mejores prácticas existentes en este momento en la educación de las ciencias y el medio ambiente a nivel de las escuelas.

Aunque existe acuerdo acerca de las metas, los medios para lograrlas suscitan bastantes divergencias. Asegurar una enseñanza de las ciencias de alta calidad no resulta fácil en ningún país y los métodos tradicionales no han arrojado los resultados necesarios en la mayoría de ellos. Es por este motivo que durante la década de los noventa se han iniciado diversas reformas en la educación de las ciencias en las escuelas. En numerosos países se están implementando reformas orientadas especialmente al nivel de la educación secundaria, muchas de las cuales han causado un profundo impacto sobre las formas y medios en que se está integrando la educación de las ciencias y el medio ambiente en los planes de estudios. La rápida evolución de las Tecnologías en las áreas de Informática y Comunicaciones de los años 90 desempeña un importante papel en los cambios de los sistemas educacionales y en la forma en que las escuelas aumentan su eficacia. Se ha dado a conocer más globalmente información acerca de muchas de las reformas incorporadas en los países industrializados (ver, por ejemplo, Black y Atkin, Eds., *Changing the Subject*, OCDE, 1996). Sin embargo, la información sobre la evolución de las ciencias a nivel de escuelas en los países en desarrollo es mucho menos habitual. Asimismo, los organismos bilaterales y multilaterales que se desempeñan en el campo de la reforma educacional se han basado fuertemente en los expertos de los países industrializados (incluso en países que no se destacan en el campo de las ciencias a nivel escolar).

Uno de los principales objetivos del presente libro es demostrar que en los países en vías de desarrollo se dispone de valiosa información y que varios de ellos han intentado aplicar reformas educacionales importantes en el campo de las ciencias durante los últimos años. Estas reformas a menudo se han realizado en entornos que son muy distintos a los existentes en los países industrializados y han producido múltiples e importantes ideas y experiencias. Es nuestro deseo que la presente publicación, al proporcionar conocimientos sobre estas actividades, permita asistir a los países inmersos en la gigantesca tarea de modernizar la educación de las ciencias y el medio ambiente en las escuelas de los países en desarrollo. Hay muchas más historias interesantes y prácticas valiosas "circulando" por ahí y esperamos que los maestros, educadores y científicos sigan enviándonos sus aportes. Si fuese posible, nos gustaría hacer de este documento una publicación anual que nos mantenga informados acerca de las necesidades y éxitos de la educación de las ciencias y el medio ambiente entre los clientes del Banco Mundial.

Erik W. Thulstrup y Jacob Bregman
Banco Mundial

Overview of the Reform Agenda

Sylvia A. Ware

Introduction

In 1992 the World Bank released a report on the status of secondary school science in developing countries (Ware 1992a). The report contained an overview of major issues related to the delivery of quality science instruction across the world, including: the curriculum; the role of the laboratory; the preparation and continuing education of science teachers; and assessment of the students, the teachers, and the system. The report also analyzed the impact of World Bank lending on secondary science education from 1963 to 1990. Appendices briefly discussed issues related to environmental education, nonformal science education, and gender factors in selecting science careers. A related report surveyed practices in the preparation and continuing education of teachers in much more detail (Ware 1992b). Both reports contained multiple summary tables as well as case studies from different countries.

In the years since, efforts to reform science education seem to have accelerated across nations, primarily at the elementary and secondary levels. (Some industrial nations have begun to address issues leading to the reform of tertiary science education.) Change is always unsettling. It involves dumping some old, preconceived ideas and embracing new ones. It involves deciding which of the old ways to keep and which of the new ways to avoid. Change is not only unsettling, it is costly. It is particularly problematic for developing countries with limited resources that—while they agree that the "traditional" science programs are not addressing the needs of the majority of students taking science, they have no compelling evidence yet that the reform programs do make a difference. (Note that many of the "traditional" programs have only been in place for some 30 years.) Developing nations cannot afford to gamble on success, particularly when addressing their scientific and technical workforce needs into the next century.

Given the understanding that quality science and technology education are integral to economic competitiveness and success in the global marketplace, the World Bank continues its interest in promoting science education reform. Research capacity building at the tertiary level depends on the production of high-achieving students at the secondary level. It also depends on the production of a scientifically literate populace capable of using their knowledge to improve the quality of daily life and to support sustainable development of the economy.

This volume, which covers developments in science education over the past six years, can be considered an update of the 1992 and 1993 publications mentioned above. However, it presents the authentic voices of those most directly involved in the reform efforts described, not the analysis of a "technical expert" far removed from the realities of implementing reform under less than ideal conditions. The experiences documented herein come from across the developing world, although not all parts of the globe are equally well-represented—a consequence of the papers being received while the project was under development. Hopefully, the publication of

this volume will lead to subsequent publications to fill in the gaps in the global record and provide a body of knowledge to facilitate the reform process internationally.

Not only are certain parts of the world not represented, but the documentation does not address all the issues covered in the earlier World Bank publications, at least not in detail. Assessment issues, in particular, are not discussed, except in the context of participation in the Third International Mathematics and Science Survey (TIMSS)—yet the assessment system in many countries is a powerful barrier to reform.

The papers collected in this volume come from Latin America and the Caribbean, Africa, Asia, Europe, and North America. While the majority address reforms in specific developing nations, some papers look at issues that cross national barriers. For example, two papers address the use of low-cost/no cost equipment to deliver hands-on science instruction. One paper examines extremely high technology-high cost methods of enhancing science instruction—methods that, although more commonly used in industrial nations, are now spreading to the wealthier developing countries. A review of the major issues of secondary science education reform follows, in the context of the papers presented here.

The Nature of Current Science Education Reforms

The ongoing reform of science education is particularly challenging because it is multifaceted. Attempts are being made to:

- Redefine the audience for science knowledge (all students not just future scientists)
- Expand the definition of science "content" (deemphasize learning facts, focus more on understanding concepts and the way in which knowledge becomes science knowledge)
- Introduce new teaching methods based on cognitive research into how students learn science (move away from the teacher teaching toward the student learning).

The Audience for Science Knowledge

Introducing reforms to address any one of these facets is work enough; tackling all three may be viewed as too ambitious. Yet we are now involved in a worldwide reform effort designed to open up the world of science to all students, not only to those students who are going to become scientists (Black and Atkin 1996; Schmidt et al. 1996). The papers in this volume also make clear that "science for all" is a concern of many developing nations. The issue has been debated from Argentina to Zimbabwe: How can we make science knowledge more accessible to more students without lowering standards in courses for those who will become the scientists of tomorrow?

The rationale behind the slogan "science and technology literacy for all" is consistent across countries. It is rooted in the belief that the literate citizens of tomorrow must have a sound understanding of the basic principles of science and technology and their interactions with society, if they are to make sound decisions (especially, but not exclusively, economic decisions) about the readiness of their society to go into the next century. While decision making in the

societal arena will involve the participation of scientifically and technologically literate citizens, such decision making depends on knowledge across a wide range of disciplines.

In the papers presented in this volume, "science education for all" is taking place within the broader context of systemic education reform as a means of developing a sustainable, equitable democracy, not just a sustainable economy. This is clearly articulated in the paper by Dr. Eduardo Doryan and Professor Eleonora Badilla, which discusses issues of developmental ethics as applied to environmental education programs in Costa Rica (not always with a direct tie to science instruction). The paper emphasizes changes in attitudes and awareness brought about by learning science knowledge with applications to stewardship of the environment as the common heritage of future generations.

Dr. Andoni Garritz and Vincente Talanquer discuss science education reform as a component of reforms that "will be considered one of the greatest transformations of Mexican education in the 20th century." The Chilean reform of science education is also taking place within a wider context of systemic reform, designed both to decentralize decision making with regard to the curriculum and to ensure its quality by setting specific mandatory objectives for all students (Martínez and Cerón in this volume). The paper by Dr. Sarah Howie also makes it clear that science education reform in South Africa is one component of the wider reforms designed to bring equity to the system and promote economic development. However, in her judgment, decisionmakers and politicians in South Africa do not make a clear enough connection between science, technology, and mathematics (STM) education, and science and technology workforce development.

Redefining Science Content

Most significantly, over the past 10 years the view that science is "objective and universal, transcending national and cultural differences," has become a matter of intensive debate, and not only in postmodernist circles. However, this particular debate is beyond the scope of this paper. As is discussed by Schmidt et al. (1996), among others, the *transmission* of science knowledge as "school science" is profoundly cultural. It differs significantly from country to country, depending on the established national outcomes for science learning and the flow of the curriculum. Interestingly enough, there appears to be no clear or shared vision internationally on the scope of knowledge that is important in introductory science instruction, nor on when to introduce topics, nor on how to sequence topics for different groups of students (Holbrook 1991; Kamens and Benevot 1991; Schmidt et al. 1996).

There does seem to be a shared reform agenda for science education. Both the TIMSS curriculum analysis (Schmidt et al. 1996) and the recent OECD study of innovations in SMT education in 13 countries (Black and Atkin 1996) point to shared characteristics in the reforms of SMT education now being implemented. These characteristics are being promulgated in developing countries through programs such as UNESCO's Project 2000+. The reform courses are, of course, concerned with the traditional topics covered in most secondary science courses, but they go far beyond the fundamental facts, concepts, and understandings in their definition of "content."

The emphasis in current science reform curricula is on the utility of science to the individual and to society at large. What is important is not merely the topics that are taught, but the context in which they are taught, and the reform context is "science for citizenship." There are a number of subcontexts that elaborate upon this broad statement: "science for sustainable development," "science to improve the quality of life," "science for future human needs," "science for sound environmental management," and the like. "Science for future scientists" is not currently a rallying cry, and teaching "science for its own sake" appears to be relegated to the category of luxury, affordable by only the privileged. Regardless of the rubric under which the reform is defined, science is being used as a vehicle to teach much more than just science. Science is being used to teach personal and social responsibility.

The paper by Tarasova and Gapanovitch very clearly illustrates this context for science education reform in Krasnoyarskii Krai, a region of Siberia that is rich in natural resources, heavily industrialized in certain areas, and, as a consequence, heavily polluted. They describe the use of a Russian translation of a U.S. chemistry textbook that teaches chemistry for citizenship in the context of the U.S. cultural experience. The teachers and students together have adapted the text to the context of the environmental problems extant in Krasnoyarskii Krai, using local examples and data. More than chemistry is being learned here. New attitudes are being formed, as is evident in the remarks of students taking the course. For example: "I now know that my personal actions are important to the future of Planet Earth," "I feel proud of my town and its natural resources," and "The children of Krasnoyarsk have the right to express their own positions."

The RADMASTE Centre in South Africa, as described by Dr. John D. Bradley, is implementing a More Relevant Science Curriculum (MRSC) project. He too is concerned with the importance of cultural context when teaching science. Bradley points out that, while there may be exemplary science courses developed outside South Africa, not only are different topics covered, but the texts are not written for the South African cultural context.

It would be an oversimplification to define the current reforms of the science curriculum solely in terms of the science, technology, and society (STS) movement, although the aims may often overlap. Clearly, the STS movement has had a significant impact on the content of reform courses, particularly at the lower secondary level. For example, with regard to reform of natural science in the junior high schools (a national curriculum) in Mexico, Garritz and Talanquer acknowledge the strong emphasis on STS issues. They also indicate that individual science subjects are taught at this level, covering a more comprehensive set of objectives than STS. At the upper secondary level, where there is no national curriculum, they report that some schools are implementing an STS-related program.

Curriculum reform in the Philippines also includes a strong STS component. It includes a "knowledge of the relationship among science, technology, and society," and a "knowledge of science in the environment" as two of the six general objectives for the four years of secondary science instruction (Beasley in this volume). Here again, the sciences are taught with an

emphasis on discipline. The Chilean reforms also expect students to use science knowledge and skills for personal and societal purposes.

The science curriculum in Thailand (Dr. Roger Downer and Kama Rana in this volume) mirrors the same ideas being implemented in the other countries represented in this volume. Science education is considered knowledge for all students that contributes positively to the economic development of the nation. Science is taught from within a societal context, and teachers are being given help in moving to a student-centered classroom.

While most of the countries represented in this volume mention ethics (especially environmental ethics) as one component of science instruction, the Costa Rican experience places a unique emphasis on developmental ethics, which influences the entire curriculum. Doryan and Badilla present a particularly compelling and clearly articulated vision of a system designed to maximize the human potential of its people and develop the economy, while respecting the natural environment.

Previously, it was suggested that perhaps "school science" has an identity of its own that varies from country to country and differs from science as practiced by "real" scientists. Several papers list the task of having students "learn to think like scientists" (including, for example, Chile, Mexico, and the Philippines) as an important objective, together with learning about the work of today's scientists. The paper by Dr Margareta Vrtacnik and Dr. Sascha Glazar focuses on the career component of science content—in particular, careers in industry. Their survey of school-industry cooperation in Slovenia shows that, while both schools and industries in the country are aware of the mutual benefits of school-industry partnerships, they do not have the same goals for these relationships and are not always ready to implement them successfully.

Teaching Methods

The introduction of new pedagogical methods into the secondary science classroom is viewed as an integral, if problematic, component of reform. Briefly, in the new "ideal" science classroom, the role of the teacher is viewed as shifting from that of authority figure—controlling the lesson from the front of the classroom, knowing all the answers to all the questions (!)—to the role of facilitator of the learning process, resource manager for the classroom, coach, and adviser. The teacher is also responsible for determining what "naive" science misconceptions students bring into the classroom, and helping students construct a scientific understanding of the natural world. Students, often working in cooperating groups, may control group and class discussions and are expected to eventually become "self-directed" learners. They participate in "inquiry-based" investigations rather than follow the detailed instructions of "cookbook" experiments.

De Feiter and Ncube, discussing reform efforts across southern Africa, indicate that "The gap between the ideal of introducing more pupil-centered education in schools and the actual practice found in most schools is enormous." Whole class discussion with teacher questioning is the principal form of instruction. They cite passive learners, "chalk and talk" delivery, and whole-class activities of note taking. They also point out that the teacher-centered form of instruction is strongly embedded in the culture of the region and that "Attempts to change the

pedagogy of classrooms conflict with the value systems of both teachers and students." Under such circumstances, they suggest that attempting to move to a pupil-centered classroom ("in line with the individualistic Western culture") may not be the best strategy for all cultures. Howie (paper on South Africa) also expresses similar misgivings about student activities and collaborative learning.

In the Philippines Beasley also found the shift from the focus on teacher teaching to student learning to be an immense challenge. The teacher development program he was involved in focused on strategies to move the teachers toward a more student-centered classroom. He still believes the shift to be important, if extremely difficult to accomplish. In an assessment of teacher needs for continuing education, the teachers themselves recognized that they did need additional help to shift to a focus on student learning. Downer and Karma express the same concerns for teachers in Thailand.

The Role of Laboratory Instruction and Hands-on Science

Time spent in the laboratory ("practicals") has been considered an essential component of science instruction for years, at least by the science and science education communities, if not by economists and politicians. After all, it is argued, science is something that scientists *do,* working in a laboratory is the quintessential activity of people who call themselves scientists. The body of knowledge called "science" has accumulated because of the data that scientists collect. If students are to understand what science is all about, then they really need to *do* science. Unfortunately, the traditional laboratory class is expensive to set up and maintain; and much of the assessment of the outcomes of laboratory instruction has been inconclusive at best.

The paper by Dr. Erik W. Thulstrup makes an eloquent case for the retention of the school laboratory in developing countries, but in a low-cost/no-cost modality. He also points out flaws in methods of assessing the impact of "hands-on" science. Although the reform agenda stresses the value of learning-by-doing, there is no reason why "hands-on" science should require expensive equipment and materials, or even the traditional school laboratory facility (see also de Feiter and Ncube in this volume). Thulstrup also argues that learning enhancements may be possible using instruments that are "transparent" to the user, rather than an expensive "black box" that cannot be repaired locally once broken. In addition to the problem of repairing expensive equipment, teachers are often held liable when equipment does break. (Beasley in this volume reports boxes of expensive science equipment unused in the Philippines.)

The work of the Edutronics Group at the University of Delhi is described by Dr. Krishna V. Sane as one example of a low-cost, locally made instrumentation facility in India. This facility has been in operation for more than 20 years and serves as a model for many other developing countries.

Dr. John D. Bradley indicates that in South Africa, despite a wide endorsement of practical work, many schools do no practical science. He discusses the reasons for this (going beyond the obvious cost issue). Low-cost, locally made, small-scale science kits are now being developed in South Africa by the RADMASTE Centre for chemistry, physics, and biology

classes. Research studies at the RADMASTE Centre have confirmed a learning bonus among students who use these kits.

The use of kits in Zimbabwe in the Zim-Sci project is discussed by Dr. Leo P. de Feiter and Kenneth Ncube, who point out that teachers considered the kits to be "second-hand alternatives" to using "real" equipment. Thus the kits were never very popular. Also, replenishment funds for the kits have now been exhausted. The consequence is that little practical work now takes place in schools in Zimbabwe, and students may take a paper and pencil version of the Ordinary-level practical science examination.

Science Teachers

The Importance of the Teacher

Previous efforts at educational reform have been subverted, intentionally or unintentionally, by the teachers ultimately responsible for implementing the reform. There is little doubt that teachers are the sine qua non of educational reform. Yet a number of the systemic reforms discussed in this volume apparently did not include teachers as an integral component of the planning of the reforms. In both Chile and Mexico the teachers were mainly excluded from the discussions and planning that took place when the reforms were being designed by university-based specialists and politicians. Garritz and Talanquer point out that "as long as teachers consider themselves mere spectators and performers of somebody else's plans, they will find it difficult to commit themselves to reform." Martinez and Cerón also express concern that the curriculum reforms in Chile will not succeed because teachers are already alienated from the process of reform. Both papers emphasize the importance of continuing teacher education programs to ensure successful reform.

Bajah, speaking about the involvement of Nigerian high school teachers in curriculum reform, in his capacity as former president of the Science Teachers of Nigeria (dominated by university teachers), expresses regret that few high school teachers in Nigeria are involved in reform. However, he indicates that before more teachers could become involved "we would first need to build up their confidence in participating in such activities."

The activities of the Science Teachers Association of Nigeria do suggest some models for developing both confidence and professionalism among the high school teachers. The importance of university and high school teachers working together on professional activities (and in social settings) in a collegial fashion cannot be overestimated.

There is certainly a degree to which the participation of many teachers in the planning of reforms is limited by their knowledge and experience. Of course, in the absence of continuing education, this same lack of knowledge and experience make it impossible for the teachers to effectively implement reforms when the classroom door closes.

The teacher-training project in the Philippines is a rare example of a teacher project that began with an assessment of teacher needs, completed by the teachers themselves (Beasley in this volume). The first concern of the teachers was to get support in using modern technology—both computers and laboratory instruments. They also expressed concern about specific teaching strategies and the process approach to science and preparing lessons, assessment instruments, and low-cost equipment. The training program for Filipino teachers was put in place at the University of Queensland only after the needs instrument had been analyzed.

Teacher Professional Development

Initial teacher preparation programs are discussed by Howie and Bradley for South Africa (also see Ware1992b for a summary of these type of programs). The RADMASTE Centre has been working with colleges of education across South Africa to draft new syllabuses in science for student teachers. The focus is on enabling the student teachers to understand the concepts they will soon be teaching in the schools and introducing them to practical work and learner-centered methodologies.

All countries represented cite the need for in-service teacher training. The magnitude of this need is documented for a number of counties in southern Africa, including Botwana, Namibia, South Africa, and Zimbabwe (de Feiter and Ncube; Howie in this volume). There are several detailed papers in this volume that describe a range of successful and unsuccessful inservice teacher education programs. One apparently effective strategy is further educating classroom teachers to serve as resource teachers for their peers, a strategy attempted in both Zimbabwe and the Philippines.

In the Zimbabwe program (de Feiter and Ncube in this volume) the teachers selected take a two-year course at the University of Zimbabwe to obtain a postgraduate diploma in science education. After graduation, among other functions, the teachers serve as mentors to their peers, running workshops and acting as general managers of regional science centers. They also interact with each other via e-mail, thus establishing a network of trained professional teachers.

The program in the Philippines is almost identical (Beasley in this volume). Some 500 principals and teachers are entering postgraduate training to become local resource teachers, again running workshops, mentoring teachers, and running regional science centers. The program is intended to prepare teachers who, with the ability to reflect on their own teaching practices, will then be capable of improving those practices.

The Third International Mathematics and Science Study

The Third International Mathematics and Science Study (TIMSS) explored the science and mathematics achievements of students in three age populations (9-year-olds, 13-year-olds, and students in the final year of secondary education) in some 50 education systems on five continents. The majority of the countries participating were industrial nations, for financial and logistical reasons (Howie in this volume). Many of the variables contributing to achievement were also measured, including curriculum, classroom, and socioeconomic factors. The TIMSS is

producing a wealth of data on science and mathematics achievement that will keep policymakers and educators busy for years.

Although the TIMSS was so much more than a "horse race," it is the ranking of a country's achievement on the tests vis-á-vis other countries that is getting the attention. Two of the countries represented in this volume took part in TIMSS—South Africa and the Philippines. South Africa participated in studies for the 13-year-old population (grades 7 and 8) and the school-leaving population (grade 12). Grade 12 participation was limited to the science and mathematics literacy tests. Howie discusses in detail the problems of conducting the survey in South Africa. The results of the tests came as a great shock to South Africans, generating a great deal of discussion in the media and much attention from politicians. The results have added impetus to the reform effort.

The Philippines ranked 37/39 for 13- and 18-year olds, a performance that has been widely discussed by politicians and the public. As a result, there is now widespread recognition of the need to raise standards in Filipino secondary school science. Beasley suggests that some major changes must be implemented if the current levels of student achievement have any hope of being raised substantially. He cites an overcrowded curriculum, large classes, a lack of resources, and the need for more teacher in-service education.

Technology

The context of reform of science education is an unprecedented electronic revolution. Communications technologies (e-mail, the Internet, the World Wide Web) are used in both industrial and developing nations to add dimensions to science education that have not been widely possible before. Students have access to raw data and to scientists in their own countries and internationally. Students can share information over the Internet not only with scientists but with students in other countries.

Berenfeld makes an exciting case for the promise of the Internet as an education tool, although he does not explore the costs of developing student communities of practice in developing nations. However, he does identify developing nations that have already made a major commitment to installing such networks. He makes clear that those that do not have access to such technologies will be left behind in the global competition for economic security.

Finally, Bregman and Morten discuss the use of the Internet as a means of teaching environmental education. While many of their examples are drawn from the European experience, they also discuss some exciting developments in Brazil, Chile, and Costa Rica. They report on financial concerns related to use of the Internet in the classroom. This concern is inhibiting use of the technology even in highly industrial nations. Whether computer-mediated communications will fulfill the anticipated promise of enhanced learning in still debatable, especially if the costs continue to be viewed as prohibitive for wide dissemination in most countries.

Some Final Reflections

Given the range of experiences described herein, it is worth noting the common problems encountered when implementing science education reform, regardless of educational system or cultural context. In reading these papers, it becomes impossible to ignore the obvious—the limiting reactant in implementing reform is *always* the classroom teacher. This is hardly a revelation, yet time and time again education systems attempt to introduce extremely complex reforms without consulting teachers, or even considering the impact of reform on teachers. The nature of the reforms currently being implemented is such that the role of the teacher has become even more critical.

It is wishful thinking to believe that better quality textbooks, programmed kits, and educational technology (TV, radio, computer, the Internet, and the like) can do the job of a highly educated, well-motivated teacher. The costs of recruiting, educating, and retaining such a teacher workforce are necessarily high. (Of course, the costs of other strategies, such as computer-mediated communications, are also very high.) However, without high-quality teachers to implement science education reform, it is difficult not to conclude that all the other costs of reform are a lost investment.

Sylvia Ware is the Director of Education and International Activities at the American Chemical Society, where she is responsible for educational programs beginning at the kindergarten level through primary, secondary, and tertiary education, and continuing education programs for chemists. She is also Honorary UNESCO Professor of the Humanities at the Mendeleev University of Chemical Technology of Russia.

References

Black, P., and J.M. Atkin, eds. 1996. *Changing the Subject*. London: Routledge with Organisation for Economic Co-operation and Development.

Holbrook, J.B. 1991. "The Relationship between Curricula and Assessment." United Nations Educational, Scientific, and Cultural Organization, Paris.

Kamens, D.H., and A. Benavot. 1991. "Elite Knowledge for the Masses: The Origins and Spread of Mathematics and Science Education in National Curricula." *American Journal of Education* 99: 137–180.

Schmidt, W.H. et al. 1996. *Many Visions, Many Aims: A Cross-National Investigation of Curricular Intentions in School Science*. Dordrecht: Kluwer Academic Publishers.

Ware, Sylvia A. 1992a. *Secondary School Science in Developing Countries: Status and Issues.* World Bank, PHREE Document 92/53. Washington, D.C.

Ware, Sylvia A. 1992b. *The Education of Secondary Science Teachers in Developing Countries.* World Bank, PHREE Document 92/68. Washington, D.C.

Présentation du programme de réforme

Sylvie A. Ware

Introduction

En 1992, la Banque mondiale a publié un rapport sur l'état de l'enseignement scientifique dans les écoles secondaires des pays en développement (Ware, 1992a). Ce rapport passait en revue les principaux problèmes que pose la prestation d'un enseignement scientifique de qualité dans les différentes parties du monde, notamment le programme, le rôle du laboratoire, la préparation et la formation continue des professeurs de science et l'évaluation des élèves, des enseignants et du système. Il analysait également l'impact des prêts de la Banque mondiale sur l'enseignement scientifique secondaire de 1963 à 1990. Des annexes traitaient des problèmes liés à l'éducation en matière d'environnement, à l'enseignement des sciences de type non scolaire et aux facteurs liés au sexe de l'élève dans le choix d'une carrière scientifique. Un rapport connexe étudiait de façon beaucoup plus détaillée les pratiques suivies pour la préparation et la formation continue des enseignants (Ware, 1992b). Ces deux rapports contenaient un grand nombre de tableaux récapitulatifs ainsi que des études de cas provenant de différents pays.

Au cours des années écoulées depuis lors, les efforts déployés pour réformer l'enseignement des sciences semblent s'être accélérés dans différents pays, principalement dans l'enseignement élémentaire et secondaire (certains pays industrialisés ont commencé à s'attaquer à certains problèmes en vue de réformer l'enseignement des sciences au niveau tertiaire). Le changement est toujours dérangeant. Il implique que l'on renonce à certaines idées préconçues pour en adopter de nouvelles. Il implique également que l'on décide ce qui doit être conservé du passé et quelles sont les innovations à rejeter. Le changement est non seulement dérangeant mais aussi coûteux. Il pose des problèmes particuliers pour les pays en développement aux ressources limitées car, bien qu'il soit reconnu que les programmes scientifiques « traditionnels » ne répondent pas aux besoins de la majorité des étudiants en science, il n'est pas encore tout à fait évident que les programmes de réforme fassent une différence. (Il est à noter que beaucoup de programmes « traditionnels » ne sont en place que depuis une trentaine d'années.) Les pays en développement ne peuvent se permettre de prendre des risques, en particulier s'ils veulent que leur main-d'oeuvre ait les compétences scientifiques et techniques voulues au siècle prochain.

Étant entendu qu'un enseignement scientifique et technologique de qualité conditionne la compétitivité et le succès économiques sur le marché mondial, la Banque mondiale continue à s'intéresser à la réforme de l'enseignement des sciences. Pour pouvoir renforcer la capacité de recherche dans l'enseignement tertiaire, il faut former d'excellents élèves dans le secondaire. Il faut également que la population ait des notions scientifiques suffisantes pour lui permettre d'utiliser des connaissances scientifiques et technologiques et d'améliorer sa qualité de vie, et pour rendre possible un développement durable de l'économie.

Le présent ouvrage, qui traite de l'évolution de l'enseignement des sciences au cours des six dernières années, peut être considéré comme une mise à jour des publications de 1992 et

1993 mentionnées plus haut. Il présente toutefois les points de vue authentiques de ceux qui participent le plus directement aux efforts de réforme évoqués, et non l'analyse d'un « expert » éloigné des réalités concrètes de réformes exécutées dans des conditions qui sont loin d'être idéales. Les expériences décrites ici concernent les pays en développement les plus divers, bien que toutes les régions du monde ne soient pas également représentées, ce qui tient à la nature des études reçues au moment où le projet était en préparation. On peut espérer que la publication du présent ouvrage suscitera celle d'études ultérieures qui combleront certaines lacunes et permettront de disposer d'un ensemble de connaissances propre à faciliter le processus de réforme à l'échelon international.

Non seulement certaines régions du monde ne sont pas représentées, mais encore la compilation ne couvre pas toutes les questions abordées dans les publications antérieures de la Banque mondiale, du moins pas en détail. Les questions d'évaluation en particulier ne sont pas traitées, sauf dans le contexte de la participation à la troisième enquête internationale sur les mathématiques et les sciences (TIMSS), mais le système d'évaluation de beaucoup de pays constitue un sérieux obstacle à la réforme.

Les études recueillies dans le présent ouvrage proviennent d'Amérique latine, d'Afrique, d'Asie et d'Amérique du Nord. Bien que la plupart traitent de réformes entreprises dans différents pays en développement, certaines abordent des questions non exclusivement nationales. C'est ainsi que deux études traitent de la question de l'utilisation de matériel peu coûteux/gratuit pour les travaux pratiques. On peut citer également une étude qui examine des méthodes très coûteuses et faisant appel à des technologies extrêmement avancées pour améliorer l'enseignement scientifique, méthodes qui, bien que plus courantes dans les pays industrialisés, sont maintenant étendues aux pays en développement de la tranche supérieure de revenu. On trouvera ensuite un examen des principaux problèmes liés à la réforme de l'enseignement scientifique secondaire, dans le contexte des documents présentés ici.

Nature des réformes actuelles de l'enseignement des sciences

La réforme en cours de l'enseignement des sciences est particulièrement problématique parce qu'elle comporte de multiples aspects. On s'efforce actuellement de :

- Redéfinir ceux auxquels sont destinées les connaissances scientifiques (tous les élèves et non pas uniquement les futurs scientifiques) ;
- Élargir la définition du « contenu » des sciences (en mettant l'accent moins sur l'apprentissage de faits et davantage sur la compréhension des concepts et de la façon dont la connaissance devient savoir scientifique) ; et
- Introduire de nouvelles méthodes d'enseignement fondées sur des recherches cognitives sur la façon dont les élèves apprennent les matières scientifiques (en mettant l'accent plutôt sur l'apprentissage de l'élève que sur l'enseignement dispensé par le maître).

Destinataires des connaissances scientifiques

Entreprendre des réformes pour s'attaquer à un seul de ces problèmes est déjà difficile, et s'attaquer simultanément aux trois peut être considéré comme excessivement ambitieux.

Cependant, nous participons maintenant à un effort de réforme à l'échelon mondial qui vise à ouvrir le monde de la science à tous les élèves et non, comme dans le passé, seulement à ceux qui font des études pour devenir des scientifiques (voir, par exemple, Black et Atkin, 1996 ; Schmidt et al., 1996). Les études figurant dans le présent ouvrage précisent également que le principe de « la science pour tous » est en vigueur dans beaucoup de pays en développement. De l'Argentine au Zimbabwe, la question fait l'objet d'un débat : comment rendre les connaissances scientifiques plus accessibles à un plus grand nombre d'élèves sans faire baisser le niveau des cours pour ceux qui seront les scientifiques de demain ?

Le principe sur lequel repose le mot d'ordre « la science et la technologie pour tous » est le même dans les différents pays. Il est ancré dans la conviction que les citoyens éduqués de demain devront avoir une bonne connaissance des principes fondamentaux de la science et de la technologie et de leurs interactions avec la société s'ils veulent prendre de bonnes décisions (en particulier, mais non exclusivement, des décisions économiques) quant à la forme que prendra la société dans laquelle ils vivent à l'aube du prochain siècle. La prise de décision dans le domaine social fera intervenir des citoyens ayant des notions de science et de technologie, mais les décisions ainsi prises dépendront de connaissances acquises dans les domaines les plus divers.

Dans les documents présentés ici, le principe de « l'enseignement scientifique pour tous » s'inscrit dans le cadre plus général de la réforme systémique de l'enseignement comme un moyen de mettre en place une démocratie équitable et viable, et non seulement une économie viable. Ce principe est clairement défini dans l'étude de Doryan et Badilla, qui examine les questions d'éthique du développement en tant qu'elles s'appliquent aux programmes d'enseignement environnemental au Costa Rica, sans avoir toujours un lien direct avec l'enseignement des sciences. Cette étude souligne les changements d'attitude et de sensibilité résultant de l'acquisition de connaissances scientifiques avec des applications pour la gestion de l'environnement, patrimoine commun des générations futures.

Garritz et Talanquer examinent la réforme de l'enseignement des sciences dans laquelle ils voient une composante des réformes qui « sera considérée comme l'une des plus grandes transformations de l'enseignement dispensé au Mexique au XXe siècle ». Au Chili, la réforme de l'enseignement des sciences s'inscrit également dans un contexte plus large de réformes systémiques visant tout à la fois à décentraliser la prise de décisions concernant les programmes et à assurer la qualité de ceux-ci en fixant des objectifs contraignants et précis pour tous les élèves (voir Martínez et Cerón). L'étude de Howie précise également que la réforme de l'enseignement des sciences en Afrique du Sud est un élément de réformes de plus grande envergure visant à rendre le système équitable et à promouvoir le développement économique. Toutefois, selon le même auteur, les décideurs et les responsables politiques d'Afrique du Sud n'établissent pas un lien suffisamment clair entre l'enseignement des sciences, des technologies et des mathématiques (STM), d'une part, et la formation scientifique et technologique de la main-d'oeuvre, d'autre part.

Redéfinir le contenu des sciences

Il convient avant tout de noter qu'au cours des dix dernières années, la théorie selon laquelle la science est « objective et universelle et transcende les différences entre les pays et les cultures »

est de plus en plus contestée, et pas seulement dans les milieux post-modernes. Ce débat sort toutefois du champ couvert par la présente étude. Comme l'ont écrit Schmidt et al. (1996), parmi d'autres, la *transmission* des connaissances scientifiques par le biais de l'école a un caractère profondément culturel. Elle diffère considérablement d'un pays à l'autre en fonction des résultats que l'on attend au niveau national de l'enseignement des sciences, et également selon le contenu des programmes. Il est à noter que l'on ne semble pas avoir, à l'échelon international, une idée claire ou une conception commune de la portée des connaissances considérée comme importante dans l'enseignement élémentaire des sciences, pas plus que du moment où il convient d'étudier certains sujets, ni de la façon de les aborder selon les différents groupes d'élèves (Holbrook, 1991 ; Kamens et Benevot, 1991 ; Schmidt et al., 1996).

Il semble bien qu'il existe un programme de réforme commun pour l'enseignement des sciences. L'analyse des programmes TIMSS (Schmidt et al., 1996) et la récente étude de l'OCDE sur les innovations dans l'enseignement des SMT dans 13 pays (Black et Atkin, 1996) montrent que les réformes de l'enseignement des SMT actuellement en cours présentent des caractéristiques communes. Ce sont ces caractéristiques que l'on s'efforce de promouvoir dans les pays en développement dans le cadre de programmes tels que le projet 2000+ de l'UNESCO. Les cours conçus dans le cadre de la réforme accordent naturellement de l'importance aux matières traditionnelles étudiées dans la plupart (mais non la totalité) des cours d'enseignement scientifiques secondaires, mais ils vont au-delà des faits, principes et concepts fondamentaux du point de vue de leur « contenu ».

Dans le cadre des programmes actuels de réforme de l'enseignement scientifique, on met l'accent sur l'utilité de la science pour l'individu et pour la société en général. L'important, ce n'est pas seulement les matières enseignées, mais le contexte dans lequel elles sont enseignées et le mot d'ordre de la réforme est « la science pour tous ». Ce mot d'ordre général s'inscrit également dans un certain nombre de sous-contextes : « la science pour un développement durable, la science pour améliorer la qualité de la vie, la science pour répondre aux besoins futurs de l'humanité, la science pour assurer une saine gestion de l'environnement », etc. « La science pour former les scientifiques de demain » n'est pas un cri de ralliement à l'heure actuelle, et l'enseignement des sciences « pour elle-même » semble être une sorte de luxe accessible seulement aux privilégiés. Indépendamment de la rubrique à laquelle se rattache la réforme, la science est actuellement utilisée comme un moyen d'enseigner bien plus que la science proprement dite. La science sert à enseigner la responsabilité personnelle et sociale.

L'étude de Tarasova et Gapanovitch illustre très clairement ce contexte de la réforme de l'enseignement des sciences à Krasnoyarskii Krai, région de Sibérie richement dotée de ressources naturelles, fortement industrialisée par endroits et, de ce fait, très polluée. Ces deux auteurs décrivent l'utilisation qui est faite de la version russe d'un manuel de chimie américain qui enseigne la chimie pour développer le sens civique des élèves dans le contexte de l'expérience culturelle des États-Unis. Les enseignants et les élèves ont adapté ensemble le texte en fonction des problèmes environnementaux que connaît la région de Krasnoyarskii Krai, en utilisant des données et des exemples locaux. Il ne s'agit pas ici d'apprendre seulement la chimie. On suscite de nouvelles attitudes, comme il ressort des observations suivantes des élèves qui suivent le cours : « Je sais maintenant que mes actes sont importants pour l'avenir de la

planète », et « je suis fier de ma ville et de ses ressources naturelles » ; et « Les enfants de Krasnoyarsk ont le droit d'exprimer leur opinion. »

Le centre RADMASTE d'Afrique du Sud décrit par Bradley met en oeuvre un projet (MRSC) qui vise à mieux adapter les programmes d'enseignement aux besoins. Cet auteur est lui-aussi conscient de l'importance du contexte culturel dans lequel sont enseignées les sciences. Il relève que, bien que des cours de sciences exemplaires soient peut-être mis au point en dehors de l'Afrique du Sud, non seulement ils couvrent des sujets différents, mais leur texte n'est pas rédigé pour le contexte culturel sud-africain.

Ce serait une simplification excessive que de définir les réformes actuelles des programmes d'enseignement des sciences uniquement par rapport au mouvement science, technologie et société (STS), bien que les objectifs poursuivis se recoupent souvent. Il est clair que le mouvement STS a eu un impact considérable sur le contenu des cours conçus dans le cadre de réformes, particulièrement pour le premier cycle de l'enseignement secondaire. C'est ainsi qu'en ce qui concerne la réforme des sciences naturelles dans les établissements d'enseignement secondaire du premier cycle (programme national) du Mexique, Garritz et Talanquer reconnaissent l'importance considérable accordée aux questions concernant le STS. Ils signalent également que différentes matières scientifiques sont enseignées à ce niveau et couvrent un ensemble d'objectifs plus complets que le STS. Dans l'enseignement secondaire du deuxième cycle, pour lequel il n'existe pas de programme national, ils signalent que certains établissements mettent en oeuvre un programme lié au mouvement STS.

La réforme des programmes aux Philippines comprend également un fort élément STS. Elle prévoit « une connaissance du rapport existant entre la science, la technologie et la société » et « une connaissance de la science et de l'environnement ». Ce sont là deux des six objectifs généraux des quatre années d'enseignement des sciences dans le secondaire (voir Beasley). Là encore, on enseigne les sciences en mettant l'accent sur la discipline. Au Chili, les réformes prévoient que les élèves utiliseront leurs connaissances et compétences scientifiques à des fins personnelles et dans l'intérêt de la collectivité.

En Thaïlande, le programme d'enseignement des sciences (Downer et Rana) reflète les mêmes principes que ceux qui sont appliqués dans les autres pays cités dans le présent volume. L'enseignement des sciences vise à faire acquérir par tous les élèves des connaissances apportant une contribution positive au développement économique du pays. Les sciences sont enseignées dans le contexte de la société tout entière et l'on aide les enseignants à axer sur les élèves l'enseignement qu'ils dispensent.

Alors que la plupart des pays cités dans le présent ouvrage font état des questions d'éthique, et en particulier d'éthique de l'environnement conçue comme l'un des éléments de l'enseignement scientifique, le Costa Rica accorde une importance particulière à l'éthique du développement, qui influence l'ensemble du programme. Doryan et Badilla présentent une image très claire et particulièrement convaincante d'un système conçu pour maximiser le potentiel humain de la population et pour développer l'économie, tout en respectant le milieu naturel.

Il a été dit par le passé que « la science de type scolaire » avait peut être une identité propre, qui variait d'un pays à l'autre et différait de la science telle qu'elle est pratiquée par les véritables « scientifiques ». Plusieurs études considèrent la tâche consistant à amener les élèves à « apprendre à penser comme des scientifiques » (par exemple, au Mexique, au Chili et aux Philippines) comme un objectif important, de même que celle qui consiste à se renseigner sur le travail des scientifiques d'aujourd'hui. L'étude de Vrtacnik et Glazar met l'accent sur l'aspect carrière des programmes d'enseignement des sciences, et en particulier sur les carrières dans l'industrie. Leur étude sur la coopération entre l'école et l'industrie en Slovénie montre que, même si dans ce pays l'une et l'autre sont conscientes des avantages mutuels de partenariats, elles ne poursuivent pas les mêmes buts et ne sont pas toujours prêtes à faire le nécessaire pour les atteindre.

Méthodes d'enseignement

L'introduction de nouvelles méthodes pédagogiques dans l'enseignement scientifique secondaire est considérée comme une partie intégrante de la réforme, si problématique qu'elle soit. En bref, dans la nouvelle salle de classe « idéale » où sont enseignées les sciences, le maître cesse d'incarner l'autorité et de dispenser un cours magistral en connaissant toutes les réponses à toutes les questions pour devenir l'intermédiaire du processus d'apprentissage, un gestionnaire de ressources pour la classe tout entière, un conseiller et un formateur. L'enseignant est également chargé de déterminer quels sont les préjugés scientifiques « naïfs » qu'ont les élèves, et de les aider à parvenir à une compréhension scientifique du monde qui les entoure. Travaillant souvent en équipe, les élèves peuvent contrôler les débats au niveau des groupes et de l'ensemble de la classe, et ils sont censés devenir des apprenants « autodirigés ». Ils participent à des recherches fondées sur des investigations au lieu de suivre un livre de recettes donnant des instructions détaillées pour faire des expériences.

Au sujet des efforts de réforme déployés dans l'ensemble de l'Afrique australe, de Feiter et Ncube indiquent qu'« il existe un écart énorme entre, d'une part, la solution idéale consistant à axer davantage sur les élèves l'enseignement dispensé dans les écoles et, d'autre part, les pratiques effectivement suivies ». Un débat auquel participe l'ensemble de la classe et fondé sur les questions posées par l'enseignant constitue la principale forme d'instruction. de Feiter et Ncube mentionnent l'apprentissage passif, les méthodes basées sur le tableau noir et l'exposé, et la prise de notes par les élèves à longueur de cours. Ils signalent également que l'enseignement de type cours magistral est profondément enraciné dans la culture de la région et que « les tentatives faites pour modifier les principes pédagogiques se heurtent aux systèmes de valeurs des enseignants aussi bien qu'à ceux des élèves ». Dans ces circonstances, ils considèrent que s'efforcer de passer à un système d'enseignement axé sur les élèves (« conformément à la culture occidentale individualiste ») n'est peut-être pas la meilleure stratégie pour toutes les cultures. Howie (Afrique du Sud) exprime les mêmes doutes au sujet des activités des élèves et de l'apprentissage collaboratif.

Au Philippines, Beasley a également constaté que le passage d'un enseignement de type cours magistral à un système fondé sur l'apprentissage des élèves posait un formidable problème. Le programme de formation des maîtres auquel il a participé reposait sur des stratégies visant à faire accepter par les enseignants un système davantage axé sur les élèves. Il reste convaincu de

l'importance de ce changement, si difficile qu'il soit à mettre en oeuvre. Dans le cadre d'une évaluation de leurs besoins de formation continue, les enseignants eux-mêmes ont reconnu avoir effectivement besoin d'une aide supplémentaire pour pouvoir commencer à passer à un système axé sur l'apprentissage des élèves. Downer et Karma expriment les mêmes préoccupations pour les enseignants thaïlandais.

Le rôle des travaux pratiques en laboratoire

Le temps consacré à des travaux pratiques en laboratoire est considéré depuis des années comme un aspect essentiel de l'enseignement des sciences, du moins par la communauté scientifique et les professeurs de sciences, sinon par les économistes et les responsables politiques. Après tout, selon cette école de pensée, la science est quelque chose que *font* les scientifiques, et travailler dans un laboratoire est le propre de ceux qui s'appellent eux-mêmes des scientifiques. Des connaissances « scientifiques » s'accumulent du fait des données que recueillent les scientifiques. Si les élèves veulent comprendre en quoi consiste véritablement la science, ils doivent effectivement *faire* de la science. Malheureusement, les laboratoires traditionnels de travaux pratiques sont coûteux à créer et à entretenir, et une grande partie de l'évaluation des résultats des travaux pratiques n'est guère concluante dans le meilleur des cas.

Dans son étude, Thulstrup préconise résolument le maintien des travaux pratiques en laboratoire dans les pays en développement, mais à un coût réduit, voire nul. Il relève également les défauts des méthodes utilisées pour évaluer l'impact des travaux pratiques de science. Bien que le programme de réforme souligne l'intérêt de l'apprentissage pratique, il n'y a pas de raison que les travaux pratiques nécessitent un matériel et des accessoires coûteux, ou même la salle traditionnelle de travaux pratiques de l'école (voir également de Feiter et Ncube). Thulstrup prétend également que l'on peut améliorer l'apprentissage des élèves en utilisant des instruments « transparents » pour l'utilisateur, plutôt qu'une « boîte noire » coûteuse qui ne peut pas être réparée localement en cas de panne. En dehors du problème que pose la réparation d'un matériel coûteux, les enseignants sont souvent tenus responsables des avaries du matériel (Beasley signale l'existence aux Philippines de caisses entières de matériel scientifique coûteux et inutilisé).

L'Edutronics Group de l'Université de Delhi est décrit par Sane comme un exemple d'installation indienne utilisant un matériel peu coûteux fabriqué localement. Cette installation fonctionne depuis plus de 20 ans et sert de modèle à beaucoup d'autres pays en développement.

Bradley indique qu'en Afrique du Sud, on ne fait pas de travaux pratiques de sciences dans beaucoup d'écoles, bien que le principe des travaux pratiques soit largement approuvé. Il examine les raisons de cet état de chose (qui ne se limitent pas aux considérations évidentes de coûts). Des petits kits scientifiques peu coûteux sont maintenant produits localement en Afrique du Sud par le RADMASTE Center pour les cours de chimie, de physique et de biologie (voir Bradley). Des recherches effectuées au centre ont confirmé que les élèves qui utilisaient ces kits apprenaient plus facilement.

L'utilisation de kits au Zimbabwe dans le cadre du projet Zim-Sci est évoquée par de Feiter et Ncube, qui signalent que les enseignants ne voyaient dans l'utilisation de ces kits qu'une « solution de rechange » à l'utilisation de matériel « réel ». Les kits n'ont donc jamais été

très populaires. En outre, les fonds nécessaires à leur renouvellement sont maintenant épuisés. Par conséquent, les travaux pratiques sont maintenant très limités dans les écoles du Zimbabwe et les élèves doivent donc utiliser un papier et un crayon pour les travaux pratiques prévus à leur examen.

Professeurs de science

Importance du professeur

Les tentatives précédentes de réforme pédagogique ont été compromises, intentionnellement ou non, par les enseignants responsables en dernier ressort de la mise en oeuvre de la réforme. Il ne fait guère de doute que les enseignants sont la condition sine qua non de son succès. Toutefois, un certain nombre de réformes systémiques évoquées dans le présent ouvrage ont été apparemment planifiées sans la participation effective des enseignants. Au Mexique comme au Chili, ceux-ci ont été dans l'ensemble exclus du débat et de la planification qui ont eu lieu lorsque les réformes ont été conçues par des spécialistes dans des universités et par des responsables politiques. Garritz et Talanquer signalent que « tant que les enseignants se considèrent comme de simples spectateurs et exécutants des plans établis par quelqu'un d'autre, ils ont du mal à s'engager à entreprendre une réforme ». Martinez et Cerón craignent également que les réformes des programmes au Chili n'aboutissent pas du fait que les enseignants sont déjà exclus du processus de réforme. Ces deux auteurs soulignent l'importance de programmes de formation continue des enseignants pour assurer le succès de la réforme.

À propos de la participation des professeurs du secondaire à la réforme des programmes au Nigéria, Bajah déplore, en tant qu'ancien président du syndicat national des professeurs de sciences (dominé par les professeurs d'université), que peu de professeurs d'établissements secondaires du Nigéria aient participé à la réforme. Il indique toutefois que, pour qu'ils y participent en plus grand nombre, « il faudrait d'abord que nous les y incitions davantage ».

Les activités du syndicat des professeurs de sciences du Nigéria indiquent effectivement quelques modèles à appliquer pour renforcer la confiance et le professionnalisme des professeurs du secondaire. On ne saurait souligner assez combien il est important que les professeurs d'université et d'établissements secondaires collaborent à des activités professionnelles (et extra-professionnelles) dans un cadre collégial.

Il est certain que la participation de nombreux enseignants à la planification des réformes est limitée jusqu'à un certain point, faute des connaissances et de l'expérience nécessaires. Il leur est naturellement impossible, pour cette raison et en l'absence de formation continue, de mettre effectivement les réformes en oeuvre une fois la porte de la classe refermée.

Le projet de formation des enseignants aux Philippines est un exemple rare de projet qui a commencé par une évaluation des besoins des enseignants et qui a été terminé par les intéressés eux-mêmes (voir Beasley). Le premier souci des enseignants était qu'on les aide à utiliser des technologies modernes, aussi bien des ordinateurs que des instruments de laboratoire. Ils ont également manifesté leur intérêt pour des stratégies d'enseignement spécifiques pour l'approche de la science fondée sur l'investigation, pour la préparation des cours, pour des instruments

d'évaluation et pour du matériel peu coûteux. Le programme de formation des enseignants philippins n'a été mis en place à l'université du Queensland qu'après que les besoins d'équipement ont été analysés.

Formation professionnelle des enseignants

Les programmes initiaux de formation des enseignants ont été examinés par Howie et Bradley pour l'Asie du Sud (voir également Ware, 1992b, pour une récapitulation de ces types de programmes). Le centre RADMASTE collabore avec des écoles normales de toute l'Afrique du Sud pour établir de nouveaux programmes de sciences à l'intention des élèves professeurs. Il s'agit de leur permettre de comprendre les concepts qu'ils sont appelés à enseigner dans les écoles, et de les familiariser avec les travaux pratiques et les méthodes axées sur les apprenants.

Tous les pays représentés reconnaissent la nécéssité d'une formation des enseignants en cours d'emploi. L'ampleur de ces besoins est établie pour un certain nombre de pays d'Afrique australe tels que l'Afrique du Sud, le Botswana, la Namibie et le Zimbabwe (de Feiter et Ncube ; Howie). Le présent ouvrage comprend plusieurs études très détaillées décrivant une série de programmes de formation des enseignants en cours d'emploi qui ont donné des résultats variables. Une stratégie apparemment efficace consiste à assurer une formation complémentaire aux enseignants pour qu'ils forment eux-mêmes leurs pairs, stratégie mise à l'essai aussi bien au Zimbabwe qu'aux Philippines.

Dans le cadre du programme du Zimbabwe (de Feiter et Ncube), les enseignants sélectionnés suivent un cours de deux ans à l'Université du Zimbabwe pour obtenir un diplôme de troisième cycle d'enseignement des sciences. Une fois leur diplôme obtenu, ils servent entre autres de mentors à leurs pairs, dirigent des ateliers et exercent les fonctions de directeur de centres scientifiques régionaux. Ils communiquent également les uns avec les autres par courrier électronique, créant ainsi un réseau d'enseignants professionnels ayant reçu une formation.

Le programme des Philippines est pratiquement identique (Beasley). Environ 500 directeurs d'école et enseignants reçoivent une formation de troisième cycle pour devenir des enseignants/formateurs locaux, dirigeant des ateliers, servant de mentors aux enseignants et dirigeant des centres scientifiques régionaux. Ce programme a pour but de préparer les enseignants qui ont les aptitudes voulues pour réfléchir à leurs pratiques pédagogiques et sont ensuite en mesure de les améliorer.

Troisième étude internationale sur les mathématiques et les sciences

La troisième étude internationale sur les mathématiques et les sciences (TIMSS) a examiné les résultats obtenus en sciences et en mathématiques par les élèves appartenant à trois groupes d'âges (9 ans, 13 ans et dernière année d'enseignement secondaire) dans le cadre d'une cinquantaine de systèmes éducatifs sur les cinq continents. Dans leur majorité, les pays participants étaient, pour des raisons financières et logistiques, des pays industrialisés (voir Howie). Un grand nombre des variables contribuant au succès d'un élève ont également été mesurées, notamment le programme, la salle de classe et les facteurs socio-économiques. Cette

étude fournit, sur la réussite en sciences et en mathématiques, une masse de données qui donnera à réfléchir pendant des années aux décideurs et aux éducateurs.

Bien que l'étude TIMSS soit bien plus qu'une « course d'obstacles », c'est le classement d'un pays aux tests par rapport à d'autres pays qui appelle l'attention. Deux des pays représentés dans le présent ouvrage ont participé à la TIMSS : l'Afrique du Sud et les Philippines. L'Afrique du Sud y a participé pour les élèves âgés de 13 ans (septième et huitième années d'étude) et ceux qui quittent l'école (douzième année d'étude). Pour ce dernier groupe, la participation a été limitée aux tests de sciences et de mathématiques. Howie examine en détail les problèmes rencontrés pour réaliser l'enquête en Afrique du Sud. Les résultats des tests ont été jugés très surprenants par les Sud-Africains, ce qui a suscité un débat animé dans les médias et une grande attention de la part des responsables politiques. Les résultats n'ont fait qu'encourager les efforts de réforme.

Les Philippines se sont classées 37e sur 39 pour les élèves de 13 et 18 ans, résultat qui a donné lieu à un débat animé entre les responsables politiques et au sein de la population en général. En conséquence, la nécessité d'élever le niveau de l'enseignement scientifique secondaire aux Philippines a été largement reconnue. Beasley estime que des changements majeurs s'imposent si l'on veut améliorer sensiblement les résultats actuels des élèves. Il fait état des programmes surchargés, des classes trop nombreuses, du manque de ressources et de la nécessité d'assurer une formation en cours d'emploi plus poussée aux enseignants.

Technologie

Le contexte dans lequel s'inscrit la réforme de l'enseignement des sciences est celui d'une révolution électronique sans précédent. Les technologies de la communication (courrier électronique, Internet, world wide web) sont utilisées dans les pays aussi bien industrialisés qu'en développement pour ajouter certaines dimensions à cet enseignement, ce qui était rarement possible auparavant. Les élèves ont accès à des données brutes et peuvent communiquer avec des scientifiques dans leur propre pays et à l'échelon international. Ils peuvent partager des informations sur l'Internet non seulement avec des scientifiques, mais avec des élèves d'autres pays.

Berenfeld est très optimiste quant aux possibilités offertes par Internet comme outil éducatif, bien qu'il n'examine pas véritablement les coûts que devraient supporter les pays en développement pour développer l'utilisation d'Internet par les élèves. Il identifie toutefois des pays en développement qui ont déjà fait un gros effort pour mettre en place des réseaux de ce type. Il précise également que ceux qui n'ont pas accès à ces technologies sont défavorisés dans la concurrence économique mondiale.

Enfin, Bregman et Morten examinent l'utilisation de l'Internet comme moyen d'éducation sur l'environnement. Bien qu'ils tirent une grande partie de leurs exemples de l'expérience de l'Europe, ils examinent également certaines évolutions intéressantes au Brésil, au Chili et au Costa Rica. Ils signalent les préoccupations financières liées à l'utilisation de l'Internet en salle de classe, qui limitent l'utilisation de ces technologies même dans les pays hautement industrialisés. On peut encore se demander si les communications informatisées

tiendront leurs promesses et faciliteront le processus d'apprentissage, en particulier si les coûts continuent à être considérés comme prohibitifs, empêchant ainsi une large diffusion dans la plupart des pays en développement et dans les autres pays.

Quelques réflexions en guise de conclusion

Étant donné la variété des expériences décrites ici, il convient de signaler les caractéristiques communes aux problèmes auxquels se heurte une réforme de l'enseignement des sciences, quel que soit le système éducatif ou le système culturel. À la lecture de ces études, il devient impossible d'ignorer cette vérité manifeste, à savoir que l'élément réactif qui freine la mise en oeuvre d'une réforme est *toujours* l'enseignant. Cela n'est pas véritablement une révélation mais, périodiquement, on s'efforce d'entreprendre des réformes extrêmement complexes sans consulter les enseignants ni même prendre en compte l'impact que la réforme a sur eux. La nature des réformes actuellement mises en oeuvre est telle que le rôle de l'enseignement est devenu encore plus critique.

Il est naïf de croire que des manuels de meilleure qualité et/ou des kits programmés et/ou des technologies au service de l'éducation (par exemple, la télévision, la radio, l'ordinateur, Internet, etc.) peuvent remplacer un enseignant très éduqué et motivé. Le recrutement, l'éducation et le maintien au poste des enseignants sont nécessairement coûteux. (Naturellement, les coûts des autres stratégies, faisant par exemple appel aux communications informatisées, sont également très élevés.) Toutefois, si l'on ne dispose pas d'enseignants de qualité pour mettre en oeuvre la réforme de l'enseignement des sciences, il est difficile de ne pas conclure que toutes les autres dépenses relatives aux réformes seront engagées à fonds perdus.

Sylvia Ware dirige les « Education and International Activities at the American Chemical Society », où elle est responsable des programmes éducatifs à partir du jardin d'enfants, notamment de l'enseignement primaire, secondaire et tertiaire et des programmes de formation continue à l'intention des chimistes en milieu de carrière. Elle est également professeur honoraire de sciences humaines de l'Unesco à l'Université Mendeleev de technologie chimique de Russie.

Bibliographie

Black, P. et Atkin, J. M., directeurs de publication. 1996. *Changing the Subject*. Londres: Routledge en collaboration avec l'OCDE.

Holbrook, J. B. 1991. *The Relationship Between Curricula and Assessment*. Polycopié. Paris: UNESCO.

Kamens, D. H. et Benavot, A. 1991. "Elite Knowledge for the Masses: The Origins and Spread of Mathematics and Science Education in National Curricula". *American Journal of Education*, 99 : 137-180.

Schmidt, W. H. et al. 1996. *Many Visions, Many Aims: A Cross-National Investigation of Curricular Intentions in School Science.* Dordrecht: Kluwer Academic Publishers.

Ware, S. A. 1992a. *Secondary School Science in Developing Countries: Status and Issues.* Washington: Banque mondiale, PHREE Document 92/53.

Ware, S. A. 1992b. *The Education of Secondary Science Teachers in Developing Countries.* Washington: Banque mondiale, PHREE Document 92/68.

Descripción general de la agenda de reformas

Sylvia A. Ware

Introducción

En 1992, el Banco Mundial publicó un informe acerca del estado de la enseñanza de las ciencias en la educación secundaria en los países en desarrollo (Ware, 1992a). En el informe se incluía una descripción general de los principales aspectos relacionados con la entrega de una instrucción científica de calidad en todo el mundo, incluyendo el programa de estudios, la función de los laboratorios, la preparación y permanente capacitación de los maestros de ciencias y la evaluación de los estudiantes, los maestros y el sistema. En el informe también se presentaba un análisis del impacto de los préstamos otorgados por el Banco Mundial para la enseñanza de las ciencias en la educación secundaria entre los años 1963 y 1990. En los Anexos se analizaban brevemente asuntos relacionados con la educación ambiental, enseñanza no formal de las ciencias y factores de género al seleccionar carreras científicas. En un informe relacionado se investigaba en mayor profundidad los procedimientos utilizados en la preparación y capacitación permanente de los maestros (Ware 1992b). Ambos informes contenían múltiples cuadros de resumen y estudios de casos de diversos países.

En los años transcurridos desde esa fecha, los esfuerzos por reformar la enseñanza de las ciencias parecen haberse acelerado en todas las naciones, en especial en los niveles de la educación primaria y secundaria. (En algunos países industrializados, se ha comenzado a abordar temas que desembocarán en la reforma de la educación de las ciencias en el nivel terciario). Un cambio siempre produce alteraciones. Implica el abandono de ciertas ideas preconcebidas a fin de adoptar las nuevas. Implica decidir cuáles caminos antiguos mantener y cuáles nuevos evitar. Y un cambio no sólo resulta perturbador, también implica grandes costos. Para los países en desarrollo con pocos recursos, resulta especialmente problemático que si bien hay acuerdo en que los programas de ciencias "tradicionales" no están respondiendo a las necesidades de la mayoría de los estudiantes que los escogen, todavía no se dispone de evidencia decisiva de que los programas de reforma sí implican una mejoría. (Nótese que muchos de los programas "tradicionales" sólo existen desde hace aproximadamente 30 años). Las naciones en desarrollo no pueden darse el lujo de poner en riesgo el éxito, en especial cuando lo que está en juego son sus necesidades de personal científico y tecnológico para el próximo siglo.

Dado que todos entienden que una enseñanza científica y tecnológica de calidad es un componente esencial para el éxito y la competitividad económica en el mercado global, el Banco Mundial muestra un permanente interés en la reforma de la enseñanza de las ciencias. La formación de la capacidad investigadora en el nivel terciario depende de la generación de estudiantes de elevado rendimiento en el nivel secundario. También depende de la producción de una población con cultura científica capaz de usar los conocimientos científicos y tecnológicos para mejorar la calidad de la vida diaria y respaldar el desarrollo sostenible de la economía.

En este volumen, donde se trata la evolución de la educación científica en los últimos seis años, puede considerarse como una actualización de las publicaciones de 1992 y 1993 mencionadas más arriba. Sin embargo, aquí se presentan las opiniones auténticas de aquellos involucrados de manera más directa en las iniciativas de reforma descritas y no el análisis de un "experto técnico" alejado de la realidad que implican la puesta en marcha de una reforma en condiciones menos que ideales. Las experiencias aquí documentadas provienen de todo el mundo en desarrollo, sin embargo, no todas las partes del globo están representadas equitativamente, debido a que los estudios se recibieron mientras el proyecto se encontraba en curso. Es de esperar que la publicación de este volumen resulte en más publicaciones y que éstas llenen los vacíos existentes en el registro mundial, proporcionando un caudal de conocimientos que faciliten el proceso de reforma a nivel internacional.

La compilación no sólo no representa a ciertas partes del mundo, sino que además no aborda todos los aspectos cubiertos en publicaciones anteriores del Banco Mundial, al menos no detalladamente. En especial, no se analizan los aspectos de la evaluación, salvo en el contexto del Tercer Estudio Internacional de Matemáticas y Ciencias (TIMSS, *Third International Mathematics and Science Survey*). Sin embargo, en muchos países el sistema de evaluación constituye una barrera muy fuerte que impide la reforma.

Los estudios reunidos en este volumen provienen de América Latina, Africa, Asia, Europa y América del Norte. Mientras que en la mayoría se aborda la reforma de naciones en desarrollo específicas, en algunos de ellos se examinan problemas que trascienden las barreras nacionales. En dos estudios, por ejemplo, se aborda el uso de equipos de bajo o ningún costo para la entrega de instrucción científica práctica. En un estudio asimismo se examinan métodos extremadamente tecnológicos y de alto costo para mejorar la enseñanza de las ciencias, métodos que si bien se utilizan más habitualmente en las naciones industrializadas, ahora se están extendiendo a los países en desarrollo de mayores recursos. En el contexto de los estudios que aquí se presentan, se agrega luego una revisión de los principales aspectos de la reforma de la enseñanza científica en el nivel secundario.

La naturaleza de las actuales reformas en la enseñanza de las ciencias

La actual reforma en la enseñanza de las ciencias representa un desafío muy especial porque es multifacética. En ella se intenta los siguiente:

- Redefinir al público destinatario de los conocimientos científicos (todos los estudiantes, no sólo los futuros científicos);
- Ampliar la definición de "contenido" de las ciencias (poniendo menor énfasis en el aprendizaje de datos y centrándose más en la comprensión de los conceptos y el modo en que el conocimiento se transforma en conocimiento científico); y
- Incorporar nuevos métodos didácticos basados en la investigación cognitiva acerca de cómo los estudiantes aprenden ciencias (alejándose del maestro que enseña y acercándose al estudiante que aprende).

El público destinatario del conocimiento científico

Incorporar reformas que aborden una de estas tres facetas ya es una tarea lo suficientemente ardua, pero enfrentar las tres simultáneamente podría considerarse como demasiado ambicioso. Sin embargo, estamos insertos en un esfuerzo de reforma a nivel mundial que busca abrir el mundo de las ciencias a todos los estudiantes y no sólo, como era en el pasado, a aquellos estudiantes que pretenden transformarse en científicos (ver, por ejemplo, Black y Atkin, 1996; Schmidt et al., 1996). Asimismo, los estudios incluidos en este volumen dejan en claro que la "ciencia para todos" es un problema que preocupa a muchas naciones en desarrollo. El siguiente aspecto se está debatiendo desde Argentina hasta Zimbabwe: ¿Cómo podemos hacer más accesible el conocimiento científico a todos los estudiantes sin disminuir el estándar para aquellos que quieren ser los científicos del futuro?

El fundamento para el eslogan "instrucción en ciencias y tecnología para todos" es coherente en todos los países. Se basa en la creencia de que los ciudadanos ilustrados del mañana deben tener sólidos conocimientos acerca de los principios básicos de las ciencias y la tecnología y de sus interacciones con la sociedad, para que así sean capaces de tomar decisiones fundadas (en especial, aunque no exclusivamente, decisiones económicas) respecto al perfil de su sociedad durante el próximo siglo. Si bien la toma de decisiones en el campo social implicará la participación de ciudadanos ilustrados tanto científica como tecnológicamente, este tipo de toma de decisiones depende de conocimientos de una amplia gama de disciplinas.

En los estudios presentados en este volumen, la "enseñanza de las ciencias para todos" se está desarrollando dentro del contexto más amplio de una reforma educacional de todo el sistema como medio para desarrollar una democracia sostenible y equitativa, no sólo una economía sostenible. Esto se articula claramente en el estudio realizado por Doryan y Badilla, donde se analiza la problemática de la ética del desarrollo en su aplicación a los programas de educación ambiental en Costa Rica (no siempre en relación directa con la enseñanza de las ciencias). En el estudio se destacan los cambios de actitud y toma de conciencia que conlleva el aprendizaje de conocimientos científicos, con aplicaciones al manejo del medio ambiente como patrimonio común de las futuras generaciones.

Según Garritz y Talanquer, la reforma de la enseñanza de las ciencias es un componente de las reformas que "será considerado como una de las mayores transformaciones de la educación mejicana en el siglo veinte". La reforma chilena de la enseñanza de las ciencias también se está produciendo en el contexto de una transformación más amplia de todo el sistema, que por un lado busca descentralizar la toma de decisiones en relación con el plan de estudios y por el otro asegurar su calidad a través de la fijación de contendidos básicos mínimos para todos los estudiantes (ver Martínez y Cerón). Del estudio de Howie también emerge claramente que la transformación de la enseñanza de las ciencias en Sudáfrica es un componente de reformas más amplias destinadas a aportar equidad al sistema y promover el desarrollo económico. Sin embargo, a su juicio, las personas responsables de la toma de decisiones y los políticos de este país no establecen un vínculo suficientemente claro entre la enseñanza de las ciencias, la tecnología y las matemáticas (STM, *science, technology, and mathematics*) y la preparación de la fuerza laboral científica y tecnológica.

Redefinición del contexto científico

Resulta importante constatar que en el transcurso de los últimos diez años, el punto de vista de que las ciencias son "objetivas y universales, y que trascienden las diferencias nacionales y culturales" es motivo de intenso debate, no sólo en los círculos posmodernistas. Sin embargo, este debate en particular escapa al horizonte de este estudio. Como se investiga en Schmidt et al. (1996), entre otros, la *transmisión* del conocimiento científico como "ciencia de colegio" es profundamente cultural. Esta difiere significativamente de un país a otro, dependiendo de los resultados nacionales establecidos para el aprendizaje de las ciencias y el desarrollo del plan de estudios. Es interesante advertir que no parece existir una clara visión compartida a nivel internacional acerca de cuál es el alcance del conocimiento que se estima como importante en la instrucción introductoria a las ciencias, acerca de cuándo introducir ciertos temas o de cómo ordenar cronológicamente los temas para los diferentes grupos de estudiantes (Holbrook, 1991; Kamens y Benevot, 1991; Schmidt et al., 1996).

Parece no existir un agenda de reforma compartida para la enseñanza de las ciencias. Tanto el análisis del plan de estudios del TIMSS (Schmidt et al., 1996) como el reciente estudio de la OCDE acerca de las innovaciones en la enseñanza de SMT en 13 países (Black y Atkin, 1996) apuntan a características compartidas en las reformas de la enseñanza de SMT que se están implementando en la actualidad. Éstas son características que se están promulgando en los países en desarrollo a través de programas como el Proyecto 2000+ de la UNESCO. Las tendencias de la reforma lógicamente se centran en los temas tradicionales que abarcan la mayoría (aunque no todos) los cursos de ciencias a nivel de secundaria, pero van mucho más lejos de los hechos, conceptos y conocimientos fundamentales en su definición de "contenido".

El plan de estudios de la actual reforma de las ciencias pone el énfasis en la utilidad de las ciencias para el individuo y la sociedad en general. Lo que importa no son sólo las materias que se enseñan, sino el contexto en el que se enseñan; y el contexto de las reformas es "ciencia para la ciudadanía". Hay diversos subcontextos que se basan en esta amplia declaración de: "ciencia para un desarrollo sostenible", "ciencia para mejorar la calidad de vida", "ciencia para las futuras necesidades de la humanidad", "ciencia para un manejo razonable del medio ambiente", etc. En la actualidad, "ciencia para los futuros científicos" no está muy en boga y "ciencia por el bien de la ciencia" parece estar prácticamente relegada a la categoría de lujo que sólo se pueden permitir los privilegiados. Sin importar la marca que se le ponga a la reforma, las ciencias se están usando como un medio para enseñar mucho más que solamente ciencias. Se están utilizando para enseñar responsabilidad personal y social.

En el estudio de Tarasova y Gapanovitch se ilustra muy claramente este contexto para la reforma de la enseñanza de las ciencias en Krasnoyarskii Krai, una región de Siberia rica en recursos naturales, fuertemente industrializada en ciertas áreas y por consiguiente altamente contaminada. Los autores describen el uso de una traducción al ruso de un libro de texto estadounidense de química, en el que se enseña química para ciudadanos en el contexto de la experiencia cultural de los Estados Unidos. Con la ayuda de ejemplos y datos locales, los maestros y estudiantes adaptaron en conjunto el texto a los problemas ambientales existentes en

Krasnoyarskii Krai. Aquí se está aprendiendo más que sólo química. Se están formando nuevas actitudes, lo que se comprueba con los comentarios de los estudiantes que asisten al curso. Por ejemplo, "Ahora sé que mis acciones personales son importantes para el futuro del Planeta Tierra"; y "Estoy orgulloso de mi ciudad y de sus recursos naturales"; y "Los niños de Krasnoyarsk tienen el derecho de expresar sus propias opiniones".

El Centro RADMASTE en Sudáfrica, según lo describe Bradley, está implementando un proyecto de Plan de Estudios de Ciencias más Pertinente (MRSC, *More Relevant Science Curriculum*). Él también se muestra preocupado de la importancia del contexto cultural al enseñar ciencias. Bradley hace notar que si bien pueden existir cursos de ciencias ejemplares preparados fuera de Sudáfrica, éstos no sólo abarcan temas diferentes, si no que además no están redactados para el contexto cultural sudafricano.

Definir las actuales reformas del plan de estudios exclusivamente en términos del movimiento de las ciencias, tecnología y sociedad (STS, *science, technology, and society*) sería una simplificación extrema, a pesar de que sus objetivos a menudo se superpongan. Es evidente que este movimiento ha afectado significativamente el contenido de los cursos de la reforma, en especial en el nivel secundario inferior. Por ejemplo, en lo que se relaciona con la reforma de las ciencias naturales en el primer ciclo de la enseñanza secundaria (un plan de estudios a nivel nacional) en México, Garritz y Talanquer confirman el fuerte énfasis puesto a los temas sobre STS. Ellos también indican que a este nivel se enseñan ramos científicos individuales, que cubren un conjunto de objetivos más globales que sólo STS. En la educación secundaria de ciclo superior, donde no existe un plan de estudios nacional, ellos informan que algunas escuelas están implementando un programa relacionado con STS.

La reforma del plan de estudios en Filipinas también incluye un fuerte componente de STS. Este comprende el "conocimiento de la relación entre ciencia, tecnología y sociedad" y el "conocimiento de las ciencias en el medio ambiente" como dos de los seis objetivos generales para los cuatro años de instrucción de ciencias en el nivel secundario (ver Beasley). También aquí, las ciencias se enseñan con énfasis en cada disciplina.
Con las reformas chilenas también se espera que los estudiantes usen los conocimientos y técnicas científicas con fines personales y sociales.

El plan de estudios de Tailandia (Downer y Rana) refleja las mismas ideas que se están implementando en los demás países representados en este volumen. La enseñanza de las ciencias se considera un conocimiento —impartido a todos los estudiantes— que contribuye positivamente al desarrollo económico de la nación. Las ciencias se enseñan a partir de un contexto social y los maestros reciben apoyo para evolucionar a una educación centrada en los estudiantes.

Mientras que en la mayoría de los países presentados en este volumen se menciona la ética, especialmente la ética medioambiental, como uno de los componentes de la enseñanza de las ciencias, en la experiencia de Costa Rica se pone un énfasis especial en la ética del desarrollo que influye todo el plan de estudios. Doryan y Badilla presentan una visión especialmente

convincente y claramente articulada de un sistema que busca maximizar el potencial humano de su población y desarrollar la economía, respetando al mismo tiempo el medio ambiente natural.

Con anterioridad se sugirió que tal vez las "ciencias escolares" tengan su propia identidad que varía un país a otro y difiere de las ciencias que practican los científicos "reales". En varios de los estudios se enumeran las tareas para que los estudiantes "aprendan a pensar como científicos" (por ejemplo, México, Chile y Filipinas) como un objetivo importante, junto con aprender acerca de la labor de los científicos actuales. El estudio de Vrtacnik y Glazar se centra en el componente de carreras con contenido científico, en especial, de las carreras aplicadas a la industria. Su investigación de la cooperación entre escuelas e industrias en Eslovenia muestra que si bien tanto las escuelas como las industrias están conscientes de los beneficios mutuos que brindan las asociaciones entre escuelas e industrias, no comparten los mismos objetivos para estas relaciones y no siempre están preparadas para implementarlas de manera exitosa.

Métodos didácticos

Se considera que la incorporación de nuevos métodos pedagógicos a las clases de ciencias en la educación secundaria es un componente integral, aunque problemático, de la reforma. En pocas palabras, en este nuevo salón de ciencias "ideal", se visualiza que la función que desempeña el maestro cambia desde una figura autoritaria, que controla la lección al frente del salón de clases y que conoce todas las respuestas a todas las preguntas (!), a la de un intermediario en el proceso de aprendizaje, un administrador de los recursos de la clase, un entrenador y consejero. El maestro también es el responsable de determinar cuáles son los conceptos científicos erróneos "ingenuos" que los estudiantes traen a la clase y ayudarles a adquirir un conocimiento científico del mundo natural. Los estudiantes, que a menudo trabajan en grupos, pueden controlar los análisis del grupo y de la clase y se espera que con el tiempo se transformen en aprendices "auto dirigidos". Ellos participan en investigaciones "basadas en la indagación", en lugar de seguir detalladas instrucciones de experimentos tipo "recetas de libro de cocina".

Feiter y Ncube, al analizar las iniciativas de reforma en el sur de África, indican que "Hay una brecha enorme entre el ideal de introducir en las escuelas una educación más centrada en los estudiantes y las prácticas reales". La principal forma de instrucción es un análisis de toda la clase con preguntas formuladas por el profesor. Ellos mencionan un aprendizaje pasivo, con entrega del tipo "ilustración en la pizarra" y actividades de toma de notas por parte de toda la clase. También destacan que la forma de instrucción centrada en el profesor está fuertemente integrada a la cultura de la región y que los "Intentos de cambiar la pedagogía de la enseñanza entra en conflicto con los sistemas de valores tanto de los maestros como de los estudiantes". Bajo tales circunstancias, sugieren que cualquier intento de evolucionar a una enseñanza centrada en los estudiantes ("en consonancia con la cultura occidental individualista") posiblemente no representa la mejor estrategia para todas las culturas. Howie (Sudáfrica) también expresa aprensiones similares con respecto a las actividades prácticas de los estudiante y el aprendizaje de colaboración.

En Filipinas, Beasley también descubrió que el traspaso de una enseñanza impartida por el maestro a un aprendizaje práctico del estudiante representa un desafío inmenso. El programa

de desarrollo de los maestros en que estuvo involucrado se centraba en estrategias para evolucionar hacia un salón de clases más centrado en los estudiantes. El todavía cree que este cambio es importante, aunque extremadamente difícil de lograr. En una evaluación de las necesidades de los maestros de una educación permanente, ellos mismos admitieron que necesitaban ayuda adicional para poder empezar a cambiar a un enfoque centrado en el aprendizaje de los estudiantes. Downer y Karma manifiestan las mismas aprensiones con respecto a los maestros en Tailandia.

El papel que desempeña la enseñanza en laboratorio de ciencias prácticas

Por años, el tiempo dentro del laboratorio ("práctica") ha sido considerado un componente esencial de la enseñanza de las ciencias, al menos por las comunidades científicas y de enseñanza de las ciencias, si no por economistas y políticos. Después de todo, se sostiene que las ciencias son algo que los científicos *hacen,* y el trabajo dentro del laboratorio es la actividad más esencial de las personas que se denominan científicos. El conjunto de conocimientos denominado "ciencias" se ha podido acumular gracias a los datos recopilados por los científicos. Si se desea que los estudiantes comprendan realmente lo que significan las ciencias, deben *practicarlas.* Desafortunadamente, las clases de laboratorio tradicionales son caras de instalar y mantener; y gran parte de la evaluación de los resultados de la enseñanza en laboratorio en el mejor de los casos ha quedado inconclusa.

En el estudio de Thulstrup se apoya de manera elocuente el mantenimiento de laboratorios en las escuelas de los países en desarrollo, pero en una modalidad de bajo costo o ningún costo. En él también se destacan los defectos presentes en los métodos de evaluación de la ciencia "práctica". Aunque en la agenda de reformas se hace hincapié en la utilidad de "aprender haciendo", no hay motivo alguno para que las ciencias "prácticas" requieran de costosos equipos o materiales, o incluso de las tradicionales instalaciones de laboratorio en las escuelas (ver también de Feiter y Ncube). Thulstrup también argumenta que se puede mejorar el aprendizaje utilizando instrumentos que sean "transparentes" para el usuario, en lugar de caros aparatos autónomos ("caja negra") que no se pueden reparar localmente una vez que se deterioran. Además del problema de reparar un equipo costoso, se hace recaer la responsabilidad por su deterioro en los maestros. (Beasley informa acerca de costosos equipos científicos que permanecen sin usar en Filipinas).

Sane describe el trabajo del Grupo Edutronics en la Universidad de Delhi como un ejemplo de una instalación de instrumentos científicos de bajo costo y fabricados localmente en India. Esta instalación ha estado funcionando durante más de 20 años y sirve de modelo para muchos otros países en desarrollo.

Bradley indica que en Sudáfrica, a pesar de un amplio respaldo al trabajo práctico, en muchas escuelas no se ejercen ciencias prácticas. Él analiza los motivos (más allá del problema obvio de costo). En este momento, el Centro RADMASTE está elaborando equipos científicos de bajo costo fabricados localmente en Sudáfrica para las clases de química, física y biología (ver Bradley). Los estudios de investigación del Centro han confirmado un incremento del aprendizaje entre los estudiantes que usan estos equipos.

De Feiter y Ncube analizan el uso de equipos en Zimbabwe en el marco del proyecto Zim-Sci. Ellos mencionan que los maestros consideraban estos equipos como "alternativas de segunda mano" frente al uso de equipos "reales". Por este motivo, los equipos nunca fueron muy populares. Además, en este momento se encuentran agotados los fondos para reponerlos. A consecuencia de esto, es poco el trabajo práctico que se realiza en la actualidad en las escuelas de Zimbabwe y los estudiantes pueden rendir una versión impresa (con lápiz y papel) del examen de ciencias práctico ordinario.

Maestros de ciencias

La importancia del maestro

Anteriores esfuerzos de reforma educacional se vieron trastocados, ya sea intencionalmente o no, por los maestros que en último término son los responsables de implementar la reforma. Existen pocas dudas de que los maestros son el *sine qua non* de una reforma educativa. Sin embargo, varias de las reformas del sistema que se analizan en este volumen aparentemente no incluyeron a los maestros como un componente integral en la planificación de las reformas. Tanto en México como en Chile, los maestros se vieron en gran medida excluidos de los análisis y la planificación cuando especialistas a nivel de universidades y políticos diseñaron las reformas. Garritz y Talanquer hacen notar que "mientras los maestros se consideren a sí mismos como meros espectadores y ejecutantes de los planes de terceros, difícilmente se podrán comprometer con el éxito de una reforma". Martinez y Cerón también están preocupados de que las reformas del plan de estudios no tengan éxito en Chile, porque los maestros ya se sienten ajenos al proceso de reforma. En ambos estudios se hace hincapié en la importancia de continuar con programas de formación de docentes para asegurar una reforma exitosa.

Bajah, al hablar de la participación de los maestros de enseñanza secundaria en la reforma del plan de estudios en Nigeria, en su calidad de ex Presidente de Maestros de Ciencias en Nigeria (dominados por profesores universitarios), expresa su pesar de que haya pocos maestros de enseñanza secundaria en Nigeria involucrados en la reforma. Sin embargo, indica que antes de lograr que más maestros participen en ella, "necesitaríamos en primer lugar desarrollar su confianza frente a su participación en actividades de este tipo".

Las actividades de la Asociación de Maestros de Ciencias de Nigeria sugieren algunos modelos para desarrollar tanto la confianza como el profesionalismo entre los maestros de la enseñanza secundaria. No es posible desconocer la gran importancia que reviste la participación conjunta de maestros de enseñanza superior/universitaria y de enseñanza secundaria en actividades profesionales (y en encuentros sociales) de una manera colegiada.

Ciertamente la participación de muchos maestros en la planificación de las reformas se ve limitada hasta un determinado grado por sus conocimientos y experiencia. Es obvio que esta misma falta de conocimientos y experiencia impide que los maestros, ante la falta de una

formación permanente, puedan implementar efectivamente las reformas una vez que se cierran las puertas del salón de clase.

El proyecto de formación de docentes en Filipinas es ese raro ejemplo de un proyecto de reforma que comenzó con una evaluación de las necesidades de los maestros realizada por ellos mismos (ver Beasley). La primera inquietud que manifestaron los maestros fue la necesidad de apoyo en la utilización de tecnologías modernas, tanto a nivel de computadoras como de instrumentos de laboratorio. También expresaron preocupación acerca de las estrategias docentes específicas y del proceso de enfoque a las ciencias, además de la preparación de las lecciones, instrumentos de evaluación y equipos de bajo costo. El programa de capacitación de los maestros filipinos sólo se implementó en la universidad de Queensland una vez que se analizaron las necesidades expresadas.

Desarrollo profesional de los maestros

Howie y Bradley analizan los programas iniciales de preparación de los maestros para Sudáfrica (un resumen de estos tipos de programa se encuentra en Ware,1992b). El Centro RADMASTE ha estado trabajando con institutos pedagógicos de toda Sudáfrica para preparar nuevos programas de estudios de ciencias para los estudiantes de pedagogía. Los programas se centran en la capacitación de estos estudiantes en la compresión de los conceptos que pronto estarán enseñando en las escuelas y prepararlos en el trabajo práctico y en las metodologías concebidas en función de los alumnos.

Todos los países representados mencionaron la necesidad de formar y perfeccionar a los maestros en servicio. La magnitud de esta carencia está documentada para varios países en la zona sur de África, entre ellos Botswana, Namibia, Sudáfrica y Zimbabwe (de Feiter y Ncube; Howie). En este volumen se encuentran además varios estudios muy detallados donde se describe una gama de programas de perfeccionamiento de maestros en servicio, que han tenido éxitos o fracasos. Una estrategia aparentemente efectiva es proporcionar capacitación adicional a maestros de educación presencial para que sirvan de asesores pedagógicos a sus colegas, actividad que se está intentando tanto en Zimbabwe como en Filipinas.

En el programa de Zimbabwe (de Feiter y Ncube), los maestros seleccionados toman un curso de dos años de duración en la Universidad de Zimbabwe para obtener un diploma de posgrado en enseñanza de las ciencias. Después de la graduación, estos maestros sirven de mentores para sus colegas (además de otras funciones), llevando a cabo talleres y actuando como administradores generales de los centros regionales de ciencias. También interactúan entre sí a través de correo electrónico, estableciendo así una red de maestros capacitados profesionalmente.

El programa de Filipinas es casi idéntico a éste (Beasley). Alrededor de 500 directores y maestros ingresan a una capacitación de posgraduados para transformarse en asesores pedagógicos y realizar talleres, servir de mentores a otros maestros y administrar centros regionales de ciencias. Con el programa se busca preparar a maestros que, con la capacidad de reflejar su propia práctica pedagógica, sean capaces de mejorar aquellas prácticas.

El Tercer Estudio Internacional de Matemáticas y Ciencias

En el Tercer Estudio Internacional de Matemáticas y Ciencias (TIMSS) se exploraron los avances en matemáticas y ciencias logrados por los estudiantes de tres edades (9, 13 y estudiantes en el último año de la enseñanza secundaria) en alrededor de 50 sistemas educacionales de cinco continentes. Por razones financieras y logísticas, la mayoría de los países participantes fueron naciones industrializadas (ver Howie). También se midieron muchas de las variables que contribuyen a los avances, incluyendo elementos del plan de estudios, didácticos y socio-económicos. El estudio está arrojando una cantidad inmensurable de información sobre los avances en ciencias y matemáticas, que mantendrá ocupados por años a las autoridades responsables y a los educadores.

Aunque el estudio TIMSS fue muchísimo más que tan sólo una "carrera de caballos", es la clasificación del logro de un país en las pruebas con respecto a otros países lo que está llamando la atención. Dos de los países representados en este volumen participaron en el TIMSS: Sudáfrica y Filipinas. Sudáfrica participó en los estudios de la población de 13 años de edad (7° y 8° grado) y la población que está egresando de la escuela (12° grado). La participación del doceavo grado se limitó a las pruebas de conocimientos en ciencias y matemáticos. Howie analiza en detalle los problemas que conllevó la realización del estudio en Sudáfrica. Los resultados de las pruebas causaron un gran impacto entre los sudafricanos, generando grandes discusiones en los medios de comunicación y atrayendo la atención de los políticos. Los resultados sirvieron para impulsar las iniciativas en torno a la reforma.

Filipinas se ubicó en el lugar 37/39 para los estudiantes de 13 y 18 años, un desempeño que fue ampliamente analizado por los políticos y el público en general. Por este motivo, se admite ahora de manera generalizada que las ciencias filipinas a nivel de enseñanza secundaria deben elevar su nivel. Beasley sugiere que para tener alguna posibilidad de lograr un aumento significativo en los actuales niveles de aprovechamiento escolar, resulta imprescindible implementar algunos cambios sustanciales. El menciona planes de estudios exagerados, cursos de gran tamaño, falta de recursos y la necesidad de más formación de los maestros en servicio.

Tecnología

La reforma de la enseñanza de las ciencias se encuentra inmersa en el contexto de una revolución electrónica sin precedentes. La tecnología de las comunicaciones (correo electrónico, Internet, World Wide Web) se usa tanto en los países desarrollados como en vías de desarrollo para ampliar el ámbito de la enseñanza de las ciencias como nunca antes fue posible de manera tan generalizada. Los estudiantes pueden acceder a datos originales y a científicos de sus propios países y de todo el mundo. Asimismo, pueden compartir información a través de Internet no sólo con científicos, sino también con estudiantes de otros países.

Berenfeld respalda fervientemente las expectativas representadas por el Internet como herramienta pedagógica, aunque no explora los costos de formación de comunidades de estudiantes dedicados a la experimentación en los países en desarrollo. Sin embargo, sí identifica

a las naciones en desarrollo que ya se han comprometido significativamente en instalar ese tipo de redes. Él también deja clara constancia de que aquellos países que no tengan acceso a ese tipo de tecnologías quedarán atrás en la competencia mundial por seguridad económica.

Finalmente, Bregman y Morten analizan el uso del Internet como un medio de enseñanza de la educación ambiental. Si bien muchos de sus ejemplos provienen de experiencias europeas, también investigan algunos procesos muy interesantes en Chile, Brasil y Costa Rica. Ellos informan acerca de los problemas financieros relacionados con el uso del Internet en el salón de clases, que están frenando el uso de esta tecnología incluso en naciones altamente industrializadas. El tema de que las comunicaciones mediatizadas por las computadoras puedan cumplir con la anticipada promesa de un mejor aprendizaje es aún cuestionable, especialmente si en la mayoría de las naciones en desarrollo (y otras) se siguen considerando prohibitivos sus costos para una divulgación generalizada.

Algunas reflexiones finales

En vista de la amplia gama de experiencias que aquí se describen, son dignos de mencionar los problemas comunes que se encontraron al implementar reformas de la enseñanza de las ciencias, independientemente del sistema educacional o contexto cultural. Al leer estos estudios, es imposible ignorar lo obvio: el agente que se interpone con la implementación de la reforma *siempre* es el maestro presencial. Esto no es ninguna revelación. Y sin embargo, los sistemas educacionales intentan reiteradamente introducir reformas extremadamente complejas sin consultar a los maestros o sin, al menos, considerar el impacto que dichas reformas tendrán sobre ellos. La naturaleza de las reformas que se están implementando en la actualidad es tal que la función que desempeñan los maestros es incluso más decisiva que antes.

Es ilusorio creer que mejores libros de textos y/o equipos programados y/o tecnología pedagógica (por ej., TV, radio, computadora, Internet, etc.) puedan reemplazar a un maestro altamente educado y motivado. Los costos de contratar, educar y mantener a una fuerza laboral pedagógica de esa naturaleza necesariamente tienen que ser altos. (Obviamente, los costos de otras estrategias, por ejemplo de comunicaciones mediatizadas por computadora, también son muy altos). Sin embargo, sin maestros de calidad para implementar la reforma de la enseñanza de las ciencias, es difícil no llegar a la conclusión de que todos los demás costos de la reforma son inversiones perdidas.

Sylvia Ware es Directora de Educación y Actividades Internacionales en la American Chemical Society, donde es responsable de los programas de educación a partir del nivel de escuela de párvulos, en la enseñanza primaria, secundaria y terciaria y en programas de ampliación de estudios para químicos de nivel intermedio. También es Profesora Honoraria de la UNESCO en Humanidades de la Universidad Mendeleev de Tecnología Química, Rusia.

Bibliografía

Black, P. y Atkin, J.M., Eds. 1996. *Changing the Subject*. Londres: Routledge con OCDE.

Holbrook, J.B. 1991. *The Relationship Between Curricula and Assessment*. Mimeógrafo. París: UNESCO.

Kamens, D.H. y Benavot, A. 1991. "Elite Knowledge for the Masses: The Origins and Spread of Mathematics and Science Education in National Curricula". *American Journal of Education*, 99: 137-180.

Schmidt, W.H. et al. 1996. *Many Visions, Many Aims: A Cross-National Investigation of Curricular Intentions in School Science*. Dordrecht: Kluwer Academic Publishers.

Ware, S.A. 1992a. *Secondary School Science in Developing Countries: Status and Issues.* Washington, DC: Banco Mundial, Documento PHREE 92/53.

Ware, S.A. 1992b. *The Education of Secondary Science Teachers in Developing Countries.* Washington, DC: Banco Mundial, Documento PHREE 92/68.

On the Road to Improving the Quality of Life: Environmental Education in the Costa Rican Education System

Eduardo Doryan and Eleonora Badilla

This paper introduces the ethics of sustainable development as applied to education in Costa Rica. It emphasizes the synergy that exists among issues of developmental ethics related to four areas: economic and productive sustainability, environmental sustainablity, social and political sustainability, and sustainable human resource development. The 10 Costa Rican environmental education programs discussed address these four areas. An emphasis is placed on the need for a comprehensive view of development so that environmental education programs have a positive impact on the environmental awareness and knowledge of future generations.

Introduction

Costa Rica covers 51,000 square kilometers of the Central American isthmus. It has a population of around 3.5 million, literacy rate of 95 percent, life expectancy of approximately 75 years, and average per capita income of $3,000 a year. Since it has no army Costa Rica has dedicated its resources to education and health. By constitutional mandate, public investment in education is currently around 6 percent of GDP. Like other nations in the area, Costa Rica has been impacted upon by the introduction of information technology, biotechnology, and the optimization of environmental standards on the one hand, and regional economic alliances and free trade agreements on the other. The country needs to prepare adequately to be a part of technological, environmental, and economic advancement. Education plays a fundamental role in making this possible. Nevertheless, education must operate from within a framework of developmental ethics—the ethics of sustainable development.

Developmental Ethics: The Basis of Environmental Education

> Values do not float above daily life, but they originate from our daily struggle to survive and to achieve or maintain a state of well-being.
>
> Mario Bunge

It is necessary to use humanism as a tool to build a network of connections allowing for sustainable development. Environmental education in Costa Rica does not take place in a vacuum; rather, it is one element that contributes to an ethical analysis of development. As one Costa Rican philosopher states:

> A genuine concern for human issues includes the protection and recuperation of different natural mechanisms. Apparently, we may conclude that we are important, but not the only ones... Humanism does not have to reduce itself to anthropocentrism. Furthermore, caring for Nature may become a source of possibilities for human thriving; and likewise, it may prove to us that Nature's impoverishment generally implies human impoverishment.
>
> Ramírez 1994

We need to use developmental ethics to produce a nation of citizens capable of living together in balance with their social and natural environments—citizens who use natural resources efficiently and design industrial processes in harmony with nature and citizens who are able to consume rationally and intelligently. Developmental ethics can be examined in four areas: environmental sustainability, human resource sustainability, social and political sustainability, and economic and productive sustainability.

Environmental Sustainability

The relationship of individuals within a given society to the natural world is one of the most important aspects of any developmental strategy. Development necessarily implies a transformation of this relationship. Traditional economic policies tend to manifest a "frontier" vision, focusing on products, disregarding the exploitation and degradation of resources and generation of wastes. Such a limited vision does not address the relationships among populations, natural resources, and territory.

At the international level there has been a change of paradigm, involving the tie between economy and ecology. The new approach is designed to include all kinds of capital and resources in the budgeting of national accounts at the macroeconomic level, in productivity at the microeconomic level, and in investment decisions at the corporate level. Developmental ethics must explain the relationship between populations, natural resources, and territory. It endeavors to produce citizens who will consider the relationship of durability to cost in their consumption decisions; who are aware of the short-, medium-, and long-term consequences of their decisions, and who realize that their decisions will impact future generations.

Human Resource Development

It is possible to catalyze development, to increase equity, to strengthen the social network, and to promote national unity with an appropriate investment in human resources. The sustainability of human resource development requires making it possible for individuals to build and strengthen their own knowledge, establishing suitable mechanisms for that knowledge to be used to benefit society, and increasing the capacity of individuals to promote their own well-being. Human resource development contributes to closing the social, economic, conceptual, and cognitive breaches that inhibit the formation of a large, dynamic middle class. The application of developmental ethics contributes to the closing of those breaches if significant resources are dedicated to the poverty-stricken sectors of society, making the most powerful instruments of social mobility available to the weakest.

Social and Political Sustainability

Social and political sustainability must involve the integration of personal and collective development, in order to assure active citizen participation in the identification and solution of national problems. This should result in the transformation of various socio-political factors at the state level, including:

- Improving the quality, coverage, and efficiency of basic and strategic services
- Strengthening of political liberties
- Consolidating gender equality—to reverse structural discrimination and to open up participation channels for women
- Fostering respect for cultural and ethnic diversity within the global context
- The simplification and transparency of governmental procedures and actions in order to substantially diminish corruption.

Developmental ethics plays an important role in developing citizens who are aware of their duties as well as their rights and who are willing to accept responsibility for solving community problems, especially those involving interactions between the physical and social environments.

Economic and Productive Sustainability

Sustainable development will only be achieved if macroeconomic stability is complemented with microeconomic efforts to increase the sources of work, efficiency, and competitiveness at the corporate level. This integration should be based on austere production processes that use energy and resources efficiently. As we are reminded:

> Most of the political systems have considered the economic growth as their main objective; and they have followed developmental strategies adapted to this purpose, with devastating ecologic consequences.
>
> Stokke 1993

Applying developmental ethics helps to make a well-integrated human being with the following characteristics:

- A dignified, free, and just individual who, within the family as the nucleus of society, is capable of cultivating spiritual and esthetic values and who enjoys healthy recreation for the promotion of physical, physiological, mental, and emotional health.
- A citizen capable of participating in democratic decisionmaking—who has both a national identity and civic awareness yet who adopts a global perspective and is capable of discerning and competing and being self-fulfilled and happy.
- An individual who, for personal satisfaction and for society, improves her abilities by learning new skills and continuously searching for new knowledge.
- A citizen who searches for new forms of cooperation and harmony between sectors, who protects the quality of life for all citizens and future generations by supporting sustainable development, and who respects of the planet's biological and cultural diversity.
- A citizen who appreciates his heritage as a Costa Rican and who can communicate effectively with other cultures as a self-contained thinker and a flexible and critical individual.

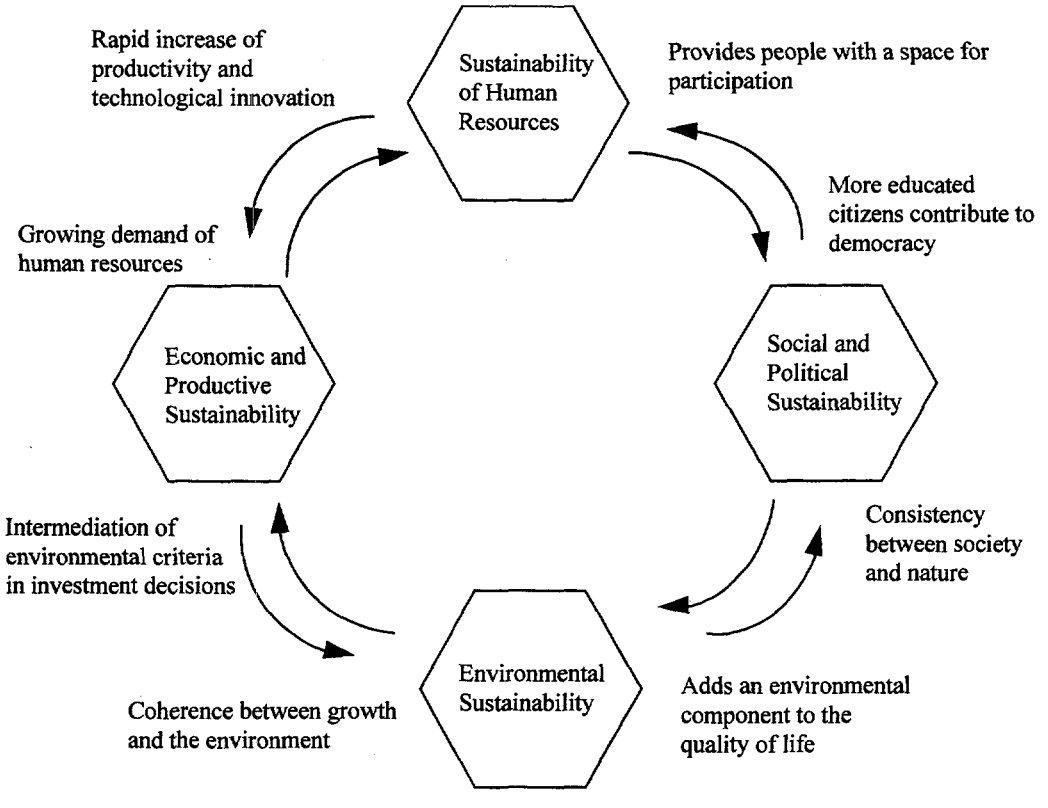
For Costa Rica, sustainability, in all its facets, implies closing a range of societal breaches and facing very specific challenges that must be addressed to achieve the human development necessary to allow us to compete in the global economy. The possibility of Costa Rica achieving

a higher standard of living will depend on our ability to face the challenges of sustainable development as a nation united.

The social challenge is to use education as an important tool to close the gap between social classes, to create new opportunities for social climbing, and to promote the active participation of all Costa Ricans in solving national problems. The economic challenge is to use education to generate the human resources necessary to increase national competitiveness and productivity and to integrate the country into the world's economy. The ethical challenge for education is to strengthen the values and attitudes required to add an altruistic, inspiring, incorruptible, and humanitarian sense to the economic and social aspects of development. Finally, the environmental challenge is to implement development that promotes harmony between man and the natural world and provides today's citizens with a sense of responsibility with respect to the needs of future generations.

Education plays a major role in the actions undertaken by the Costa Rican government and society to address these challenges. It provides a means to integrate our needs with our reality to achieve the concrete environmental objectives of Costa Rica and its education institutions (figure 1).

Figure 1 Interactions Among the Components of Sustainable Development



Integrating Environmental Education into the National Education System

The incorporation of environmental education for sustainable development into the national education system is vital. Environmental education, which integrates interactions among the natural environment, the population, and development, is a central focus of the formal curriculum, which is closely related to community concerns. This implies that environmental education is not only a commitment made by the traditional educational structures, but also includes actions proposed by the nonformal structures (for example, private corporations, nongovernmental organizations, and community organizations). It is important to view environmental problems in the context of the community to ensure that solutions are practical and likely to be implemented.

To achieve our goals, on June 29, 1994, the Ministry of Public Education of Costa Rica created the Administration of Environmental Education and Sustainable Development. The Administration has collected information on previous relevant programs and publications, including those addressing the biological preservation of species, the relationship between human society and the natural environment, and society's commitment to the needs of future generations.

The Administration operates numerous programs to train and support teachers and students on the subject of the environment and sustainable development. Students of different ages participate in all the programs described below. Most are ages 10–16 (grades 5–11). Each program conducts workshops, seminars, courses, consultancies, and meetings in order to provide permanent support to teachers and students in the classroom. Most important, all programs are linked to the community, in order to provide opportunities for students, teachers, and community organizations to carry out joint investigations, projects, and activities to improve the quality of life in Costa Rica.

Educational Program for Handling Solid Waste

This program is designed to create an awareness of environmental problems associated with the inadequate handling of solid waste and to foster responsible attitudes that contribute to the modification of the consumption patterns, habits, and values of the student community. Through this program 50,000 educational documents have been distributed to students, teachers, and parents. Among these documents are handbooks, letters to parents, and copies of the pamphlet *Trash, a Misplaced Resource.* There have been training sessions for both students and teachers. The program has been widely publicized by both the print and broadcast media.

The program has been supported by governmental institutions (the congress and various ministries) and private companies. Education institutions have become involved in paper recycling projects and have generated some of their own finances.

"Environmentalization" of the Institution with Community Participation

Through this program education institutions write a funding proposal addressing ways to accomplish the "environmentalization" of the institution and the classroom with the cooperation of the community. The proposal includes a diagnosis of local environmental problems and the design of an action scheme to address these problems. Teachers, children, parents, and members of the community of every educational region of the country have become involved in this program.

School Support for the Sustaining River Basins

Through this program, students develop an awareness of the importance of and need to protect the river basins. They actively participate in community actions to protect and rescue the river basins of Costa Rica. For example, there is an agreement to protect and rejuvenate the Virilla river basin, (the river flows through the capital city). There are also actions intended to rescue and protect the river basins of the Sonador and Convento rivers in San Pedro and Pérez Zeledón and Buenos Aires, Puntarenas, the southern rural area of the country.

Student Conference on the Environment, Population, and Development

The teenagers who participate in the Student Conference on the Environment, Population, and Development have an opportunity to identify problems and needs related to sustainable development and to propose alternative solutions to improve the quality of life in Costa Rica.

Earth Education Program

The Earth Education Program supports the formation of a network of environmental clubs in high schools across Costa Rica. These clubs promote innovative educational programs addressing issues related to the environment and sustainable development. They contribute to the formation of young leaders who are capable of accepting and offering proposals to solve social and environmental problems. These young leaders are trained in different locations, such as scientific stations, museums, and national parks.

Educational Program for Emergencies

This program fosters the development of individuals who are aware of the need to preserve the environment and live in harmony with the natural world, in order to prevent disasters. In case of natural disaster students and teachers are trained to react in the most appropriate way to save their own lives and the lives of others. In addition, they commit themselves to participate responsibly in rehabilitation and reconstruction activities after a disastrous event.

The program organizes training workshops on school safety for students and teachers. A document for school organization in disasters was edited and distributed in coordination with the National Commission for Emergencies, and with the World Bank's support. Also, different types of educational materials, such as posters, handbooks, and pamphlets have been handed out to

students, all of them addressing the appropriate way to handle disasters such as fires, floods, and earthquakes.

The Global Learning and Observations to the Benefit of the Environment Program

The Administration of Environmental Education and the Ministry of Public Education of Costa Rica encourage our students to participate in the international Global Learning and Observations to the Benefit of the Environment (GLOBE) program, which focuses on the environment, science, and education. Its main objective is to form an association of students, teachers, and the scientific community to collect data about environmental issues on a global level. GLOBE encourages students from preschool to high school to become involved in a continuous program of scientifically significant environmental measurements. Students and scientists exchange meaningful environmental data via the Internet.

The measurements taken by participating students will be used by scientists, mainly from the United States, in research programs to improve our understanding of the global environment. Students not only learn how to carry out a stringent scientific Earth observation program, they also use their own measurements and the data obtained from other participating institutions as key information for their environmental science studies.

The positive participation of Costa Rican students in GLOBE has encouraged the Ministry of Public Education to introduce a more active pedagogy into other science and mathematics classes, allowing students and teachers to play a more participatory role in designing local scientific experiences.

Permanent Project for Teaching of Energy Conservation

This project, which is jointly coordinated by the Ministry of Public Education and the Ministry of the Environment and Energy, promotes the formation of values, skills, attitudes, and knowledge oriented to the conservation of energy and to the use of new and renewable energy sources by the population, in general, and students, in particular.

Demographic Education Project

This project, which was created in 1985 through an agreement between the Costa Rican government and the Population Fund of the Nations (FNUAP), deals with human sexuality, population and the environment, family life, and sociodemography. The purpose is for students to acquire a comprehensive view of the causes and consequences of the country's sociodemographic dynamics. Students as informed citizens will be able to contribute to the establishment of national policies related to population issues.

The project produces and distributes manuals, educational handbooks, videos, and workbooks on the subjects of population, human sexuality, and gender. Various seminars, workshops, and courses have been developed. Among the topics included are "Self-esteem and Human Sexuality," "Family Life," "Environment, Population and Development," and "AIDS." In 1994 the National Youth Congress on Family Matters was held. Also, every year a series of

painting, drawing, and poster design contests are organized, at the national level, on subjects such as "Women's Equality," "Towards Better Families," and "Population, a Key Issue for the 21st Century."

Program of Environmental and Farming Education

This is a joint project of the Ministry of Public Education, the Ministry of Agriculture and Cattle Raising, and the Chamber of Farming Materials. Its main objective is to create an awareness among elementary school students of the importance of world food production. The project is directed mainly toward rural school children. Between 1996 and 1997, 257 rural schools participated in the project. The topics covered include human health, agricultural production, and the protection of natural resources. Teachers have received instructional manuals and attended training workshops.

Overall Impact of the Ten Environment and Sustainable Development Programs

These programs have moved the development process forward in an environmentally and ethically responsible fashion. As indicated above, developmental ethics related to the four facets of sustainable development have provided the focus for Costa Rican environmental education programs. The relationship of the 10 programs to the 4 facets of sustainable development was identified by a panel of experts (table 1).

Table 1 Relationship of Environment and Sustainable Development Program to Aspects of Sustainable Development

Program	Environmental sustainability	Economic/ productive sustainability	Social/political sustainability	Human resources
Solid waste	X	X	X	
Environmentalization	X		X	X
River basins	X	X	X	X
Conference	X			X
Earth education	X	X		X
Emergencies	X	X		
Global Learning and Observations to the Benefit of the Environment	X		X	X
Energy conservation			X	X
Demographic education	X	X	X	X
Environment and farming	X	X		

Regular formal education should include specific topics related to the conservation of energy (the management of solid waste and recycling), in the study plan of subjects such as science and social studies. Still more important is the inclusion of topics related to the environment and sustainable development in study plans and official textbooks. In Costa Rica,

the textbooks for all subjects for grades 1 through 9 were prepared based on the approach explained earlier in this paper. The list of topics to be tested in the national *Bachillerato* examinations (a requirement to obtain a high school diploma) includes specific items on the environment.

Significantly, the 10 programs on environmental education were created to support the regular practice in the classroom, including the additional element of learning by doing. These programs call for attitude changes among students rather than just the acquisition of academic knowledge. There is evidence that our students are becoming more aware of, and concerned about, environmental problems in their communities. They are also capable of suggesting various strategies to conserve the environment.

In March 1998 a joint research project was carried out by the Universidad Nacional de Costa Rica and the Ministry of the Environment and Energy. The findings of the study, "The Costa Rica of the 21st Century Expected by Youngsters," showed that our young people (age 16, grade 11) are really concerned about the degree of contamination that exists in the different components of the environment, namely air, water, plant, and animal life (table 2).

Table 2 Student Concerns about Environmental Issues
(n=2480)

	Percentage degree of concern			
Environmental issue	**Total**	**Much**	**Little**	**No concern**
Loss of forest area	100.0	90.0	8.7	1.3
Reduction of species	100.0	87.5	11.1	1.4
Quality of the air	100.0	85.8	12.7	1.5
Quality of rivers and oceans	100.0	82.4	15.9	1.7
Contamination of land	100.0	80.2	17.9	1.9

In addition to their concerns with respect to conservation of the environment, Costa Rican young people have developed a holistic attitude toward sustainable development that enables them to propose solutions to environmental problems across disciplines. The research study explored the students' understanding of strategies to promote environmental conservation. The most frequently mentioned strategy was to strengthen environmental legislation in order to protect the environment from people or entities who are polluting it. Other specific recommendations are shown in tables 3 and 4 for grade 11 students (age 16).

Table 3 Student Selection of Various Environmental Conservation Strategies, by Priority and Residence

Strategies	Urban students (n=1104)		Rural students (n=1376)	
	First option (percent)	**Second option (percent)**	**First option (percent)**	**Second option (percent)**
Strict laws against those who contaminate the environment	23.7	18.5	22.9	18.8
Program for the conservation of ecosystems	22.4	12.0	21.4	16.3
Environmental education plan	21.6	10.8	20.0	10.4
Classification and recycling of trash	8.8	13.8	9.3	11.0
More civic participation	8.2	16.1	9.0	14.0
Program of industrial waste treatment	7.6	12.0	7.2	9.8
Construction of landfills	3.1	4.5	3.6	5.4
Plan for the treatment of household waste	3.0	7.3	2.8	6.0
Educational plan for farmers	1.6	5.0	3.8	8.3
Total	100.0	100.0	100.0	100.0

Table 4 Student Selection of Community Measures to Solve Environmental Problems (n=2480)

Measures to be taken	First option (percent)	Second option (percent)
Forming groups or committees	36.2	22.2
Actions to protect the environment	22.0	20.0
Adequate handling of waste	14.6	16.4
Exercising pressure on the government	8.1	3.3
Educating and creating awareness	7.7	10.1
Denouncing and avoiding problems	3.0	3.3
Others	2.2	3.3
Don't know/no answer	6.2	14.2
Total	100.0	100.0

Enhanced teacher-students, students-community, and school-society communications added relevance to the environment-related topics and to the concept of sustainable development in general. The national tests, taken by students in grades 6–9, show clear statistical evidence of above-average results on environmental topics. For instance, as seen in table 5, among the 20 objectives tested for science in the grade 9 test of 1997, those objectives related to biology and ecology were achieved by the greatest percentage of students taking the examination, regardless

of the type of school they attended. Note that the students taking the test from the academic and technical schools were grade 9 students (age 14), while the students at night school were adults.

Table 5 Student Achievement of Objectives
by Type of School

Objectives	Academic school (percent)	Night school (percent)	Technical school (percent)
Distinguishing the anatomy and the physiology of the human reproductive system	97.43	73.21	95.01
Identifying biology's object of study and its importance and branches of study—zoology, botanics, genetics, ecology, evolution	89.56	85.09	82.83
Recognizing the specific use of measuring instruments	83.18	89.55	76.12
Distinguishing among cell, tissue, organ, and system	86.33	94.01	78.79

Conclusion

All the programs discussed share the following characteristics: a close relationship between the school and the community, an emphasis on learning by doing, and a holistic approach to tackling the issues of sustainable development. They are all based on principles of developmental ethics.

The research evidence suggests that this approach is successful with students, bringing about awareness and cognitive learning. Including environmental topics in school programs gives them legitimacy. However, there is more to be done. It is also necessary to give ongoing support to the teacher through systematic training, to encourage community participation, and to coordinate efforts among different institutions. An enhancement of these efforts should result in an even greater positive impact on student attitudes, as well as improve their academic performance in environmental subjects.

Dr. Eduardo Doryan is Director of the Latin American Center for Competitiveness and Sustainable Development at INCAE, a multinational, nonprofit graduate school of business, economics, and environmental studies. He was formerly the Deputy Minister for Science and Technology, and the Minister of Education in Costa Rica, and professor at the University of Costa Rica.

Professor Eleonora Badilla, an Associate Professor at the University of Costa Rica, is the Director of Informatics for all programs and Coordinator of the Center for Educational Innovation at the Omar Dengo Foundation, a nonprofit organization that works closely with the

Ministry of Public Education. She was formerly Director of the National Center of Didactics and Director of the National Computers in Education program.

References

Consejo Superior de Educación, Centro Nacional de Evaluación para la Educación CENE-EDU. 1997. *Informe Nacional*, Tercer Ciclo.

Doryan, E. 1994. *La Formación del Ciudadano de la Era de la Sustentabilidad.* San José, Costa Rica: Ministerio de Educación Pública.

Doryan, E. and E. Badilla. 1998. *Cambio Histórico e Implicaciones para la Educación.* Paris: UNICEF.

Chavarría, S. and others 1998. *La Política Educativa Hacia el Siglo 21: Propuestas y Realizaciones.* San José, Costa Rica: Ministerio de Educación Pública.

Molina, J.M. 1998. *Bases para una Política Nacional de Educación Ambiental y una Educación Ambiental.* San José, Costa Rica: Ministerio de Educación Pública.

Ministerio de Educación Pública. 1997. *Memoria.* San José, Costa Rica.

Ramírez, E.R. 1994. *Hacia un Humanismo Renovado. S*an José, Costa Rica: Ministerio de Educación Pública.

Rodríguez, A. 1994. *El Humanismo, el Constructivismo y la Academia a través de una perspectiva filosófica.* San José, Costa Rica: Trabajo Inédito

Rodriguez, A. 1994. "Análisis y Apuntes sobre Política Educativa." San José, Costa Rica.

Stokke, O. 1993. "Los Dilemas del Desarrollo Sostenible." *Cuadernos de Ciencias Sociales* 63.

Universidad Nacional y Ministerio del Ambiente y Energía. 1998. *La Costa Rica del Silo 21 que Anhela la Juventud Costarricense.* San José, Costa Rica: Ministerio de Educación Pública.

Zúñiga, M. 1998. "Del Constructivismo al Construccionismo". www.mep.go.cr/documentos

Adaptation of the U.S. *ChemCom* Course for Secondary School Students in Krasnoyarskii Krai, Siberia, Russia

Natalia E. Gapanovitch and Natalia P. Tarasova

Krasnoyarskii Krai is a region of Siberia that is rich in natural resources and, as a consequence, has been heavily industrialized in certain areas. The Krai has become heavily polluted—the air quality is of particular concern. The regional government has recognized the importance of environmental education in the schools, and has taken steps to introduce concepts of sustainable development to the students as part of the science curriculum. Many students in the Krai are using a U.S. chemistry textbook, *ChemCom: Chemistry in the Community*, to learn how to use chemistry to become environmentally conscious citizens in their own community. This program has involved not only teachers and their students, but also parents and politicians, in efforts to understand the root causes of a range of environmental issues, as well as ways to address these issues.

Introduction

Modern society is characterized by the increasing role of science and technology in all aspects of development. The Industrial Revolution made a significant contribution to improving living standards in most nations. However, because of our incomplete understanding of the consequences of development on both human societies and the environment, we are now facing the deterioration of global life-support systems in a degraded environment.

People living in Siberia have only recently become aware of the magnitude and complexity of their particular environmental problems. They are just recognizing the need to use modern science and technology and the principles of sound environmental management to address these problems. Environmental problems have become of special concern in the administrative region of Siberia known as Krasnoyarskii Krai.

Krasnoyarskii Krai (Krasnoyarsk Territory) extends from the Arctic to the mountains of southern Siberia. The climate of the region is sharply continental, with air temperatures varying in January from –18°C to –37°C, and in July from 10°C to 20°C. Much of the territory is covered with taiga (boreal forests), a rich resource of high-quality wood. Krasnoyarskii Krai is unique within the Russian Federation as far as the diversity of its natural resources—its forests, its wild life, its fish, and so on. The northern part of the Krai is the permafrost zone, famous for deer breeding and fur farming. The southern part of the region is an agricultural area—wheat, rye, buckwheat, millet, barley, potatoes, vegetables, and animal husbandry.

The population of the Krai exceeds 3.1 million, with 70 percent settled in urban areas. The capital of the Krai is the town of Krasnoyarsk (founded in 1628). Krasnoyarskii Krai is a highly developed industrial region with a large number of heavy and light industries: nonferrous metallurgy, machinery building, metalwork, mining (coal, iron ore, natural gas, plumbago), the

chemical industry (synthetic fibers, synthetic rubber, tires), light industry, pulp and paper, building materials, food, and timber. There are two hydroelectric power plants and one coal-burning power plant.

Atmospheric pollution is considered the main environmental problem in the Krai, a problem that is getting worse. In 1992 Krasnoyarskii Krai was responsible for 10 percent of the total emissions from stationary sources in Russia; in 1995 the value was 12 percent. Currently, Krasnoyarsk is on the federal list of highly polluted urban territories.

The Krai's legislative bodies are concerned about pollution in the territory and have been actively pursuing legislation to protect the environment. Of particular importance is the policy document, "The Concept of the Sustainable Development of Krasnoyarskii Krai." This document has generated a great deal of public discussion within the region. The local government believes that environmental improvement will only happen when the general populace is more aware of environmental issues. Thus it has paid a great deal of attention to the development of environmental education programs for the region. One clear indication of this is the legislative mandate to spend 10 percent of the budget of the regional environmental fund (which accumulates environmental fees from industry and other sources) on environmental education programs.

The Department of Education of Krasnoyarskii Krai (a regional branch of the Ministry of General and Specialized Education of the Russian Federation) is strongly supporting the efforts of local school teachers to modernize the science curricula and introduce new pedagogical approaches to teaching science in the schools. One facet of this modernization is the inclusion of concepts of sustainable development in school science classes. The Center of Poly-discipline Training Intensive Methods, located in the town of Krasnoyarsk, is playing a leading role in implementing such efforts. Its Laboratory of Environmental Education is currently running the program Environmental Education for Sustainable Development. Thus while the term "sustainable development" is rarely introduced in a standard Russian school curriculum, it is now quite familiar to the schoolchildren and teachers of the Krasnoyarskii Krai.

Developing the Environmental Program

In April 1993 an international workshop was held in Krasnoyarsk for Siberian secondary school teachers to introduce them to curriculum materials developed by chemistry educators from Russia, the Netherlands, and the United States. The materials were developed as one component of an educational collaboration sponsored by the United Nations Education, Scientific, and Cultural Organization (UNESCO). This collaboration involved both joint curriculum development and teacher continuing education (UNESCO 1992). Also introduced at the workshop was the U.S. high school course, *ChemCom*: Chemistry in the Community. *ChemCom* is a one-year high school chemistry course developed by the American Chemical Society, the professional association for individual chemists from academia, industry, and government. The course is built around societal issues involving chemistry—issues on which the students will be making decisions as voting citizens in the future. Chemistry concepts are introduced on a "need-to-know" or "just-in-time" basis. The issues addressed include water and air pollution;

management of mineral and petroleum resources; nuclear power in energy, medicine, and agriculture; food and health; and the role of chemical industries in society. Since many of the environmental issues covered in *ChemCom* were of great concern in Siberia, the content coverage of the U.S. text was viewed as very relevant to Siberian students.

The UNESCO Collaboration

The "Chemistry in Modern Society" collaboration with UNESCO began in 1990, when a group of Russian and Dutch educators attended a two-week workshop on *ChemCom* for U.S. chemistry teachers at the State University of New York in Cortland. From this initial meeting came the concept of a three-nation partnership to develop chemistry modules written from the cultural context of the participating nations. It was also decided that an important component of accepting the new materials would be the provision of teacher workshops.

In 1992 the first *ChemCom* workshops for teachers in what was then the Soviet Union were organized by the Mendeleev University of Chemical Technology of Russia. The workshops were run by a group of U.S. high school and college teachers in five schools in Moscow and its suburbs. More than 150 chemistry faculty, teacher-training faculty, secondary school teachers, and school administrative personnel attended these workshops. It was through participation in this program, that Siberian educators first became involved in the UNESCO program, and were first introduced to *ChemCom.*

Bringing ChemCom to Siberia

The 1993 Krasnoyarsk *ChemCom* workshop involved more than 150 secondary school chemistry and biology teachers from Krasnoyarsk, Krasnoyarskii Krai, other Siberian regions (Yakutia, Khakasia, Tomsk, Omsk), as well as from central Russia. The workshop was also attended by representatives from local environmental nongovernmental organizations (NGOs), children's environmental centers, and field stations. A number of the participants had taken part in the 1992 *ChemCom* workshop in Moscow.

After analyzing the state of chemical literacy in their respective countries, workshop participants agreed that the media, the public, and the politicians in their countries often blame chemical industry, chemists, and chemistry for the degradation of the environment, health problems, and a range of societal ills. They do not seem to realize that these types of problems will be solved only by people who understand chemistry. Thus the participants agreed that it was important for all students to learn chemistry, and that chemistry should be made accessible to all students. To achieve these goals, teachers from Krasnoyarsk enthusiastically accepted the *ChemCom* philosophy and approach, which demonstrates to students the role of chemistry in everyday life and prepares them to become responsible citizens, ready to participate in community decisionmaking involving science and technology.

The final communiqué from the Krasnoyarsk workshop recommended that future educational programs in the region should:

- Stress the importance of teaching science to all students
- Support the teaching of science in the context of global change
- Address the motivation of students by presenting science on a "need-to-know" basis
- Recognize the value of teaching science from the cultural context of the students
- Include more practical activities
- Develop science curricula that address national priorities and concerns.

The participants in the workshop—teachers and teacher trainers from the region—also expressed an interest in using microscale laboratory techniques in secondary school chemistry classes, as most environmentally appropriate.

The idea of translating *ChemCom* into Russian was initiated by Rector Pavel D. Sarkisov of the Mendeleev University of Chemical Technology of Russia. He had participated in the *ChemCom* workshop at Cortland College in the United States. The translation was sponsored by the Mendeleev Chemical Society of former Soviet Union. Together with Dr. Natalia P. Tarasova, Rector Sarkisov collected funds from a variety of sources to pay for the translation and printing of *ChemCom* into Russian. Funds were received from federal, state, and private sources. These included E.I. du Pont de Nemours, the American Chemical Society, the Moscow Environmental Fund, the Soros Foundation, the Department of Education of Krasnoyarskii Krai, and several private Russian banks and companies.

In 1995 both the textbook (10,000 copies) and the teachers guide (1,000 copies) were published in Russian. The price of the book (US$3) was much less than its cost to publish, but the leaders of the project wanted to make the book accessible to as many teachers and students as possible. The book was translated, but not adapted to the Russian cultural context, partly for financial reasons, but also in an effort to get the material into the schools as soon as possible.

Three years ago School #42 in Krasnoyarsk was one of the first schools to begin using *ChemCom* in the Russian translation on a regular basis. The driving force for the acceptance of *ChemCom* by this school was a chemistry teacher, Alexandra Selivanova. She had participated in the 1993 *ChemCom* workshop, and was quite insistent and enthusiastic about implementing *ChemCom* in her school. Initially, 63 students in grade 9 (ages 14–15) participated in the piloting of the program. They had already taken chemistry classes for a year (three hours per week) when a standard Russian chemistry textbook was used.

Note that, according to the federal secondary school curriculum in Russia, chemistry is taught from grades 8–11. In grades 8–9 students study inorganic chemistry; in grades 10–11 students take organic and general chemistry. The programs are confirmed by the Ministry for General and Professional Education of Russia. However, the Department of Education of Krasnoyarskii Krai can authorize the use of so-called "authors' programs."

ChemCom became an authorized text in the Krai, with strong support from the school principals and the school boards. However, the majority of the principals expressed concern that the book had not been adapted to the Russian cultural context, just translated. To address this

concern, the Center of Poly-discipline Training Intensive Methods organized teacher workshops to adapt *ChemCom* to the local context. At these workshops the regional environmental problems are discussed in detail, teachers received environmental literature addressing local issues and containing locally relevant data, and local scientists are invited as consultants to answer teachers' questions.

In School #42 it was clear from very early on in the program that the philosophy of *ChemCom* was understood and shared by the students. Fourteen-year-old students and their parents were impressed by the possibility of understanding the principles of chemistry and applying them to decisionmaking in situations found in their everyday lives. One of the students, who was being interviewed on TV, said:

> "Chemistry in the 8th form was complicated and strict—every time I had to learn something by heart. But then I changed my school and entered school #42. And now every day I look forward to coming to my chemistry classes. First, the teacher introduces the problem, for example, the pollution of a river. Then, we students together try to find out what kind of scientific knowledge we need in order to resolve the problem. But what I find the most important is the fact that we consider several possible approaches to solving the problem and discuss them before making a final decision."

The *ChemCom* text continues to be very popular with students in School #42. During their final examination in chemistry and ecology (June 1997), 11th grade students were asked to respond to the question, "What did you learn from the *ChemCom* course?" Some answers follow:

- "I now feel myself responsible for Russia and for the globe."
- "I now know that my personal actions are important to the future of planet Earth."
- "The school children of Krasnoyarsk have the right to express their own positions."
- "I feel proud of my town and its natural resources."
- "My parents were surprised with my interest and achievement in learning chemistry."
- "The concepts of sustainable development will penetrate into all people's minds within a decade."

The Wider Adoption of *ChemCom* in Krasnoyarsk Krai

In September 1996 a second international workshop took place in Krasnoyarsk under the auspices of the American Chemical Society (ACS) and UNESCO. This workshop catalyzed the wider adoption of *ChemCom* in Siberia. The ACS team was led by Professor Conrad Stanitski from the University of Central Arkansas, editor of the 3rd edition of *ChemCom.* Some 27 Siberian teachers participated in the workshop, 13 of them from remote rural schools and 14 from town schools for the children of the local establishment. All of these teachers are now using the *ChemCom* course.

The workshop program included consideration of the *ChemCom* philosophy, approach, and structure. Participants also carried out several practical activities based on microscale

chemistry. One important feature of *ChemCom* is the inclusion of decisionmaking activities that involve the application of chemistry knowledge to societal problem solving. There are three types of decisionmaking activities found in *ChemCom:*

- The "Chem Quandary" is a short discussion activity that gives students an opportunity to brainstorm the parameters of a problem without necessarily coming to any particular decision (for example, the positives and negatives of adding chlorine to the water supply). It serves as a motivator for further student questions and activities.
- The "You Decide" activity requires students to collect, analyze, and synthesize data to address a specific issue or answer a particular question. Students may be required to graph data on ambient carbon dioxide levels, predict future levels, or identify factors that could change the historical trend.
- The "Putting It All Together Activity" brings science into the community decisionmaking process. Here, students ask questions that involve defining the science and technology problem to be addressed and proposing solutions. They are also asked to confront the issue of who pays to solve the problem and what policies need to be established to help address the problem (for example, students may explore the problem of dead fish in a river with all that implies for community action).

In the *ChemCom* text (which was written for U.S. students) these decisionmaking activities are, of course, framed in the U.S. cultural context and often use data specific to the United States. At the 1996 Krasnoyarsk workshop, a teacher from a rural school in Bolshoi Ului gave a presentation on this issue. It is now often difficult to find the necessary data to use in the decisionmaking activities presented in the Russian cultural context. This is especially a problem for teachers from small villages. One of the *ChemCom* units addresses the issue of "Petroleum: To Burn? To Build?" Since the Bolshoi Ului region is known for huge oil deposits, this is as relevant a question in Siberia as in Texas! Although local data were not readily available, the students and their teachers were quite inventive. Two students together with their parents were sent on a mission to the town of Achinsk to try and obtain the information they needed from the local Committee for Environmental Protection. They did receive the data they were seeking. Furthermore, the village broadcasting station disseminated a request to collect and donate newspapers and magazines to the local school to help students prepare for a lesson on "The Natural Resources of Bolshoi Ului: To Reserve or to Use?" Two years have passed since that day, but still the inhabitants of the village help the children find the information they need for chemistry class. The students can conduct risk-benefit analyses using this expanding data base.

Other teachers at the workshop from Krasnoyarsk pointed out that their *ChemCom* students begin to understand the interdisciplinary nature of many problems and see the necessity of using knowledge acquired in other school classes (economics, biology, geography, physics, and others) to address chemistry-related societal problems. Most important, the teenagers have started to understand that it is often impossible to make "the only right decision" in the real world, but that to make no decision in a given real world situation is in itself a decision with unpredictable consequences.

Surprisingly enough, many teachers reported that the absence of a Russian context in *ChemCom* was not considered to be an obstacle by the students (T. Danilova, school #142, L. Chuprova, school #27, and E. Moltchanova, school #144, all from Krasnoyarsk; N. Morozov and A. Pronina from the Yrbei region; V. Lucsha from the Partizan region; and V. Maksimchuk and V. Krivosheeva from the town of Divnogorsk). The students use local press, textbooks, and reference books as sources of local examples. The most popular are annual reports of the State Committee for the Environmental Protection of Krasnoyarskii Krai; sets of maps published by the Krasnoyarsk Publishing House, and the monthly 16-page newspaper, *Ecology of the Krasnoyarsk Region.*

One clear obstacle to the implementation of *ChemCom* in Siberia is the lack of chemicals and micro equipment for practical activities as a result of the general economic crisis in Russian education. The teacher's lack of information on the processes of decisionmaking is compensated for by the seminars, lectures, and consultations organized by the Laboratory of Environmental Education.

Many active local decisionmakers have been involved in the program, including the deputy-governor of the Krasnoyarskii Kkrai, S. Arintchin; the Chair of the Committee on Ecology of the Administration of the Krai, K. Raspopin; the Head of the Department of the Committee, I. Zuravleva; Professor V. Mozarov, an expert in public health issues; and T. Stepanova, a representative of the State Committee on Hydrometeorology.

The system of teacher training is one of the most important components responsible for the success of *ChemCom* in Krasnoyarskii Krai. Teachers from the towns of Divnogorsk, Igarka, Kansk, Krasnoyarsk, Lesosibirsk, Sosnovoborsk, and Turukhansk, as well as from the rural areas of Bolshoi Ului, Karatuzskii, Partizanskii, and Yrbeiskii, and have participated in six workshops in the past two years. Two teachers, N. Gapanovitch and O. Tchurilova, took part in a *ChemCom* training workshop at the University of South Carolina in July 1997. Other teachers attended the ACS workshops in the United States this year. All of the teachers hope to see the ACS team in Krasnoyarsk again.

The teachers involved in the *ChemCom* project were asked to analyze the two approaches to knowledge acquisition: applied and student-centered, as in the *ChemCom* curriculum, and discipline- and teacher-centered, as in the traditional introductory chemistry curriculum. The questionnaire was supplied by Albert Disi, director of the Center for Local Cooperation, an NGO located in Krasnoyarsk (Disi 1994). Groups of answers follow:

- *Traditional chemistry*—This is based on the assumption of the inequality of the students (some of them will work hard, the others will not; some of them will get excellent marks, the others will fail).

  ChemCom—This is based on the assumption that everyone is capable and can succeed. Everyone can get "5" (the highest grade possible).

- *Traditional chemistry*—The mode of instruction is teacher-centered, where the majority of lessons are conducted in the form of a lecture. The students are persuaded that "teaching means talking."

  ChemCom—Instruction involves small and large group work by students. The teacher and the students seek the information they need to solve a problem together. New questions arise in this process, and the exchange of information and opinions is very intensive. Where listening is a two-way active process, positive feedback loops develop between teacher and students and students and students.
- *Traditional chemistry*—In too many chemistry classrooms, students are motivated through coercion—fear, shame, or the threat of punishment. The emphasis on compulsion suppresses student initiatives, since the emphasis is on "getting the correct answer." Students are assessed by considering whether or not they meet arbitrary established rules and norms.

  ChemCom—Instruction is based on encouragement, cooperation, student self-discipline, expectations mutually agreed upon, and results that feed the student's desire to learn and gain knowledge. The students, together with the teacher, evaluate whether or not they have succeeded in achieving agreed upon goals and, if so, to what extent.
- *Traditional chemistry*—Conflicts, mistakes, and misconceptions are perceived negatively and often result in immediate punishment, rude censure, or bad marks. Intellectual conflicts must be eliminated or completely avoided.

  ChemCom—Conflicts, mistakes, and misconceptions serve as an additional source of knowledge for the students. They can assess their own ways of thinking and implementing actions. The democratic assessment encourages open confession of difficulties that arise in a classroom. The conflict resolution may involve a constructive dialogue, negotiations, class meetings, one-on-one talks, and mediation.
- *Traditional chemistry*—The assessment process can be very intimidating and can ultimately depend, on a final examination grade. It may exclude any classroom exchanges between teacher and student that are indicative of learning. It may also have no bearing on the life experiences of the students and their ability to use their knowledge in the real world.

  ChemCom—Assessment is more varied and includes performance assessment, group grades, classroom participation, oral presentations, and interactions between teacher and student, as well as a final examination. Students are encouraged to feel successful when they complete a task. Student performance is linked to their understanding of the links between everyday life and scientific knowledge. The work on which students are assessed is connected to the real problems of the school or region. The students develop strong feelings of self-worth.
- *Traditional chemistry*—The atmosphere in the classroom is the teacher's responsibility, since the teacher is the only leader. As a result, the students tend to be passive, and are less likely to take responsibility for their own learning. Decisionmaking is in the teacher's hands.

  ChemCom—Both the teacher and the students are responsible for the atmosphere in the classroom. Both are continuously developing leadership skills. The responsibility for results is shared. The students become responsible for their own learning. Decisions are often made as a team, so all parties are interested in the results. Decisionmaking is a part of the education process. Students are taught to achieve consensus, evaluate the results of their decisions, feel themselves responsible for the results, and base their evaluations on the information

available.

Conclusion

Despite obstacles, including the lack of a culturally adapted text, readily available local data, and few classroom resources, *ChemCom* has been successful and influential in Krasnoyarskii Krai. However, the continued development of *ChemCom* in the Krai is threatened by the current economic situation in Russia. In *ChemCom* students are involved in practical and laboratory activities about half the time. At present, not only are funds not being allocated for equipment and chemical reagents, but the teachers are not being paid a salary. In some rural areas the teachers have not been paid for six months.

Thus the teachers are now demoralized and have little incentive to proceed with the reforms. Yet the majority still feel personally responsible for developing the human potential of the nation, and they continue working. However, if *ChemCom* is to continue its influence in Siberia, it will probably require the infusion of financial aid from international agencies and the adoption of small-scale chemistry techniques and low-cost laboratory equipment. The teachers of the Krai have shown a tremendous willingness to participate in this type of reform. They have also displayed great ingenuity in making the adaptations necessary to make a textbook designed for U.S. students relevant to the life experiences of teenagers from Siberia.

Acknowledgments

We would like to thank Academician Sarkisov, rector of the Mendeleev University of Chemical Technology of Russia, and Professor Sylvia Ware, Director of Education and International Activities at the American Chemical Society, for their support over the years.

Natalia Gapanovitch began her career in chemical research, but left resarch to become a teacher in Krasnoyarskii Krai. She later became head of the Laboratory of Environmental Education at the Center of Poly-discipline Training Intensive Methods.

Dr. Natalia Tarasova is head of the Department of Problems of Sustainable Development at the Mendeleev University of Chemical Technology of Russia, and Vice-President of the UNESCO Center for Chemical Sciences and Education at the Mendeleev. She is a corresponding member of the Russian Academy of Sciences.

References

American Chemical Society. 1998. *ChemCom: Chemistry in the Community*, 3rd edition. Washington, D.C.

Disi, A. 1994. "Cooperation." In John M. Novak, ed., *Radical Change in Assessment: A Catalyst for Democratic Action*. Albany: State University of New York Press.

UNESCO (United Nations Educational Scientific, and Cultural Organization). 1992. *Chemistry in Modern Society*. Moscow.

School-Industry Cooperation in the Republic of Slovenia: Does It Exist?

Margareta Vrtacnik and Sascha A. Glazar

During the 1990s, in many countries, a new policy framework for sustaining economic development resulted in the reform of their education systems, reforms in which school-industry cooperation played an important role. Many partnerships between school and industry evolved. The results of industry-school cooperation in the Republic of Slovenia are presented in this study. The results are based on a study in which questionnaires and interviews were used to elicit opinions on existing school-industry cooperation.

Economic and social turmoil resulted in a breakdown of the links between schools and industries in the Republic of Slovenia, where such connections had once been well developed. Currently, both schools and industries are aware of the mutual benefits that result from cooperation, especially for career counseling and attracting young, talented people to pursue careers in industry. Readiness for cooperation depends on the size of the economic problems of different industrial branches. The industries that are still coping with transition problems are not yet ready for cooperation, while the more prosperous industrial branches are ready to establish partnerships with local schools.

A Need for Change—The Development of Partnerships

During the past decade industry has gained a bad reputation as an employer because of the introduction of advanced technologies and automation, which has resulted in the loss of many jobs. In addition, many emerging environmental problems are—in the eyes of the general public—due to industrial production. As a result, the recruitment of talented, young people who are educated, morally and environmentally aware, and prepared to work with industry is becoming increasingly difficult. Even those young graduates who have decided to pursue their careers in industry often lack the knowledge and skills needed by these industries. Consequently, at the beginning of the nineties, the new policy framework to sustain economic development also stressed the need to reform the education system to include a component of school-industry cooperation (Kim 1994; Athanasou 1995).

In 1989 the problem was also recognized within the European Community, which delegated to the Industrial Research and Development Advisory Committee the task of establishing a working party on education and training issues relevant to industry (IRDAC 1990). A subgroup on schools and industry identified the dominant influences on initial and adult training policy for the 1990s and beyond, as follows:

- The need to adapt the policy to meet the rapidly changing requirements of industry
- The short supply of young people
- Negative images of employment in industry, or of the general practices of industry.

The subgroup also identified the crucial role of schools in developing the necessary positive attitudes toward continuous training and reasons for the involvement of industry in school-industry links. The IRDAC identified five important issues with regard to the school-industry interface (IRDAC 1990):

- Challenges for education and training
- Getting in touch with young people
- The question of image
- Mobility between education and training tracks
- The status and management of the teaching profession.

In order to establish better school-industry links, schools must use better marketing techniques to help employers understand education. They must also continuously monitor their programs to ensure that they are teaching practical skills (Winiarski-Jones 1987).

Goals of School-industry Cooperation

Over the past decade a new form of school-industry cooperation has evolved (especially in the United Kingdom and the United States) based on partnerships that aim to bring about change in the school curriculum to promote students' understanding of industry and industrial society (Matthews 1990). For a partnership to succeed, all the partners must contribute and receive something in return that they value. Industry is interested in education to attract talented and motivated students, and through general education to address the public understanding of science and technology (Lazonby and Waddington 1996).

As a result of the meaningful participation of industries in the education process, several efficient models of partnerships between industry and schools have emerged. Some are industry-specific and rather informal, others are broader and more formal. Comparative analyses of 10 models of partnerships between industry and school (Clark 1984; Reynolds 1984; Jenkins 1987; Marsh 1989; Miller 1989; Patrick 1989; Roberts and Dolan 1989; Williams and Hornsby 1989; Karlin 1993; Calabrese 1996; Evers 1996; Isuyama 1996; Mapletoft 1996; Wongtschowski 1997) have shown that the goals of cooperation can be classified under three major categories:

Education *about* industry involves:

- Development of authoritative and up-to-date teaching materials
- Raising the overall level of technological literacy
- Development of public understanding of science and technology
- Development of the awareness of the contributions of industry to the economy
- Understanding the relationship of industry with the environment.

Education *through* industry involves:

- Using industrial practices and activities to bring science and technology curricula alive
- Changing children's perception of work

- Encouraging the pursuit of scientific and technical careers
- Preparing for and understanding job responsibilities
- Helping students to develop skills, confidence, and pride in attaining an education and earning a high school diploma.

Education *for* industry involves:

- Shifting vocational education tradition to a broad-based preparation for work, including the development of higher-order thinking skills
- Broadening the scope of qualifications
- Career and work awareness programs
- Establishing school-industry training links
- Increasing government involvement in the effort
- Recruiting outstanding high school graduates into science and technology fields.

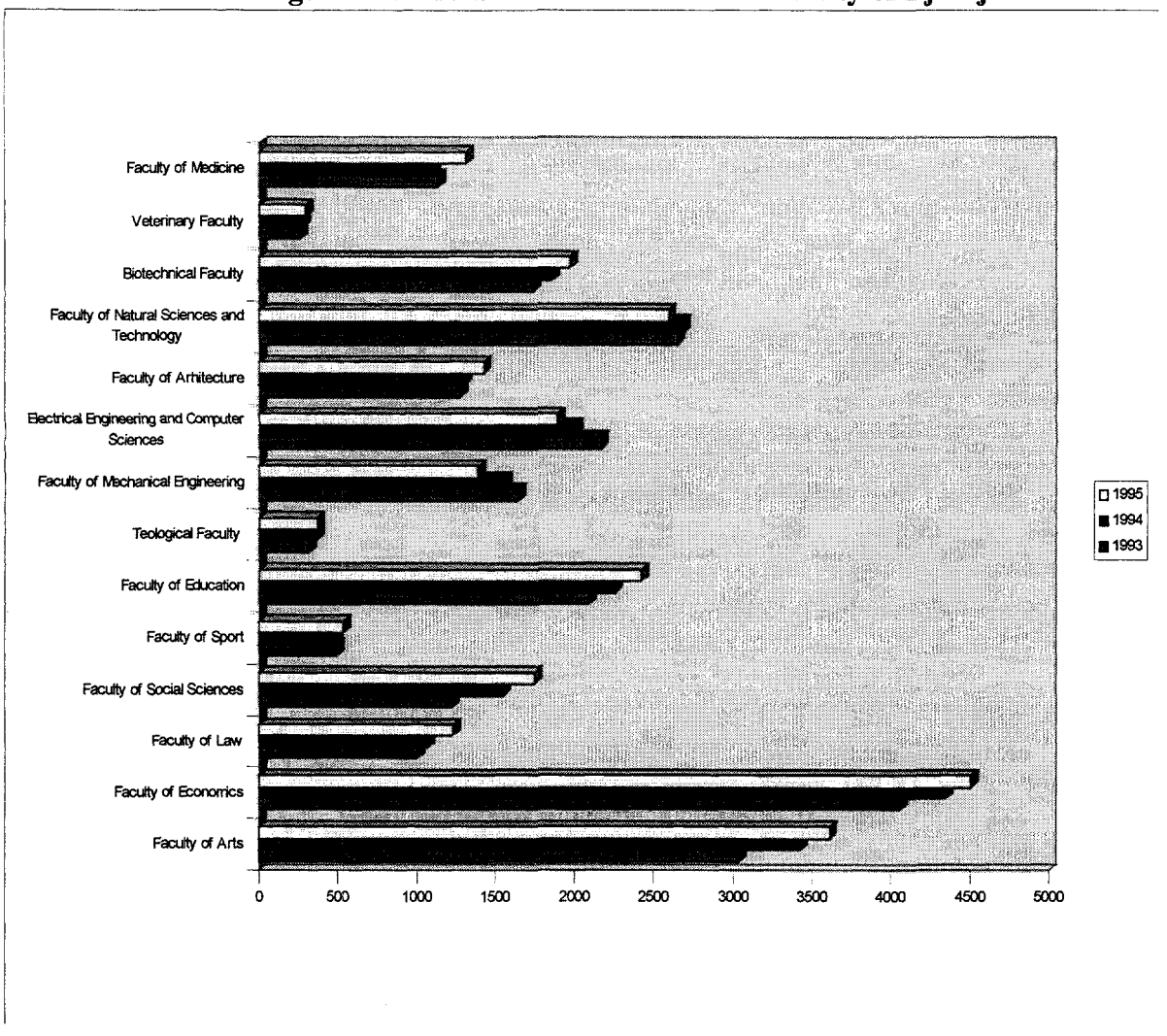
School-industry Partnerships in the Republic of Slovenia

Primary school in Slovenia extends from ages 7 to 14; high school extends from ages 15 to 18. Only the first eight years are compulsory, but the majority of students will continue for an additional three or four years at the high school level.

At the primary level—grades 7 (age 13 years) and 8 (age 14 years)—chemistry, physics, and biology are taught as separate subjects, and they are all compulsory. At the high school level—grades 1 to 3 (ages 15 to 17), chemistry, physics, and biology are still compulsory subjects. At grade 4 (age 18), science subjects are elective for those students who finish their schooling with a baccalaureate.

Formerly, Slovenia used to have a well-developed cooperation between schools and industries. After the liberation in the nineties, the established links and forms of collaboration broke down, since industry suffered severe problems of transition. Many important industrial branches collapsed; others are still striving to survive in the emerging market economy, and the related privatisation processes. The economic and social turmoil led to the loss by industry, as well as by schools of an interest and willingness to co-operate. Slovenian high school graduates are increasingly attracted to professional careers in arts, economics, social sciences and other, nontechnical or nonscientific disciplines. This trend can be followed through student enrollment at the University of Ljubljana in three subsequent school years (figure 1).

Figure 1. Student Enrolment at the University of Ljubljana



After analyzing the high school graduate enrollment patterns displayed in figure 1, several questions can be asked. For example, what are the reasons for such a situation? Is it possible to change pupil attitudes toward science and technology through teachers' or parents' personal engagement in the pupils' career decisions? These questions are connected with the new social and economic order in the country. They are rooted in the changes of values and in the new cultural and emotional identification of the younger generation that emerged during the transition and democratization of our society. Quite often, graduates of technical faculties complain that current study programs are out-of-date and lack the content required for a successful industrial career (Cuk 1998). These claims should be considered important, since they call for radical changes in university programs.

Although in 1996 the Slovenian government recognized the need to change primary and high school curricula, industries are still not playing an active role in this process. Responsibility for changing the curricula remains exclusively in the hands of educators, administrators, and teachers.

The School-industry Cooperation Study

In order to establish the scope of cooperation between industry and schools in the Republic of Slovenia, a study was designed with two sets of goals:

- To analyze and evaluate existing practices in school-industry cooperation from the view point of school experiences, goals, advantages, and drawbacks to mutual cooperation.
- To analyze and evaluate the industry viewpoint on cooperation with the schools in terms of expectations and experiences, as well as actions that the industry is willing to undertake to develop better links with local schools.

Two types of instruments were used for collecting data—questionnaires and interviews. Two different questionnaires were designed—one for the schools and one for industry. Altogether, 210 primary and high schools were originally selected for inclusion in the study (140 primary schools and 70 high schools). All regions of Slovenia were included—industrial as well as rural, developed and less developed regions. After two weeks 142 answers were received (98 from primary schools and 44 from secondary schools); these were analyzed. The questionnaires were complemented by interviews with selected teachers (17) from different regions.

The School View of Cooperation

In the first set of questions on the school questionnaire teachers were asked to specify the types of industries with which they cooperated most frequently (figure 2). Four industrial branches—food processing, chemicals, metal finishing, and agrochemicals—were of special interest to the teachers (with a response rate greater than 10 percent).

In the second set of questions teachers were asked to specify local industries they worked with the most frequently (figure 3). Although "occasional visits" were still considered an on-going form of cooperation at the primary and secondary school levels—frequency for primary school more than 35 percent, and for secondary schools 25 percent, other forms of cooperation are now emerging, especially at the secondary school level, where some elements of partnership occur. Industrial experts were often mentioned as mentors of high school student research projects (with a frequency greater than 15 percent), and high school students acquire industrial skills through practice in industry (with a response frequency of more than 15 percent). "Planned excursions" were also recognized as an important form of cooperation at both the primary and secondary school levels. At the primary school level industrial experts often participated as lecturers for pupils or teachers (with a response frequency greater than 15 percent). It is also worth mentioning that, especially at the primary school level, industries covered part of the material costs for schools (with a response frequency for primary schools of approximately 10 percent). This form of support was negligible for the secondary schools (with a response frequency of less than 5 percent).

Figure 2. Industries of Special Interest to Primary and Secondary Schools

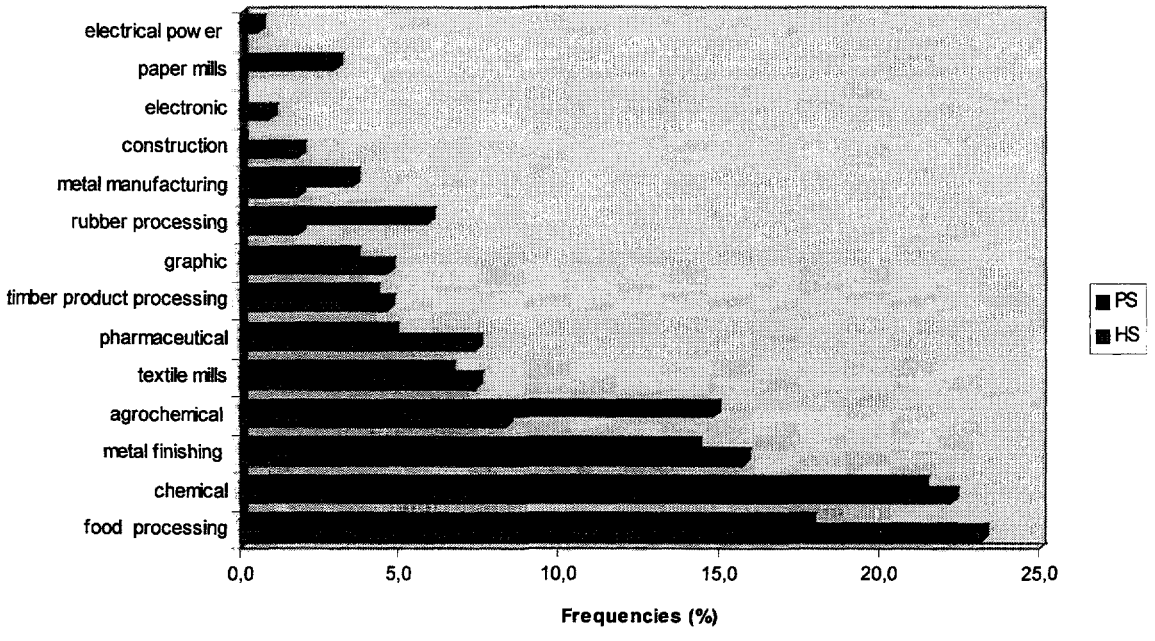
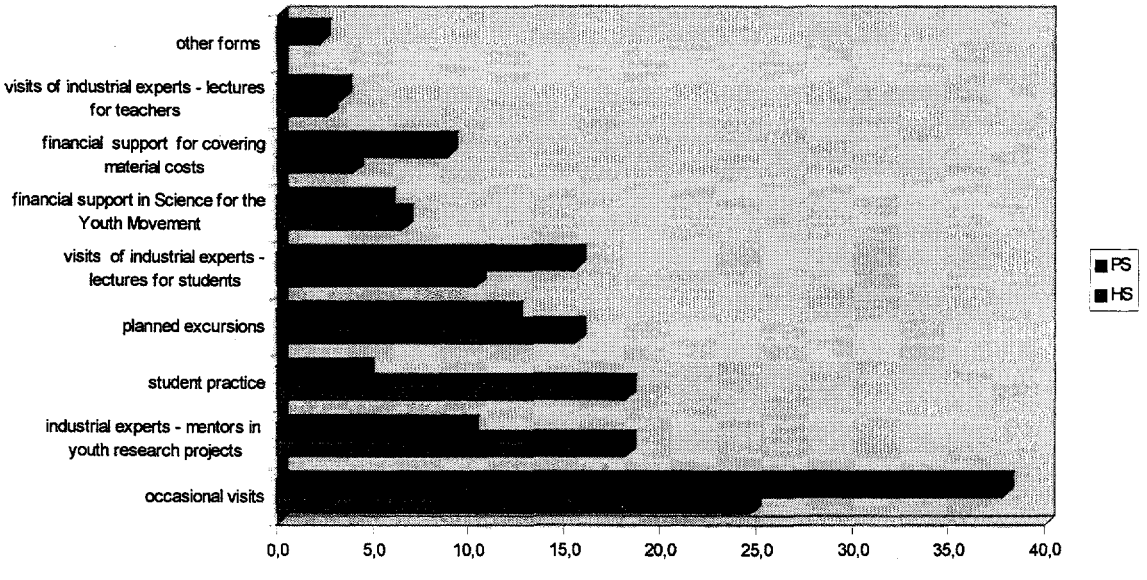
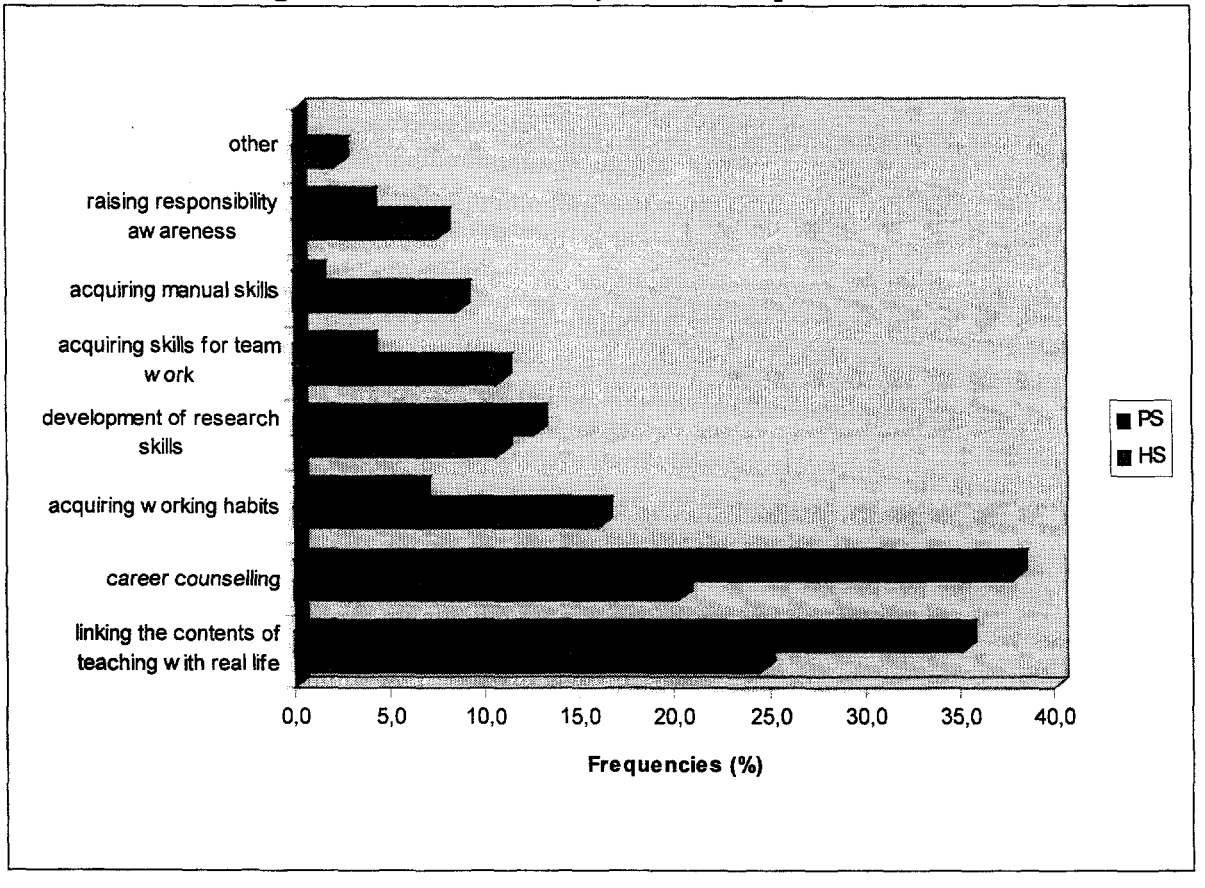


Figure 3. Most Frequent Forms of Local Industry-School Cooperation



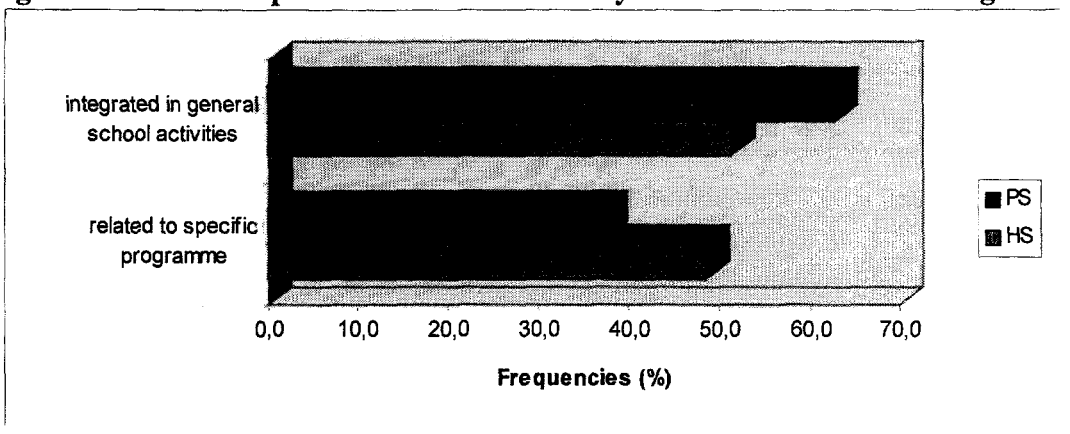
In the third set of questions teachers were asked to specify the goals of cooperation efforts with industry (figure 4). Primary and secondary schools were identified as pursuing similar goals of cooperation with local industries. As a major goal of cooperation at both levels of education, "linking the content of teaching with everyday life experiences" received a response frequency for primary schools of about 35 percent, and for secondary schools about 25 percent. "Career counseling," "acquiring work habits," and the "development of research skills" were also considered important goals at the secondary school level. At the primary school level, "career counseling" was identified as the most important goal of cooperation with industry. "Acquiring manual skills" was important for secondary schools (with a frequency of answer of about 10 percent). Yet at the primary school level this goal was of minor importance.

Figure 4. Goals of Industry-School Cooperation Efforts



In the fourth set of questions teachers were asked to specify the relationship between school-industry activities and specific or general school programs (figure 5).

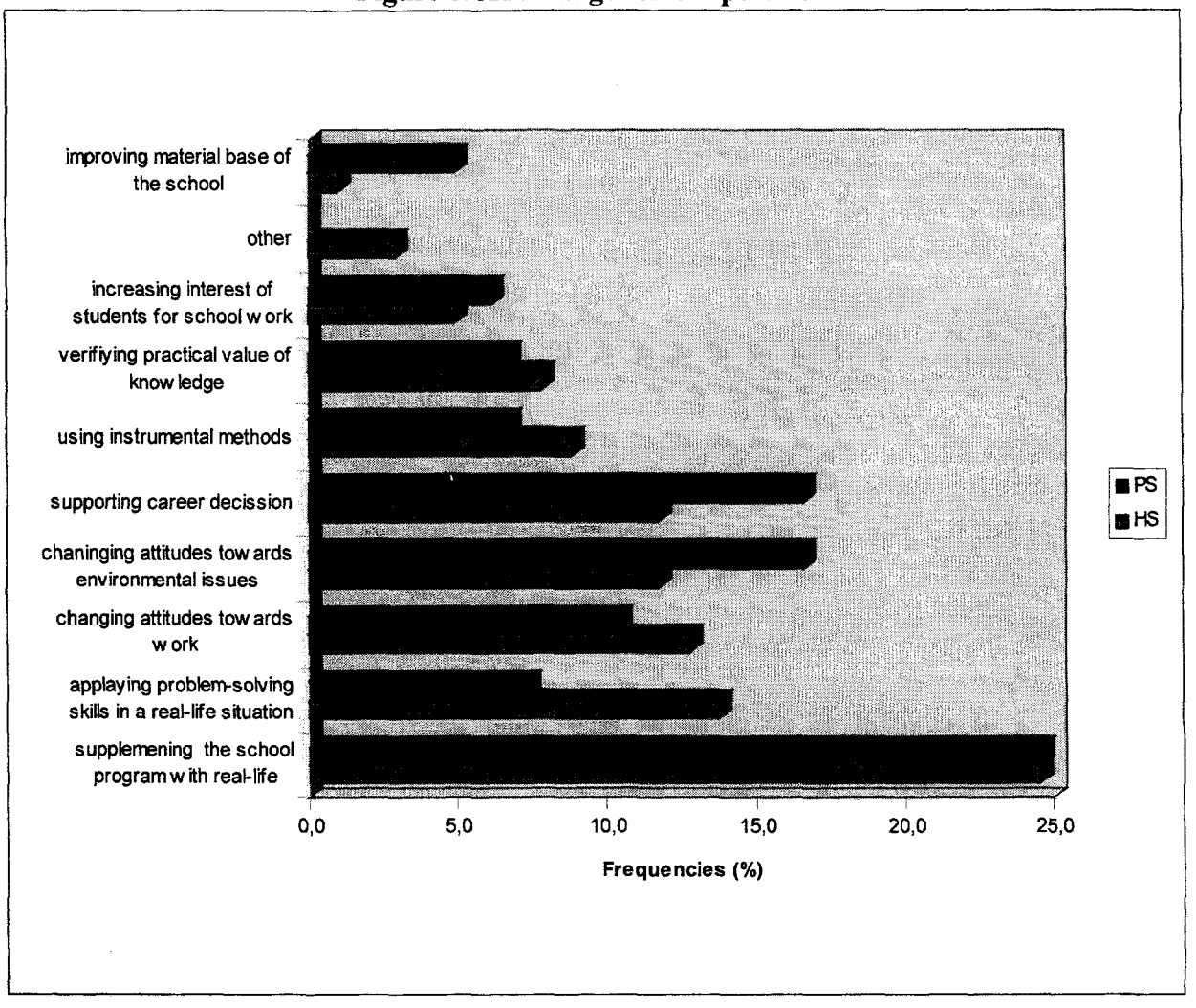
Figure 5: Relationship between School-Industry Activities and School Programs



At the secondary school level the ratio between subject-specific cooperation and general cooperation was almost the same, while at the primary school level the integration of co-operative activities into general school activities prevailed. Schools organize science and technology days in which industrial experts participated; likewise industries organized open-door days, when pupils and teachers had an opportunity to visit local industries and to participate in some industrial activities.

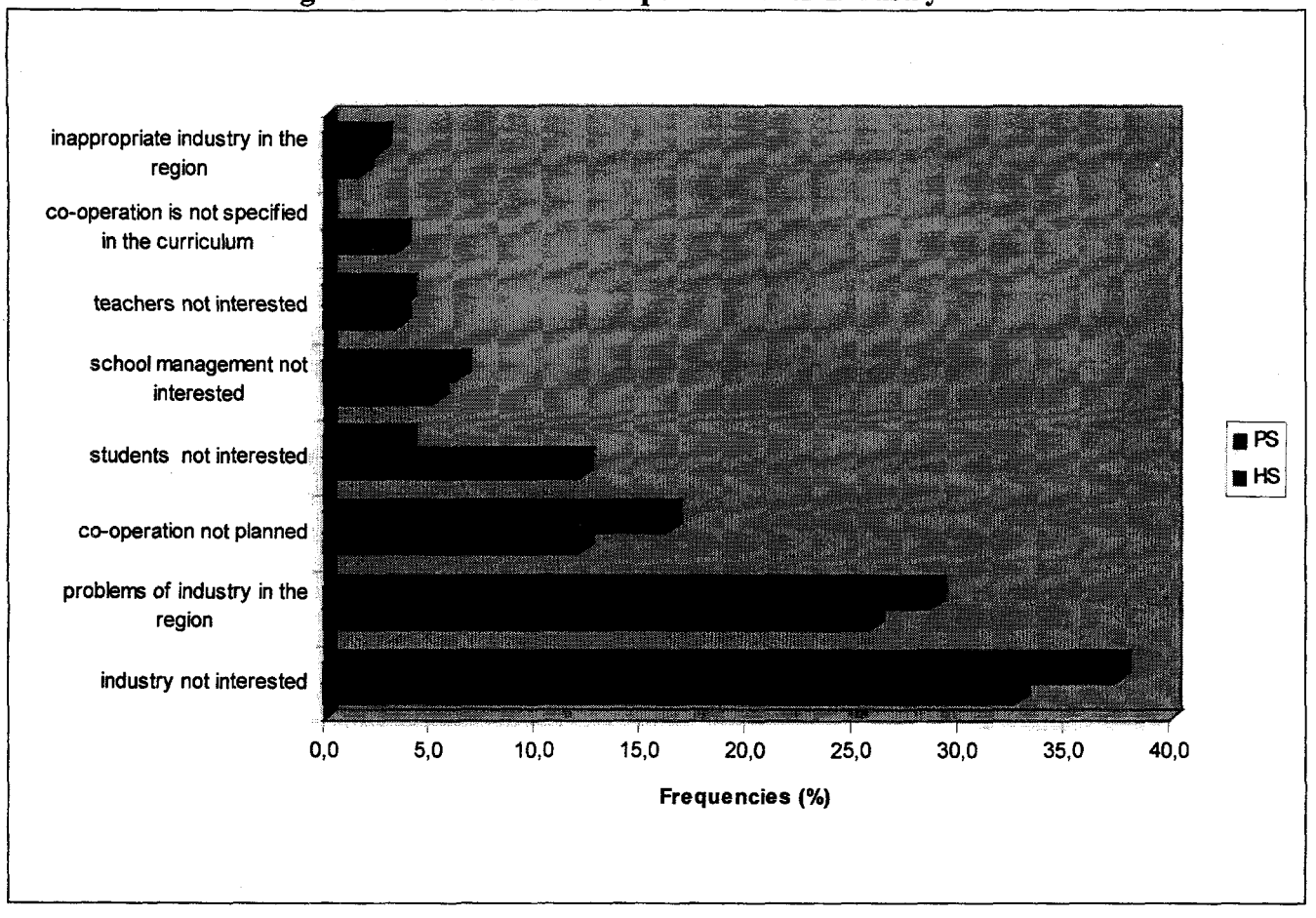
At both the primary and secondary school levels, "supplementing school programs with real-life experiences" was identified as a major advantage of school-industry cooperation (with a response frequency of more than 20 percent). At the primary school level teachers found that "changing attitudes towards environmental issues," and "supporting career decisions" of equal significance. Teachers at the secondary school level identified the "application of problem-solving skills in real-life situations," and "changing attitudes towards work" as major advantages of cooperation (with response frequencies 14 percent and 13 percent respectively) (figure 6).

Figure 6. Advantages of Cooperation



In addition to the advantages, teachers were also asked to identify the drawbacks of cooperation with industry (figure 7). At both levels of education the same causes hindering better links with industry were identified, but with different frequencies. Both primary and secondary school teachers recognized the "lack of interest by industry" for establishing better links with schools as a major drawback. This was frequently connected to problems within different industrial branches and also the lack of interest displayed by students, teachers, and the school administration.

Figure 7. Drawbacks to Cooperation with Industry



The overall finding of the analyses of the teachers questionnaire was that the teachers were well aware of the need for cooperation with industry. They identified many interesting forms of cooperation and recognized the important goals of cooperation, but many lacked the initiative to establish links with local industries. Teachers felt that industry representatives were not really interested in linking with schools and that school management was not playing an appropriate role in supporting better links with local industries. In some cases they also claimed that the curriculum was to blame, since such cooperation was not specified in the program. A catalyst is needed to bring together school authorities, teachers, and industries.

The Industrial Point of View

In order to obtain local industries' view on cooperation with the schools, a special questionnaire was designed for industry. This questionnaire was sent to 176 industries that were identified as being important for cooperation with schools, based on the response frequencies to the first question of the school questionnaire.

The response rate to the industry survey was 43 percent. The frequency of responses for six sets of questions are presented in table 1, which shows that two thirds of the industries responding established links with schools occasionally, upon receiving specific requests from

teachers or school management. One third of the industries developed more permanent links based upon preplanned programs.

Table 1 Comparative Results of the Industrial Questionnaire

Frequency of cooperation

Frequency of cooperation	*Percent*
Occasionally—upon request from teachers or schools	62.9
Regular cooperation—based on a specific program	31.4
Other	5.7
Total	100

Forms of cooperation

Forms of cooperation	*Percent*
Organize work practice for students	24.8
Organize well-prepared visits to our company	20.9
Support schools with materials and equipment	15.2
Occasional visits with a limited number of students	13.3
Occasional covering of material costs	8.6
Industrial experts organize lectures for students	8.6
Industrial experts act as mentors in youth research projects	3.8
Partial covering of material costs for schools	1.9
Industrial experts organize seminars for teachers	1.9
Organization of visits by teachers to companies or vice versa	0.9
Total	100.0

Goals of cooperation

What are the goals of cooperation with the schools?	*Percent*
Increasing interest of the young in a profession	32.1
Co-operating in career counseling	25.6
Improving the professional image of the company	23.1
Acquiring good work habits	6.4
Introducing the young to research work	5.1
Raising the responsibilities of working in a group	3.8
Raising responsibility awareness	2.6
Other	1.3
Total	100

Integration with school programs

How is the cooperation integrated with the school program?	*Percent*
Related to specific school program	51.4
Planned within the regular activities of your company	45.7
Other	2.9
Total	100

Assessment of cooperation

Advantages	*Percent*	*Disadvantages*	*Percent*
Supplements the school program with real-life experiences	17.8	Unplanned cooperation	27.3
Develops understanding of the problems of industry	15.5	School management not motivated	20.0
Verifies the practical value of knowledge acquired at school	13.2	The needs of schools are not known	12.7
Introduces learning methods and techniques used in industry	13.2	Teachers are not motivated	10.9
Increases interest of students in the work of industry	11.6	Industrial experts not involved in planning the cooperation	9.1
Changes student attitudes to work	9.3	Problems of industry in the region	9.1
Increases the esteem of the company	8.5	Company management not motivated	5.5
Facilitates students' decisions in selecting a profession	5.4	Other	3.6
Changes the attitudes of students towards environmental issues	4.7	Students not motivated	1.8
Other	0.8		
Total	100.0	Total	100.0

Among the many forms of cooperation, industries were especially interested in organizing work practice and well-prepared visits for students. They were also willing to support schools (24.8 percent) with materials (20.9 percent) and equipment (13.3 percent). However, they were less prepared to cover the material costs of schools (8 percent).

Generally, the goals that industries identified as important were different from those of interest to the schools. "Increasing the interest of students in a specific industrial profession" received the highest response frequency (more than 30 percent). Both schools and industries recognized "participation in career counseling" as an important goal of cooperation (with a response frequency of more than 25 percent); "increasing the professional image of the company" was next on the list of industry goals (with a response frequency of more than 20 percent), while other goals received response frequencies of less than 10 percent ("acquiring

working habits," "introduction to research work," and the like). Cooperation of industries with local schools was, on average, 50 percent related to specific school programs.

Industries identified many advantages of cooperation, although response frequencies were rather scattered. The highest frequency was assigned to "supplementing school programs with real life experience." This answer also received the highest frequency rate on the teacher-school questionnaire. Industries also recognized drawbacks in cooperating with schools. However, while schools claimed that industry was not interested in them, the industries recognized that "unplanned cooperation" (more than 27 percent) and "nonmotivated school management" (more than 20 percent) were major drawbacks in the cooperation. Industries also admitted that they were not sufficiently aware of school needs, and they were aware that industrial experts were not properly involved in planning the cooperative activities.

In comparing the responses from the schools and the industries, one gets the impression that in the Republic of Slovenia—as far as school-industry cooperation is concerned—schools and industries are on two different river banks, and a solid bridge will be needed to bring them closer. One such "bridge" of excellent cooperation, which was built 30 years ago in a rural, underdeveloped region of Slovenia, can still serve as a model for bridging the gap between industries and schools in the nation.

Bridging the Gap: The Krka Model

In the 1960s Krka was a small pharmaceutical firm located in southeast Slovenia (the Dolenjska region), which was then quite underdeveloped and mostly rural. Krka very soon recognized that in order to overcome problems in recruiting talented young people who are prepared to work in the pharmaceutical industry, it was necessary to start attracting local students, since staff who came from more developed parts of the country did not remain long.

Krka then launched a special program to recruit outstanding high school graduates from the Dolenjska region, encouraging them to study science and technology. To do this the company established the Krka awards. Since 1969 they have presented more than 170 awards, the majority of them for chemistry but also some for social studies. Former recipients of Krka awards are now successful researchers or managers at Krka; representatives of Krka in foreign countries; or excellent students of chemistry, biochemistry, medicine, and pharmacy. As high school graduates many of them also received state awards for their research projects within the Science for the Youth contest scheme; two also received silver and bronze medals at the International Chemistry Olympiads.

In order to promote and sustain cooperation with local schools, Krka has established an education center. The center is responsible for the professional training of Krka's employees and for preparing programs of cooperation with local schools, organizing seminars for student mentors, and establishing links with local authorities.

Three interviews were conducted with chemistry teachers from the Dolenjska region to get their personal opinions on school programs with Krka. They all agreed that this cooperation

was mutually beneficial. Krka promotes investments in the schools' facilities (laboratories and libraries) and also provides schools with laboratory equipment. As a result the schools in this region are better equipped for experimental work than many other schools in Slovenia.

In addition, the teachers, who are often co-mentors in youth research projects, help students to correlate school knowledge with experimental problems. Some outstanding research results have been achieved through this cooperation. The teachers also work on research problems, an activity that helps them in their professional growth. They keep current with new developments in a specific field and are, therefore, more resourceful and motivated in the classroom. In addition, they feel well equipped with experiences related to the application of knowledge in real-life situations. This helps them demonstrate the meaning of abstract chemical concepts to their students. Finally, cooperation in research projects also leads to professional promotion and improved salaries for teachers.

After graduation, many young, talented people from the Dolenjska region decide to pursue their professional career at Krka—this is where Krka also benefits, since recruitment problems are minimized. However, due to the enforcement of stricter regulations concerning proprietary industrial knowledge, Krka is becoming aware that its practice of involving young high school graduates in real research and development problems could be problematic—they cannot hide secret knowledge from intelligent young people. Consequently, they are seeking new forms of cooperation that would not expose their industrial secrets.

An Indirect Form of Cooperation Between School and Industry

During the 1980s a group of chemistry enthusiasts decided to launch a journal titled *Chemistry in the Classroom*, aimed at meeting the needs of chemistry teachers in Slovenia by helping them to improve both their knowledge of chemistry and chemical technology and their methods of teaching chemistry. The journal also offered teachers the opportunity to publish examples of good practice in the classroom.

In the beginning the journal had many opponents who predicted that it would not last more than a year. Nevertheless, the journal gained popularity among chemistry teachers and experts from the chemical industry and from research institutes. Thus it managed to survive the turmoil of the 1990s. Soon it will be celebrating its 10th anniversary.

During all these years individuals from the chemical industry have been important partners of the editorial board. Industry has both given financial support and attracted leading industrial experts to participate as authors on topics related to the chemical industry in Slovenia. Again, the benefits are mutual. Through the articles in the journal, industry is informed about problems in chemistry education, while teachers can gain ideas on how to relate chemical concepts to real-life experience from the industrial contributors.

Conclusion

Two viewpoints on school-industry cooperation were analyzed—the school view and the industry view. Schools and industries are both aware of the mutual benefits from such a cooperation for career counseling and attracting talented, young people to pursue careers in industry. Yet in Slovenia both parties seem to lack the motivation for establishing stronger links. On the one hand, the schools claim that industries are not interested, while on the other hand the industries stress that school management and teachers are not motivated to cooperate.

Nevertheless, in spite of the different views, some important changes in attitudes have been identified in many elements of the partnerships. Industries are supporting schools with materials and equipment; their experts are often mentors for student research projects; they also cooperate in the organization of "days of open doors" and "science days." They would like to play a more significant role in curriculum development.

Readiness for cooperation is related to the size of the economic problems of different industrial sectors. Those industries that are still struggling with transition problems do not seek school partnerships, claiming that they cannot offer positive experiences to the students. By contrast, the more prosperous industrial sectors have recognized the need for cooperation and are willing to establish better links with local schools.

Acknowledgments

The authors wish to thank the schools, teachers, and industries who participated in this study. Their views and opinions were essential to the successful completion of this study on school-industry cooperation.

Dr. Margareta Vrtacnik is Associate Professor in the Department of Chemical Education and Informatics at the University of Ljubljana, Slovenia. Her expertise is in developing methods courses in chemistry education and in conducting studies on information transfer between academia and industry.

Dr. Sascha Aleksij Glazar is Associate Professor in the Faculty of Education at the University of Ljubljana, Slovenia. He covers general and inorganic chemistry with a special emphasis on chemical education. Currently, he is the national curriculum consultant for the primary and secondary school levels, studying the possibility of including environmental education in science programs.

References

Athanasou, J. A. 1995. "Combining School and Work: New Pathways for Learning in Australia." *International Journal of Vocational Education and Training* 3 (2): 21–28.

Calabrese, A. 1996. "The Teaching Model Developed by Lonza Polymers and Additives: A Contribution to the Professional Education of Students." *Chim. Ind. (Milan)* 78 (6): 724–26.

Clark, R. J. 1984. "Factors Influencing Success in a School-University-Industry Partnership for Teacher Education." ERIC database, abstract number ED258955 SP026353: Columbus, Ohio.

IRDAC (Industrial Research and Development Advisory Committee). 1990. "School and Industry." *IRDAC Opinion*. Brussels: Commission of the European Communities.

Cuk, J. 1998. "Why High School Graduates Are Not Interested in Science and Technology." Opening address at the press conference of the president of the Chamber of Commerce and Industry of Slovenia, January 21, University of Ljubljana, Faculty of Natural Sciences and Engineering, Slovenia.

Evers, J. 1996. "Effective Methods for Industrial Support for Chemistry Teaching, Symposium S.W1." In *Partners in Chemical Education. Proceedings of the International Conference on Industry-Education Initiatives in Chemistry, August 29–September 2, 1995*. University of York.

Issuyama, R. 1996. Effective Methods for Industrial Support for Chemistry Teaching, Symposium S.W1. In: *Partners in Chemical Education. Proceedings of the International Conference on Industry-Education Initiatives in Chemistry, August 29–September 2, 1995.* University of York.

Jenkins, D. E. 1987. "Career Guidance Articulation: The District of Columbia Model." *Vocational Education Journal* 62 (6): 42–43.

Karlin, A. R. 1993. "T.I.P.S. for Being at Risk and Loving It." *Teacher Education and Practice* 8 (2): 43–50.

Kim, Taeck-Duck. 1994. *The Role and Function of the Vocational Education and Training in the New Economic Plan in Korea. Case Studies on Technical and Vocational Education in Asia and the Pacific*. Melbourne: Royal Melbourne Inst. of Tech (Australia).

Lazonby, J., and D. Waddington, eds. 1996. *Partners in Chemical Education. Proceedings of the International Conference on Industry-Education Initiatives in Chemistry, August 29–September 2, 1995.* University of York.

Mapletoft, M. 1996. "The Chemical Industry Educational Centre—AUK Industry-Education Partnership." In *Partners in Chemical Education. Proceedings of the International Conference on Industry-Education Initiatives in Chemistry, August 29–September 2, 1995.* University of York.

Marsh, S. 1989. "Schools Industry Links in the North East." *British Journal of Language Teaching* 27 (2): 77–80.

Matthews, M. 1990. "Industry Moves into the Curriculum." *British Journal of Special Education* 17 (3): 95–97.

Miller, G. M. 1989. "Involving Industry." *Agricultural Education Magazine* 61 (7): 4–23.

Paterson, H. A. 1990. "School-industry Links: A Survey among Science Teachers in Surrey." *School Science Review* 72 (259): 41–46.

Patrick, C. L. 1989. "School-Industry Partnership Academies: Programs That Work." *Supporting Leaders for Tomorrow*, Occasional Paper 11. Washington, D.C.: Institute for Educational Leadership.

Reynolds, D. F. 1984. *The Peninsula Academies. Third Yearly Interim Report 18.* Palo Alto, Calif.: American Institutes for Research in the Behavioral Sciences.

Roberts, R. J., and J. Dolan. 1989. "Children's Perceptions of Work—An Exploratory Study." *Educational Review* 41 (1): 20–28.

Tasker, M., and D. Packham. 1990. "What Are the Needs of Industry?" Paper presented at the Society for Research into Higher Education Conference, December, Guildford, England.

Vignes, J. L., M. Moranville, and J.P. Bournazel. 1996. "A Biography of Cement. Chemistry Experiments on the Use and Properties of a Material." *Bull. Union Physiciens* 90 (780): 57–80.

Williams, C.G., and H.H. Hornsby. 1989. "Vocationalism in U.S. and U.K. High Schools." *Economics of Education Review* 8 (1): 37–47.

Winiarski-Jones, T. 1987. "How Close Is the Partnership between Industry and Education?" *Transition.*

Wongtschowski, P. 1997. "The Interaction of the Chemical Industry and Education." Abstracts, Second International Conference of Industry-Education Cooperation, December 7–12, Sao Bernardo do Campo, SP, Brazil.

Advances and Obstacles to the Reform of Science Education in Secondary Schools in Mexico

Andoni Garritz and Vicente Talanquer

This paper analyzes progress in reforming science instruction at the secondary school level in Mexico. These reforms are taking place at the lower secondary level (grades 7–9), where the national curriculum now emphasizes a science-technology-society (STS) approach to reform, and at the higher secondary level (grades 10–12), where there is no national curriculum and a variety of curriculum approaches are still being developed including STS approaches. Although reforms at the lower secondary level were introduced five years ago, they have not yet been implemented in all classrooms. There is a problem with the training and continuing education of the science teachers; the teacher training colleges are still in the process of producing new teachers comfortable with the new curriculum and instructional methods. Teacher quality is also a barrier to reform at the upper secondary level. Also, at the upper level, the decentralization of the system and high student dropout rates have been a problem.

Introduction

In this paper we present an analysis of the present situation and the problems confronted by the reform of science teaching at the secondary level in Mexico. This period covers grades 7 to 12 and is divided into two large sections with specific characteristics based on their particular historical development and their organization within the national education system:

- The so-called "educación secundaria" (junior high school, grades 7–9), which corresponds to the last three of the nine years allocated for basic education, with students between the ages of 13 and 15
- The "educación media superior" (high school, grades 10–12), which covers the next three years—those just before higher education, where pupils are generally between 16 and 18 years old.

Before discussing the educational reform of science teaching, it is important to become somewhat familiar with the policies and organization of the system as well with some general data on the secondary level in Mexico. The Plan Nacional de Desarrollo (the National Development Plan) 1995-2000 sets the goal of realizing the mandate established in Article 3 of the Constitution, guaranteeing a basic education for all Mexicans that is free, nonreligious, democratic, and based upon scientific knowledge (Poder Ejecutivo Federal 1995). It also hopes to establish a national system for the formation, training, and professional development of the basic-level teachers and, simultaneously, to provide the current schools with new technologies in communication and computing. The Plan also proposes revising the high school education system to facilitate students' progress to the next level, providing a greater flexibility than at present so that graduation rates are substantially increased.

Today Mexico has almost 96 million inhabitants, a third of whom are less than 12 years old. In the 1996/97 school year of the 27.4 million students in the education system, 83 percent (22.7 million) were at the basic level, which includes nursery, primary, and junior high school (K–9) (SEP 1997a). In the whole education system 17.5 percent of the students (4.8 million) were in junior high school (grades 7–9), while 9.5 percent (2.6 million) were in high school (grades 10–12) (table 1).

Table 1 Number of Students at the Junior High School and High School Levels

Cycle 1996/97	Junior high school (grades 7–9)	High school (grades 10–12)
Number of students	4,809,266	2,606,099
Yearly increase—1993–96 (percent)	2.7	4.0
Percentage of the age group enrolled	75.4	42.2
Number of graduates from the cycle	1,271,675	444,396[a]
Number of teachers	275,331	182,185
Average number of students per teacher	17.5	14.3
Number of schools	24,402	8,280
Average number of students per school	197	315

a. This does not include graduates from the so-called technical professional track (SEP 1997c)

1993 Reform of the Junior High School System

Since 1993 this junior high school system has undergone important changes as a result of an agreement between the federal government, the state governments, and the National Union of Teachers. In the words of the undersecretary for education, "the agreement will be considered one of the greatest transformations of Mexican education in the 20th century" (Fuentes-Molinar 1998). The reform has tried to reorganize the education system at the basic level (K-9), modify the curriculum content and educational materials, and reassess the teaching function. In the Program of Educational Development 1995–2000 (Poder Ejecutivo Federal 1996) the goals mentioned were: the correct application of the curriculum approved in 1993 together with the preparation of teaching materials and the training of teachers in the details of the reform.

The main proposal of the 1993 curriculum reform was to stimulate the skills necessary for ongoing, lifelong learning. Basic education should help students develop the skills, attitudes, and values necessary to acquire, organize, and apply their knowledge in everyday life and in their communities. To attain these objectives, the reform proposes strengthening the teaching of Spanish and mathematics—subjects that constitute the educational heart of primary education, and which are strongly emphasized during junior high school (SEP 1993a, 1993b). In the area of science, the reform advocates a teaching methodology that encourages children to be curious, to make observations, and to develop explanations and a love of nature. At the same time, the goal is to stimulate their ability to understand problems of special importance to

the quality of life: the maintenance of health, a balanced personal development the protection of natural resources, and conservation of the environment. From the point of view of technology the 1993 reform seeks to increase the students' interest to stimulate reflection about available technologies, the reasons for their use, their advantages, and the risks run when they are not used correctly (Poder Ejecutivo Federal 1996).

The following are among the measures that have had a direct impact on the junior high school system (Bonilla 1997):

- Decentralization of basic education and teacher training services to the 31 states of the Republic (previously, these services were managed centrally from the offices of the Secretary of Public Education (SEP) in the capital). It is important not to forget the complexity of such an enormous reform with millions of students, hundreds of thousands of teachers, tens of thousands of schools, all in a system that had suffered from progressive centralization for 70 years (Fuentes-Molinar 1998).
- Reform at the constitutional level to lengthen compulsory education from six to nine grades, including the junior high school grades.
- Integral reform of the national curriculum of both primary education (grades K–6) and junior high school (7–9), which, for the first time, was jointly designated to ensure continuity and congruence.
- Preparation of teaching materials that include didactic and evaluation strategies.
- Creation of a national program of evaluation, covering curricular and knowledge assessment for both teachers and students; the participation of the teacher in the program will have positive effects on his salary.
- Creation of a national program of continuing education that offers distance learning, national standardized examinations, and the creation of study centers for teachers in various cities throughout the country.

High School Education

In Mexico the high school system is not included as part of basic education; it has only been partially decentralized to the states. So, in contrast with the junior high school, where there is a single curriculum for the whole country, the high school is divided into three educational tracks (table 2) with very diverse objectives, developed from around 300 different plans and programs of studies (OECD, 1997)1. For these reasons, it is a very heterogeneous system:

- Bachillerato General—a high school that prepares students for college education. An enormous amount of valuable information on this track can be found in Direcíon General del Bachillerato (1998).
- Bachillerato Tecnológico—a technology high school. A track with a double purpose where students receive training in a specific technological area, in addition to the basic elements of high school education

1. Probably, this number has been reduced because of the curricular changes that took place between 1995 and 1998.

- Educación Profesional Técnica—a technical professional education, designed to train students for technical work in many different specialties.

Table 2 Distribution of Students in High School

Cycle 1996/97	College preparatory high school	Technological high school	Technical professional education
Number of students	1,507,028	715,311	383,760
Percentage of students	57.8	27.5	14.7

It is important to emphasize that three-fifths of all Mexican high school students are enrolled in the first track. In the past, this imbalance was even larger and there was a greater number and diversity of plans of study. In 1982 the different high school systems convened a congress to examine the present state of this level of education (SEP 1982). In this congress an agreement was reached on the general objectives and contents of this education system, with a set of common course requirements to ensure a minimum level of homogeneity. Unfortunately, since then there has not been a second meeting of equal importance. A reasonably complete historical summary can be found in Castrejón (1985).

A fact that made a great impact on recent foreign observers of the system (OCDE 1997) and that should be kept in mind is that the majority of Mexican high schools (46.6 percent in 1993) are attached to university institutions for historical reasons (the National University of Mexico was founded in 1910 by absorbing the National High School, created in 1867). This imparts very special characteristics to the system. The same OECD report on higher education in Mexico presented a series of comments and recommendations:

- There is an inconvenient downward trend in the numbers registering for technical professional education, even though the number of schools has increased, confirming the decrease in the attraction of this educational track and revealing a primary parental interest in helping children to attend the universities.
- A national high school system should be created that allows the fair admission of all candidates satisfying minimum requirements, with common objectives and regulations defined at the federal level, but leaving the responsibility of applying the program to the states.

1993 Reform of the Natural Sciences in the Junior High Schools

The 1993 reform in the natural sciences required the replacement of the education model favored during the 1970s, in which teaching was based on the use of the scientific method as a process of discovery, and the content was based on the idea of "learning science by doing science" (Talanquer 1990). In contrast, the new curriculum uses the principles of constructivist learning, based on understanding that students bring their own ideas and explanations into the science

classroom, and the role of the teacher is to shift the students' naïve explanations toward the scientific. The reforms also include a strong emphasis on science-technology-society (STS) issues.

From 1975 until 1993 the teaching of sciences in the great majority of schools developed along the lines of an integrated science curriculum approach (SEP 1977). However, the lack of teacher training, the large gulf between teachers and a curriculum in which they had very little input, and the lack of support and resources made it very difficult to apply the plan in the classroom. With the reform in 1993, teaching is divided into subjects—biology, chemistry, physics, and geography—but an educational focus is established with the following common objectives and strategies:

- To link the acquisition of knowledge about the natural world with the formation and practice of scientific perspective and skills.
- To relate scientific knowledge to its technical applications.
- To promote an integrated vision of science.
- To encourage learning by experimentation.
- To establish consistent relationships between scientific knowledge, daily life, and social phenomena.
- To emphasize the character of the sciences as a human activity.
- To maintain a line of environmental education, health preservation, and understanding of the processes that characterize puberty.
- To recognize the importance of the experiences of the students, along with their understanding of the learning process.
- To use questions as the initiating or triggering elements of discussion.

To assist in recognizing the specific emphasis placed on science courses in the junior high school curriculum, table 3 presents a complete listing of courses and the weekly allowance of time for classroom work.

Table 3 How Junior High School Subjects are Allocated in the 1993 Reform Plan, by Hours per Week

Grade 7	Grade 8	Grade 9
Spanish (5)	Spanish (5)	Spanish (5)
Mathematics (5)	Mathematics (5)	Mathematics (5)
World history (3)	World history (3)	Mexican history (3)
Civics (3)	Civics (2)	Career advice (3)
General geography (3)	Mexican geography (2)	Optional (3)
Biology (3)	Biology (2)	—
Introduction to physics and chemistry (3)	Physics (3)	Physics (3)
—	Chemistry (3)	Chemistry (3)
Foreign language (3)	Foreign language (3)	Foreign language (3)
Artistic expression (2)	Artistic expression (2)	Artistic expression (2)
Physical education (2)	Physical education (2)	Physical education (2)
Technological education (3)	Technological education (3)	Technological education (3)
Total =35 h	Total = 35 h	Total = 35 h

It can be seen that the natural sciences area comprises nine compulsory subjects that represent 24 percent of the total work time in the classroom. In addition, there is an optional subject whose content is decided independently in each state, but which frequently relates to environmental education.

The contents of natural science courses include central issues and ideas in each subject, very often related to important social problems. For example, biology courses cover the origin of life, biological evolution, ecology, genetics, cellular organization and vital functions, health, and human reproduction. Meanwhile, chemistry classes include subjects such as chemistry and daily life, properties of elements, compounds and mixtures, discontinuity of matter, chemical reactions in the aqueous phase, oxidation reactions, principles of organic chemistry, and electrochemistry. In physics the properties of physical systems are analyzed and the basic ideas of mechanics, energy, heat and temperature, electricity and magnetism, and optics and sound are considered. Geography courses analyze the themes related to the large-scale physical phenomena that have occurred on our planet—from the geological evolution of Earth to the physical and climatic characteristics of its diverse natural regions (SEP 1993b).

Problems and Obstacles to Junior High School Reform

Although the new curricular proposal came into effect five years ago, it is far from being in general use in the classroom. The existing difficulties are multiple and diverse. Solving these difficulties will require the effort and will of both teachers and students and the authorities and society as a whole. Some of the problems confronting the reform process are discussed below. The list is incomplete and its analysis reflects the authors' personal view of the situation. In the italicized portions of the text we glimpse some possible solutions.

Design Flaws

Every process of change has to confront the natural resistance of those who participate in it, since they have to accept the challenge to walk a partially unknown path. The problem becomes even more serious if such a path has been selected by specialists who might never walk it, and with the marginal participation of those who will undertake the adventure.

Without denying the value of the proposal of reform of the natural sciences in junior high level (Educ. Quím 1993), it is important to recognize that the proposal preserves a traditional flaw in the national education system. In general, plans and programs of studies are initially designed by specialists; at a later stage they are presented to the actual teachers and a discussion process is started, which very often only has the objective of legitimizing the plans and falsely presenting them as collective collaborations. However, this does not mean that the teachers will accept the proposals as their own; it only ensures that they will implement them based on their own knowledge and experience—that is, the teachers restructure the syllabus according to their personal preconceptions and their own reference systems (Toledo 1987).

In Mexico institutional needs and political projects rarely provide the space and the necessary time to build collective proposals. *This is why it is necessary to create forums that*

allow teachers to think about their practices and initiate a worthwhile exchange of ideas, proposals, and opinions with other teachers and the specialists in charge of curricular design and the preparation of support materials. For the teachers to accept the objectives and targets of the reform as their own, they must be given the opportunity to analyze them collectively, to discuss them, and redefine them as they think right. For as long as teachers consider themselves as mere spectators and performers of somebody else's plans, they will find it difficult to commit themselves to reform.

Deficient Continuing Education Programs

The continuing education activities offered by the authorities or by the different agencies responsible for teacher training have been uncoordinated for years. Generally, teachers only participated in these courses if they were offered points on the promotion ladder, or if they were offered specific training about how to deal with a topic that they had to teach immediately.

It is important to point out that about half the teachers were trained in the escuelas normales (teacher training schools), using plans of study that followed the education philosophy of the time before the reform. The other half consists of university graduates, although not necessarily in the field in which they teach, whose pedagogical training tends to be deficient. Consequently, a high percentage of both groups have to be brought up to date and need to consolidate their scientific knowledge and the modern pedagogical strategies required to develop a student-centered learning approach. Today, the majority of teachers practice a traditional manner of teaching in which lecturing, dictating, memorizing, and copying are the preferred didactic tools. Therefore, it is necessary to develop or renew didactic skills and create the conditions in which teachers can translate their knowledge and skills into activities that are effective in the classroom.

A significant effort to improve the situation has begun in recent years. Among the actions undertaken is the National Project of Continuing Education—Proyecto Nacional de Actualización Permanente (PRONAP)—which started in 1995 and aims to create the conditions to meet the requirements of continuing education at the national level (Sánchez, 1997). The task facing PRONAP is enormous if we consider how far behind the continuing education system has fallen over the years and how many teachers need to be retrained.

About 300 teachers centers have been established throughout the country through PRONAP. Each center contains a book library, video library, distance-learning classroom, and computers with multimedia and Internet capabilities. One center aims to encourage academic life in its area of influence (SEP 1997b; Sánchez 1997). Because of the newness of the program, a large number of teachers do not know of the help the centers can offer them, and their value generally depends on the specific characteristics of the academic community they serve. *Therefore, it is necessary to strengthen the academic work in the centers, offering more resources to PRONAP to support the development of teaching materials and offer more courses, seminars, and lectures, both at the center and at a distance.*

Some continuing education courses for teachers are being offered within PRONAP at the federal and state levels. These courses have a strong remedial character and aim at the independent retraining of teachers using of self-study methods. With this objective in mind, supporting materials have been prepared for mathematics, physics, chemistry, biology, and geography, whose teaching and disciplinary contents are focused on the requirements of the new curriculum. Today, about 25 percent of active junior high school teachers are taking part in one of these courses (Sánchez 1997), which is an insignificant number.

Although it is still too soon to evaluate the breadth and impact of PRONAP, it is probable that its success will be limited by the ability of the teachers to study independently. Many teachers have not developed this ability and the conditions under which they work do not favor it. *Fostering and supporting the formation of study groups seems a possible way to strengthen the program and induce cooperative work. It would also be desirable to develop a complete program of continuing education that, by taking into account the classroom and laboratory needs as well as the particular characteristics of the targeted teachers, would offer other teaching development alternatives. We need a program that lays the foundations for the on-going training of teachers and does not solely respond to immediate requirements.*

Delay in the Reform of Initial Education Programs

Beginning in 1984, for the first time, the teacher training colleges began offering bachelor's degrees and became a part of the system of higher education. Teacher training colleges train students to be teachers from nursery to junior high school levels, the numbers at the junior high school level being the greatest—93,700 students (49.7 percent) in 1997]. There are 536 teacher training colleges in the country. As mentioned above, the universities contribute indirectly to the education of teachers in junior high school, since some of their graduates become teachers at this level (SEP 1997b; Sánchez 1997).

In 1996, three years after the curriculum reform was initiated, the teacher training colleges began the process of changing their curriculum to match the reform already in progress. Since then, they also have attempted to update the educational materials and the staff responsible for educating of the new teachers, strengthen the work infrastructure, and redefine its organization to encourage participation of the academic community in decisionmaking (SEP 1997b).

Within the scope of the reform, the new plan for the bachelor's degree in teaching at the primary level (K–6) has only just started. It is hoped that the proposed plan for junior high school teaching will start this year. For the education of teachers of the natural sciences, a basic corpus of general requirements is being considered, followed by a period of specialization in one of the disciplines, with an in-depth study of its contents and specific teaching methods.

Although the new plans of the teacher training colleges are appropriate to meet the requirements of the reform, we will have to wait four years for the arrival of the first generation of junior high school teachers. On the way, the program will certainly face problems similar to those encountered during educational reform in the schools themselves. *In this new process of*

initial education it is vital to give priority to the experimental component in science education and supply the necessary support.

Nascent Mechanisms of Evaluation

Only recently has the need to evaluate the learning achievements of students been recognized in Mexico, in order to improve the quality of education offered as well as to evaluate the education system per se as part of the planning strategy (Schmelkes 1997). Thus the reform process has been promoted without a complete evaluation of the scope and limitations of the previous curriculum. Today, the established mechanisms are very new and the results obtained have not fully impacted the education process.

When the reform process was started, the education authorities proposed the development of a national system of education evaluation to assess a mechanism for supporting and stimulating the process. Two parallel programs were enacted:

- The Programa de Carrera Magisterial (Program for the Teaching Profession, 1993)—a program to evaluate the professional performance of teachers, in which standardized examinations are used to measure student progress. It is designed to provide information on the academic results of 6.5 million students throughout the country.
- The Programa de Instalación y Fortalecimiento de las Áreas Estatales de Evaluación (Program to Set-up and Strengthen the State Areas of Evaluation, 1996) a program "to build information systems on the quality of education, train evaluators and advise teachers on evaluation materials" (SEP 1997b). Up to the present, the measures developed are concentrated on primary education and concern the definition of national standards for the different subjects and grades of basic education.

On the other hand, since 1996 all those graduating from junior high school who wish to enter high school in metropolitan Mexico City (239,000 students in 1997) must take an examination of general knowledge and reasoning ability, the result of which determines whether they will be accepted into high school and in which of the different tracks. The design, implementation, and grading of this examination is the responsibility of a nongovernmental organization, the Centro Nacional de Evaluación (National Center for Evaluation, CENEVAL), and it is guided by the standards, policies, and criteria laid down by a technical council made up of representatives of the different institutions responsible for teaching at both the basic and high school levels.

Until now, the evaluations that have been carried out seem to serve more for accreditation, selection, and promotion of teachers and pupils. These evaluations suffer from the fact that the evaluation tools were developed before the definition of the national standards for junior high school education and that, once again, teacher participation has been marginal in the design process. *It is necessary to redirect the usage of evaluation so that it works as a tool for feedback and training of the different participants of the system and contributes to the improvement of the quality of education. The active participation of teachers is fundamental in*

the definition of knowledge, skills, and attitudes that should be evaluated and the criteria to guide the job of the evaluator.

Adverse Economic and Social Conditions

An important component of the problems facing education reform in the sciences is based on historical factors and institutional, social, and economic conditions that are outside the control of the teachers and do not depend on their wishes. The economic restrictions imposed by the "crisis" that our country has suffered have impoverished the middle class. This has forced teachers to move from one classroom to another, and from one school to another, teaching all day long. Academic overload is a common factor in a teacher's life. Many have between 6 and 14 groups of 55 and 60 pupils each, and receive a very low salary for their efforts.2 The working conditions have notably deteriorated, and with them the social status of the teaching profession (Toledo 1987; Zúñiga 1987).

As a federal effort to palliate this situation, the Program for the Teaching Profession offers economic incentives to the participating teachers, upon accepting the evaluations applied both to them and to their students. It is a promotion system that comprises five levels to which access is gained by means of professional performance and training, participation in continuing education, academic degrees, and seniority at work (SEP 1997b). Today, almost 675,000 teachers of basic education are registered in the program, which confers an important increase in their basic salary (Sánchez 1997). *However, the program is only a palliative and the global problem will continue without the professionalization of the teaching activity and a substantial increase in economic investment in the education system.*

Rigidity in the Organization

In addition, the teacher also has to confront the mechanisms of control and the rigidity of the present academic-administrative organization. The forms of political power developed over the years have frequently created administrative obstacles to any modernizing proposal. In the junior high school system there is a tradition of silence, individualism, and obedience that has grown for many years. Any collective autonomy on the part of the teachers causes suspicion and, consequently, is restricted (Martín del Campo 1988)

The organization has to be gradually transformed to eliminate the bureaucratic hierarchies that limit the communication and participation of the teachers. The school principals should participate in the reform so that instead of acting as obstacles to transformation, they promote and motivate it. It is also important to encourage social participation in decisionmaking, since Mexican society has sadly and worryingly remained at the margins of the reform. The schools have to create the spaces that teachers need in order to analyze, discuss,

---

2. In May 1998 a 27 percent increase in salaries was agreed on, this in a year when the 14 percent expected inflation coupled with a downward trend in the price of petrol has had a serious impact on government finances, which shows willingness on the part of the authorities. However, the present monthly salary is less than US$400.

reflect, investigate, propose, and make decisions about their educational practices. Only in that way can the foundation be laid to ensure an on-going reform of science education and to avoid the problems accumulated by educational proposals that, in our country, tend to be considered permanent.

Lack of Coordination in the System

The disarticulation of the components of the system and the lack of continuity of the educational policies are other factors that need to be considered. Teachers, educational program designers, textbook writers, teacher trainers, executive and administrative personal, education inspectors and supervisors, and government authorities live in very different worlds. Their aims are not necessarily the same, and their interactions are often rough and at a distance. These issues have somehow been reflected in the guidance documents and support materials developed for reform in the teaching of sciences (Léon 1993). Some of these are the result of work by different groups that have not been in contact at all and do not share the same objectives.

Although it is necessary to recognize that in recent years the different participants in the reform have made an important effort to close the gulf separating them, trying to unify the criteria used as a guide, *a reorganization, which allows the reconciliation of interests, the establishment of common goals, and the substitution of the unilateral decisions by reflection and collective effort is still necessary.*

Reform of High School Science Education

The analysis of science education in this part of the paper is more complex because of the enormous diversity in existing curricula. However, since we are interested in a science education reform that is not based on trends, but on factors of significance to everyone in the community, the recent results in curricular design with this focus are relatively small. Thus the following discussion will list the most important recent efforts in the field of science teaching in each educational track and comment on the obstacles the authors foresee to reaching a more generalized reform.

Bachillerato General (College-preparatory High School)

El Colegio de Bachilleres is a decentralized system in each state that does not belong to any higher education institution. It had 411,000 students registered for the 1996/97 school year (15.8 percent of the national total). In 1992 the system ended an important process of curricular reform in the schools within Mexico City, a process that has been moving slowly toward the states. It incorporates three mandatory semester-long courses in physics, three in chemistry, three in biology, two in health, and one in earth sciences. In large measure, these courses preserve their traditional character, although they incorporate social subjects and problems where science plays an important role. For example, in chemistry they include the following aim, "the students should know the implications of chemistry in their daily life, should identify their role in them and should take a responsible attitude, contributing to the understanding of the problems and participating in the proposal of actions to solve them" (Colegio de Bachilleres 1992). Some of

the subjects in this area are: toxic substances in the environment, metallurgy, petroleum, polymers and petrochemistry, and the processes of fermentation and alimentation.

- The high school of the Autonomous University of Nuevo León, one of the highest quality programs in one of the most prosperous states in the Republic, modified the contents of its science courses in 1993. Although these changes were enunciated within a traditional focus, their program is exceptional because of highly developed experimental teaching, based on a great number of basic and open-ended experiments that occupy a large amount of the total teaching time.
- The National Autonomous University of Mexico (UNAM) has a high school education program that accounts for about 10 percent of the national total of pupils at this level. Half of these are enrolled in the schools of its own two systems—The National High School (ENP) and the College of Sciences and Humanities (CCH)—and the other half are in private schools that follow UNAM's plan of studies. Curriculum reform streams appeared in both systems during this decade, the first becoming reality in the CCH in 1995 and the second in the ENP in 1997. In the CCH more attention was given to the subjects of natural sciences, as well as a focus completely based on the STS reform trend, particularly chemistry and biology. Three years after its initiation the process is not without problems, due to the total change of the educational objectives, the slow adaptation of the teachers to the new plan, and the initial absence of study materials. However, teacher training continues to move forward within a program for which UNAM has received the financial support of the Inter-American Development Bank, including work visits and teacher exchanges with Canada, France , and Spain. At the end of the current school year the first evaluation of the new curriculum of the CCH will be undertaken. Similarly, it is still too soon to speculate on the results of the ENP reform.
- The Dirección General del Bachillerato (General Authority for High School Education) is the responsibility of the Secretary of Public Education, which coordinates the Colegios de Bachilleres and other high schools within this educational track that do not belong to the universities. This system has started an important process of structural change that emphasizes the assessment not only of teaching, but of all aspects of school organization. Within this curriculum the natural sciences are responsible for 21 percent of the common core courses: two courses of physics, chemistry, and mathematics and one of geography, ecology, and the environment. For those students who wish to enter higher education, there are additional selected subjects (DGB 1998). In the majority of the schools dependent on this authority, science teaching has a mixed focus, between a traditional and a STS approach, that has allowed teachers to gradually begin teaching science in ways that are more meaningful to the students.

Bachillerato Tecnológico (Technological High School)

- During the 1996/97 school year the curricula were restructured, resulting in a reduction from 60 specialties to only 17, each with its own character and focused on learning a technological area rather than completely mastering a specific technique. In particular, the General Authority for Industrial Technical Education has completed a full cycle of curricular design by skill areas, induced by the recent work of an evaluation body for graduates at the technical

level: the Consejo Nacional de Certificación de Competencias. The science courses that form part of the basic core in this system have an important emphasis on technological applications.

Educación Profesional Técnica (Technical Professional Education)

- The model system in this category is the Colegio Nacional de Educación Profesional Técnica (CONALEP), with about 50 percent of all the students registered in this track. During 1995 and 1997, with the participation of experts from the managerial and social sectors, a very important change was made. The 146 different options within technical education were reduced to 29, emphasizing the creation of professional values and competencies, the teaching of mathematics and its uses, and also teacher training. The growth in the number of registered students from 87,000 in 1983 to 200,000 in 1996 has been important (Argüelles 1998). In this educational track the science courses are geared toward technical applications necessary for industries, such as clothing, food, chemical, automotive, electronics and communications, machine tools, metallurgy, refrigeration, and the like. Although these types of schools were designed to be noncollege preparatory in nature, they have added six subject areas since March 1997 to give students an opportunity to pursue higher education (CONALEP 1998).

Problems and Obstacles to High School Education Reform

Coordination

This educational level lacks effective mechanisms for coordination. Even though there have been (and are) divisions within the Secretary of Public Education (SEP) responsible for coordination, they have not fulfilled their purpose. At present these coordinating functions are carried out by the Coordinación Nacional de la Educación Media Superior (National Co-ordination of the High School Education), by another recently created group under the mandate of the Secretary for Education, and by various state organizations responsible for planning and programming.

This is a fragmented system that lacks a central policy to give high school education the importance it should have. On the one hand, the schools that depend on the universities enjoy the universities' autonomy, and so it has been difficult for the educational authorities to interfere in their curriculum development or their teacher training programs. On the other hand, the SEP is divided into two very large and powerful independent subsecretariats, responsible for managing high school education. The first one, Educación Superior e Investigación Cientifica (Higher Education and Scientific Research) is responsible for both the universities' high schools and for those high schools that depend on the Dirección General del Bachillerato. The second, Subsecretaría de Educación e Investigación Tecnológica (Subsecretary of Technological Education and Research), is responsible for the technological high school education and some schools within professional technical education. So, there are multiple decision centers, and most of this level of study uses the same resources and mechanisms as higher education, so there is

competition between them for financial resources. Finally, CONALEP is relatively independent of the government.

This is an unresolved problem that could possibly be improved by centralizing some key functions, such as the establishment of national standards for content and assessment of students, teachers, schools, and the whole education system. Centralizing the process for teacher certification would also help, since in high school education there is not a program of rewards similar to the Program for the Teaching Profession for basic education.

Efficiency in Question

The education authorities are worried about the high dropout rate in the high school system. All the education-related documents, including presidential reports, mention the low graduation rate as a worrying point. The official statistics calculate the efficiency as the ratio of graduates in a year over those who entered high school three years before, and this varies for each educational track (in the 1996/97 cycle, it was 43 percent for technical professional education and 57 percent for college-preparatory and technological high schools). The statistics indicate an initial dropout rate of 27 percent and 17 percent in both tracks (SEP 1997c). *It would be important for the SEP to head a complete study of the reasons for school dropouts, to understand the internal and external reasons, and to be able to attack them directly.*

Diversity—the Generalized Pattern

There is an enormous difference between the objectives and curricular structure in the different educational tracks, and even within them. Some systems have a strong technical specialization character, others share a common core with final specialization areas, while the college-preparatory schools are exclusively focused on preparation for higher education. There are structures for both year-long and semester-long plans. The plans of study generally last three years, but some last only two. Some of them place an enormous workload on the students, while others rely more on work outside school. There is inequality in accommodations and quality of resources and also in the socioeconomic characteristics of the students.

This diversity also occurs in science teaching: the number of courses in each subject offered as optional or compulsory is quite variable, there may or may not be laboratory facilities in the schools, and there are different pedagogical approaches for teaching experiments. Also, the contents vary from schemes of reform, which are purely STS, through some directed to a pragmatic science applied to technology, to very traditional teaching patterns that exist alongside others with some mixed character.

It seems to us fundamental to acquire some unity by the establishment of minimum standards for science teaching appropriate to each educational track. It would be necessary to consider a special chapter for the experimental teaching of sciences, which is vital to improving educational quality. Important support for the development of educational materials for teacher training should arise from these standards of contents. Also, these standards should offer

valuable planning information through the evaluations that CENEVAL is applying more commonly to students seeking to enter institutions of higher education.

Flexibility and Social Valuation

Today, the high school level faces the challenge of generating mechanisms to allow greater flexibility of movement within the various options and the development of a student profile to promote a similar social valuation of all courses of study, regardless of the educational track followed. Now that there is a single mechanism to access this level in Mexico City, the social preference for the college-preparatory education plans has been dramatically shown. High school education is considered by a majority to be the stepping stone to higher education, and it is the needs of this higher level that determine the curriculum design of high school education, and not always the social demands, except perhaps for the technological and technical professional tracks. *It is necessary to have better coordination among the different sectors of society.*

Maybe to change this social view it is necessary to plan an increase in the salary of the technical professional education graduate and allow some years for this information to flow from the labor market. Meanwhile, it is important to help the flexibility of movement between the different educational tracks by means of equivalent patterns and the definition of a common basic core. The core should not favor particular areas of human knowledge, but should give students the minimum cultural elements for citizen life and the ability to make a rational decision on the continuation of studies when necessary.

Quality of the Teaching Profession

There are no mechanisms for teacher formation or assessment. The working teachers are graduates of an undergraduate program that, in a worrying number of cases, they did not complete. Hence, their pedagogical or didactical knowledge is deficient. Also, because of low university registration in scientific fields such as mathematics, physics, chemistry, and geography and, to a lesser degree, biology, teachers in these subjects are frequently engineers, odontologists, doctors, veterinarians, and the like. As in junior high school collegial or collaborative work among these high school teachers is uncommon.

Each system has its own mechanisms to assist its teachers to improve, some more successful and complete than others. In continuing education, they offer both one-time courses and, for the past several years, those that lead to a diploma. Those that lead to a diploma involve a series of related courses of 200 to 400 hours or more, which combine subject-specific contents with educational contents. In the best of cases teachers pursue a Specialization Diploma, which in Mexico is the first step toward postgraduate studies. *It is important to strengthen the professional character of the teaching career, both in the required characteristics of training or continuing education as well as in promotion and recognition. Also, it is necessary to establish general support, assessment, certification, and encouragement mechanisms for a teaching career as well as consider the option of a master's degree as a training and updating mechanism. It is also important to establish contractual policies that will favor those with such a degree.*

Infrastructure Status

Between a third to a quarter of the schools lack laboratory or workshop facilities for the teaching of natural sciences. (There is always some doubt about the extent to which these facilities are used in those schools lucky enough to have them.) A third do not have equipment related to television and, even worse, about a tenth do not have a school library, or even telephones. Also, the general maintenance of the school buildings is very poor in many cases. *Of course, the solution depends on the injection of additional resources to build and maintain infrastructure, but another face of the problem is that experimental teaching has certainly been neglected. It is necessary to have adequate written materials for teacher training that contain both demonstrations and experiments with inexpensive materials and to provide the school laboratories with the minimum necessary equipment and reactants.*

Updating of Plans of Study

Although it is mentioned in the National Development Plan, the plans of study are not updated with due regularity and, when they are, it is after a long delay. The authors know of one private institution where the internal regulations mandate the updating of programs of studies every five years. *It would be highly advisable to approve an agreement applicable to public and private education institutions as a whole, to revise the curriculum at least as regularly as this. During this exercise, modern pedagogical strategies would be incorporated, more focused on the student and less on traditional lecturing and more on developing intellectual abilities and less on thoughtless memorization. That is, the curriculum should be more interested in developing students' skills to learn by themselves; to appreciate culture; to possess good oral and written expression; to learn other languages; to employ new information technologies; to solve problems; and to work in teams.*

Dr. Andoni Garritz, Professor of Chemistry at the National University of Mexico (UNAM), is Editor of the journal Educación Quimica. *He is the former Head of the School of Chemistry at UNAM. A prolific textbook writer, Dr. Garritz has won many prizes for his teaching and is a long-time consultant to UNESCO.*

Dr. Vicente Talanquer is Professor of Physics and Physical Chemistry in Secondary and Higher Education at UNAM. He is the author of several science textbooks for the junior high school level and was a member of the team in charge of writing the new national science textbooks for primary and junior high schools in the 1993 Mexican educational reforms.

References

Argüelles, A., ed., 1998. *La Educación Tecnológica en el Mundo.* México: Limusa.

Bonilla, E., A. Sánchez, T. Rojano, y J. A. Chamizo. 1997. "Mexique: Demógraphie Scolaire et Réforme de l'Enseignement." *Revue Internationale d'Education* 14: 10; *Curriculum Scientifique et Innovation* 14: 53. Este último se publicó en español en *Educación 2001* 28: 42.

Castrejón, J. 1985. *Estudiantes, Bachillerato y Sociedad.* México: Colegio de Bachilleres.

CCH (Colegio de Ciencias y Humanidades). 1995. *Plan de Estudios Actualizado.* México: UNAM, Colegio de Ciencias y Humanidades, Grupo de Síntesis.

Colegio de Bachilleres. 1992. *Programas de las Asignaturas, Dirección de Planeación Académica.* México: Colegio de Bachilleres.

CONALEP (Colegio Nacional de Educación Profesional Técnica). 1998. "Memoria del Cambio." México: CONALEP.

DGB (Direccíon General del Bachillerato). 1998. "Página Internet de la Dirección General del Bachillerato." http://168.255.115.5/dgb/principal.htm (Distrito Federal) or http://www.cobaed.mx/c1dgb.htm (Durango).

1993. "Debate: La Enseñanza de la Química en la Secundaria." *Educ. Quím.* 4 (3): 134.

ENP (Escuela Nacional Preparatoria). 1997. *Planes de Estudio.* México: UNAM, Escuela Nacional Preparatoria.

Fuentes-Molinar, O. 1998. *Periódico Reforma* (15 de mayo): A4.

León, A. I. 1993. "¿Dónde Está el Currículo?" *Educ. Quím.* 4 (3): 150.

Martín del Campo, J. 1988. Puntos de Vista sobre la Calidad de la Educación. *Cero en Conducta.* (11/12): 5.

OCDE (Organisation de Coopération et de Développment Économique). 1997. *Exámenes de las Políticas Nacionales de Educación: México, Educación Superior.* París.

Poder Ejecutivo Federal. 1995. *Plan Nacional de Desarrollo 1995–2000.* México.

———. 1996. *Programa de Desarrollo Educativo 1995–2000.* México.

Sánchez, A. 1997. "La Formación y Actualización de Maestros de Ciencias Naturales y Matemáticas en México." Presentación en el Seminario Internacional sobre Innovaciones Educativas en Ciencias Naturales y Matemáticas, OCDE, México.

Schmelkes, S. 1997. "Evaluación del Aprendizaje y Calidad de la Educación Básica." Presentación en el Seminario Internacional sobre Innovaciones Educativas en Ciencias Naturales y Matemáticas, OCDE, México.

SEP (Secretary of Public Education). 1977. *Programas Maestros para la Educación Secundaria.* México.

———. 1982. "Memoria. El Congreso de Bachillerato." Cocoyoc, México:SEP.

———. 1993a. *Plan y Programas: Educación Básica—Primaria.* México.

———. 1993b. *Plan y Programas: Educación Básica—Secundaria.* México.

———. 1997a. *Informe de Labores 1996–1997.* México.

———. 1997b. *Perfil de la Educación en México.* México.

———. 1997c. *Prontuario Estadístico, Cultural y Presupuestario 1997.* México.

Talanquer, V. 1990. ¿Qué Pasa en Nuestra Secundaria? *Educ. Quím.* 1(2): 92.

Toledo, M. E. 1987. "La Reforma a la Educación Normal y la Participación Magisterial." *Cero en Conducta* 8: 10.

Zúñiga, R. M. 1987. "¿Para Cuándo los Cambios en la Educación Secundaria?" *Cero en Conducta* 7: 14.

Chilean Education Reforms during the Current Century

Manuel Martínez M. and Raul Cerón F.

This paper discusses the recent reforms in basic- and middle-level education in Chile, with an emphasis on science curriculum for students in middle-level education (ages 14–17 years). The Ministry of Public Education is attempting to decentralize the curriculum while defining a set of minimum mandatory content and specific objectives, which students should attain before they leave secondary education. The science objectives for general education (rather than science specialization) focus on both science knowledge and science process. Science is taught from the context of the students, emphasizing the utility of science and its affective component. Although the reforms have only recently been introduced, there are already problems with implementation, primarily involving the role of and support for the classroom teacher. There is also concern that the mandatory content is overloaded, and that many schools do not have the resources they need to implement reform.

Introduction

The Chilean education system has experienced three significant reforms during this century. The first occured beginning in 1920; the second began in 1965; and ongoing reforms began in 1996. Between 1891 and 1920, the Chilean economy suffered a deep depression as a result of the saltpeter crisis, high inflation, and unemployment rates. Education was the focus of much attention and criticism. Efforts were made to eradicate illiteracy and to institutionalize mandatory elementary education. In particular, secondary education was strongly criticized because of its scarce contribution to the country's economic development. The middle class and the working class sought participation in society and saw education as a way to reach a more privileged status. In 1920, Law Number 3,654, the Mandatory Primary Instruction Law, was enacted during the presidential period of Salvador Sanfuentes. The impulse of this education reform ended in 1928, with a total of 525,000 children registered in elementary school and 26,800 registered in high school.

The 1920 law created mechanisms of continuity between primary education (grades 1–6) and secondary education (grades 7–12) at a time when education was focused on elementary education. This reform was in force throughout the mid-1960s and created a highly selective education system in which primary education was mandatory, although in practice the attrition rate was high. Secondary education was even more selective; universities performed special admission tests.

The second significant reform was initiated during the presidential term of Eduardo Frei by enactment of Decree Law Number 27,952. At the time, society demanded that education be relevant to life and students' motivations and that programs pose real challenges to the students. However, entrepreneurs were concerned that if the pedagogical processes and teachers' academic

background focused on the concepts of production and services, social unrest would be triggered similar to that which catalyzed the first reform movement.

The 1965 law defines standard education as having the following four levels: kindergarten, basic general education, middle, technical-professional and scientific-humanistic education, and higher education. Notably, kindergarten is considered an important stage in the education process of the individual. Basic general education, which includes grades 1–8 (between 6- and 13-years of age), is mandatory. Middle education includes grades 9–12 (between 14 to 17 years of age).

Middle education is offered in two ways: technical-professional education that is oriented toward students seeking to join the work force (although they could continue university studies if they fulfill the requirements) and scientific-humanistic education for students seeking to continue college education. The reform increased the school time, extending the mandatory period from six to eight years. It established academic subjects with objectives, content, and evaluation standards and required teachers to take courses to help them adapt to the reform. The Center of Perfection, Experimentation, and Pedagogical Research, which reports to the Ministry of Education, was created for that purpose.

Between 1970 and 1973, there was an attempt to transform Chilean society by introducing an educational reform known as the Unified National School. The movement failed and the system established in the mid-1960s prevailed with few significant changes.

In the 1970s, the earlier reforms produced a rapid expansion of registrations in the Chilean university system estimated at around 70 percent. Thus, plans and programs to modify middle education were again introduced in 1981 (Supreme Decree Number 30) and sought greater flexibility in the system. One significant change was that two scientific academic subjects, chemistry and physics, were no longer compulsory. This situation was reversed in 1988 (Supreme Decree Number 188) when both academic subjects again became mandatory. Content also changed and the use of the Science Technology Society (STS) approach was adopted for chemistry programs in the first and second years of middle education.

In the early 1980s, the growing educational system constituted the heterogeneous public sector, serving principally the poorest members of the community, and the homogeneous private sector. The system was not coping effectively with either the heterogeneity or the growth. Standardized test results (1992–1993) for students in basic- and middle-level education were very low. In summary, the youth in Chile learned half or less than half of what they should have learned and were repeating years at both levels of education. New reforms were needed to focus on both the quality of education and issues of equity.

In 1990, the third significant education reform was initiated through the enactment of Law Number 18,962, known as the Constitutional Organic Law of Teaching. It established the general requirements and minimum graduation requirements for basic- and middle-level education. It also required that the Ministry of Education establish a curricular framework of fundamental objectives and mandatory minimum content to define the level of achievement

expected from students by the end of middle education. The four components of this newest reform are described below.

Curriculum Reform

The core of the latest reform is the decentralization of decisionmaking in the Ministry of Public Education. Starting from the basic curriculum framework and mandatory minimum content, academic institutions now have the freedom and autonomy to establish their own programs. The curriculum reform incorporates child and youth culture into the schools as a tool to transform the students' education with respect to the teaching and learning process. The implication is that the process is now established in a context relevant to the students. The fundamental objectives are the competencies or capabilities that students should achieve by the end of the middle education level. The objectives are:

- *Vertical fundamental objectives* refer to specific courses and levels. The achievement of these objectives requires learning and experiences related to specialties and sub-specialties of the middle-education curriculum. The vertical fundamental objectives are the objectives that students must achieve in each of the four years of middle education.
- *Terminal fundamental objectives* are those objectives that students must achieve at the end of four years of middle school when they are enrolled in technical-professional education.
- *Transverse fundamental objectives* have a general and comprehensive character. Their achievement is based on the formation of a curriculum set or subset that crosses traditional subject matter boundaries.

The minimum mandatory content describes the specific knowledge, abilities, and attitudes that must be introduced to students if they are to meet the fundamental objectives for each level. They are expressed as a comprehensive set of detailed performance objectives for each subject taught. Content defined as "knowledge" includes concepts, conceptual systems, and information about facts, procedures, processes, and operations. The minimum mandatory content distinguishes, like the fundamental objectives, between knowledge as information—of objects, events, phenomena, and symbols—and knowledge as understanding—of information placed in a relationship or in a context, integrating an explicative framework, and providing a basis for discernment and judgments. Abilities refer to performance capabilities or procedure capabilities that the students must acquire throughout the learning process. These are capabilities in the intellectual or practical areas based on routines or on open processes such as investigations, creativity, and imagination. Attitudes are dispositions toward objects, ideas, and persons that have affective, cognitive, and value components that influence the person's actions. For instance, the objectives and the curriculum content framework are designed to promote positive attitudes with respect to personal development and learning, the relationship of self with knowledge, the relationship of self with others, citizenship rights and obligations, discipline to study and complete personal work, teamwork, the management of evidence, truth and criticism, dialogue and conflict management, the natural environment, and other dimensions.

Despite enactment of the 1990 law, it was only in 1996 that Education Decree Number 40 created the fundamental objectives and minimum mandatory content for basic education, thereby

beginning reform in grades 1–2 in 1997. In 1998, the reform continued with grades 3–4. Thus began the transformation of the Chilean educational system to create a significant social consensus about the strategic character of education to achieve economic, social, and political development. This change is recognized as being necessary because of the growth in the global economy and global communications and the increase in the science and technology gap between industrial and developing nations.

In 1998, Decree Number 220 became law and established the fundamental objectives and minimum mandatory content for middle education and set general application norms. The decree recognizes that, given the rapidity of change in our knowledge and in society, there will be a continuing need for teacher reorientation and curricular enrichment.

Improvement and Innovation Programs

In 1992, the Ministry of Public Education began programs to improve the quality and equality of both basic and middle education. One component of this effort, the construction of the curriculum framework, has already been described. The second component attempts to stimulate and create the necessary capacities in schools to implement the general curriculum framework according to the particular reality of each school. Variables that must be considered during implementation are: those that impact the educative process (innovations and improvements), those that provide support and resources (infrastructure, libraries, and books), and those related to consolidating the autonomy of the schools (school management).

The current innovative programs include the following:

- The *900 Schools* program targets assistance to the most primitive schools within the country with more than the initial 900 participating schools.
- The *Chains* program is developing a network of computer links among elementary schools, high schools, and universities.
- *Education Improvement* projects make competitive grants available to schools and universities for educational innovations.
- *Project Montegrande* supports the development of high schools of excellence.

Between 1992 and 1993, the Ministry of Education commissioned the universities and independent academic centers to conduct 13 research studies to determine the nature, magnitude, and specific deficiencies of middle education. At the same time, a national public debate—the National Conversation about Middle Education—began, involving about 30,000 people who participated in more than 2,000 discussion groups around the country. These groups, formed by students, professors, attorneys, entrepreneurs, and other diverse groups who were united by their interest in middle education and its development, generated new knowledge about the expectations and claims for secondary education in Chile.

Strengthening the Educational Profession

This program is considered to be essential to produce qualified and motivated teachers who are capable of assuming the new challenges introduced by education reform. The number of teachers in the municipally-subsidized sector and the private sector is about 120,000. One component of this program involves significant efforts to substantially improve the initial preparation of basic and middle education teachers. The Ministry of Education runs a competitive grant process to fund efforts by universities to renew their teacher preparation curricula.

A second component of the program is referred to as "fundamental perfectionism" and focuses on excellence in service. It includes support for efforts to encourage teachers to share their teaching experiences across the various disciplines and to learn from each other.

It is important to mention the study abroad teacher training program that is conducted partly in Chilean universities and partly in foreign universities. The Ministry of Public Education selects participants from basic and middle education teachers who are still taking classes or already have a diploma. In 1996, 588 teachers participated in the program, and in 1997, 666 teachers.

Extending the School Work Day

In Chile, the school day lasted either a morning or an afternoon (excluding evening school). Now, based on international experiences on how to improve learning, the school day has been extended to include both the morning and the afternoon. Each school decides how to manage the extra time. The time can be used for the reinforcement of learning, extra-curricular programs, additional study of specific subjects, or any other activities that the educational community considers relevant.

General Characteristics of the Current Educational System

It is noteworthy to mention that Chile is among the top Latin American countries in terms of investment in education. The number of students in basic education, between 6 to 13 years of age, is estimated at 2.18 million, representing 95 percent coverage of the cohort. The middle education students between 14 and 17 years of age are estimated at .71 million, representing 80 percent coverage. In total, 2.89 million students are enrolled in about 10,000 basic education schools and 1,600 high schools (Cox 1997).

This coverage can be considered satisfactory but the low quality of much of this education and the inequality resulting from the social distribution between public and private education are problems. To measure the quality of basic education, annual tests are taken in grades 4 and 8 through the Sistema de Medición de la Calidad de la Educación. There is no such system for middle education, although in 1992 an experimental program was tested. However, according to standardized admission tests (including academic aptitude tests and specific knowledge tests) administered by the public universities, the quality of middle education is not satisfactory (Donoso and Hawes 1994).

Decree Number 220 defined the new middle education curriculum in terms of a curriculum framework for both the scientific-humanistic stream and the technical-professional stream. The decree defines two cycles for middle education; the first corresponds to grades 1–2, and the second to grades 3–4. The curriculum framework is divided into three areas—general formation, differential formation, and free disposition—according to their general nature or specialized content and their regulation. The general formation area articulates objectives and common content for all youth, and covers most of the first cycle. The differential formation area defines specialization channels for both streams of middle education but is broader and deeper in the second cycle. The free disposition area corresponds to an unregulated component of the curriculum to be defined by the individual institutions themselves.

The general formation area covers the basic education needed to prepare students to function in a socially responsible fashion, to develop workplace skills, and to contribute to the economic and political development of the nation as informed citizens. For the first two years of middle education, the general formation area is the same for the two streams of middle education, providing a common or standardized experience for all middle education students. In grades 3–4, there is no common experience, since most of the time is dedicated to the differential formation area, when students begin to specialize.

The general formation area includes nine learning sectors, some of which are separated into subsectors to total of 13 disciplinary groups:

- Communication and language sector
    - Spanish language and communication subsector
    - Foreign language subsector
- Mathematics sector
- Social science and history sector
- Philosophy and psychology sector (only for grades 3–4)
- Natural science sector
    - Biology subsector
    - Chemistry subsector
    - Physics subsector
- Technological education sector (only for grades 1–2)
    - Artistic education sector
    - Visual arts subsector
    - Musical arts subsector
- Physical education sector
- Religion sector

The differential formation objectives address the aptitudes, personal interests, and vocational dispositions of the students in the context of the national culture and the social and economic development of the country. Introduction of differential formation objectives into the curriculum starts intensively in the third year of middle education. While students begin to

specialize at that time, they can still change their specialization plans as their interests and aptitudes develop or as the school adds new areas of specialization to the curriculum. One of the advantages of postponing specialization to the third year of middle education is to give the students more time to make sound vocational decisions. In the case of the differential formation scientific-humanistic stream, students may have already begun to specialize within the general formation objectives, depending on their interests, capabilities, or future career plans.

In the technical-professional stream, the differential formation area defines terminal objectives, grouped into "departure profiles," and corresponding to 13 occupational sectors and 44 specialization channels. The profiles were defined with the cooperation of business and industry, individuals already in the workforce, and government institutions. They address the human resource needs of a developing economy attempting to compete effectively in the global market place.

Reform in the Natural Science Sector

General Formation Objectives

Objectives for this sector can be grouped according to the following three broad goals:

- The development of the ability to think as working scientists and to relate science to the socio-political-personal contexts of contemporary life.
- The acquisition of scientific knowledge that contributes to a respect for the natural environment and its inhabitants.
- The generation of enthusiasm, wonder, and personal satisfaction resulting from understanding and learning about the natural world.

More specifically, students will attain the following:

- Scientific knowledge of the natural world and a respect for its unity.
- An understanding of scientific concepts and key principles.
- The capacity to think in a scientific way.
- An understanding of science as a historic and human enterprise.
- An ability to use science knowledge and skills for personal and societal purposes.

The nature of these objectives makes clear that value is placed both on the body of science knowledge in the different disciplines (facts, concepts, and fundamental principles) and on the processes of science (methods, reasoning, and skills). Both aspects of science content are important and should be integrated with each other if the student is to develop the higher-level thinking skills required to use science knowledge either as a scientist or a citizen. The content also reflects an implied understanding that student learning will be enhanced if science is taught from a context that is relevant to the learner. Efforts must be made to use the student's own curiosity, ideas, intuitions, and goals to facilitate learning. The mission is not to cover as much of the content of any given discipline as possible but to understand some basic concepts and

fundamental science principles, procedures, and applications. One pivotal assumption is that science learning must be an active process where investigation and problem solving are central. Investigations and experiments become particularly rich instruments of the learning process if they are related to science history, social perspectives, personal uses, and contemporary technological applications.

The curriculum framework for individual disciplines within the science sector was delineated primarily by groups of subject matter specialists. The biology curriculum during the four years of middle education integrates three conceptual areas:

- Organisms as biological systems.
- Interactions of organisms with the environment.
- Man as an organism with a conscience.

In the first and second year of middle education, the physics curriculum includes topics directly related to the personal experiences of the students. Basic vocabulary is introduced, methods and instruments to measure and analyze physical reality are illustrated, and students gain a better comprehension of the relationship of physics to other science disciplines including chemistry and biology. In the third and fourth year, without changing this orientation, as the students' mathematical competence increases, the complexity and range of topics introduced increases.

The chemistry curriculum helps students to appreciate the chemical processes of the natural world and the chemical processes developed by humankind. It is designed to increase student motivation to learn more about the chemistry around them as they begin to appreciate both the explanatory power of chemistry and its contributions to society. In the first year, students learn about the composition, characteristics, and properties of common substances such as water, air, soil, and petroleum. They observe, experiment, analyze, and discuss the chemistry of these substances. In the second and third years, a conceptual approach is emphasized. The second year covers the nature of matter, atomic structure, and the fundamentals of organic chemistry. In the third year, chemical reactions and the fundamentals of stoichiometry are studied. The second and third years continue to offer chemistry in the context of the students' personal experiences. In the fourth year, students revisit the conceptual knowledge they learned previously and apply this knowledge to an understanding of more complex chemical phenomena.

Differential Formation

The focus of differential formation is on science for the future science specialist. Each discipline addresses themes of the general formation area with greater sophistication and complexity. The curriculum is designed to stimulate analytical thought and to reach a high level of conceptual understanding. Each academic institution is autonomous in its own community and, thus, chooses which specialties will be offered during the last two years of middle education.

Biology is structured around two modules: evolution, ecology, and the environment and the genome, the cell, and the organism. The treatment of these themes builds student

understanding of the nature of scientific knowledge and investigation and stimulates analytical thought and an understanding of biological mechanisms. There are also two physics modules; they give a mathematical treatment of mechanics and thermodynamics. Chemistry offers four complementary modules that embrace the last two levels of middle education. One module takes a historic approach to the development of modern chemistry and the current international scientific community. The other three modules cover thermodynamics, catalysis, and fundamentals of spectroscopy.

Impact of the Reforms and Barriers to Change

The reform of basic education began in 1997 whereas the reform of middle education began in May 1998. It is obviously much too soon to come to any conclusions about the merit of these reforms, which are still being debated. The new curriculum framework presents two fundamental changes: the freedom for schools to develop their own projects, plans, and programs and the introduction of the fundamental objectives and the minimum mandatory content. The first change supports the decentralization that the Ministry of Education is interested in producing with respect to curriculum development. The second change helps ensure quality control by providing clearly defined objectives for student learning, which apply to all students in public institutions. Previously, only the private institutions had such clearly defined objectives.

However, a number of issues (confirmed by coverage in the print and broadcast news media) have arisen that could jeopardize this reform. First, teachers need more time in their daily schedules, to implement reform within their own schools. Teachers need time to reflect, plan, interact with fellow teachers, and learn more about how they can become an active part of the innovation process. Studies in the schools show that such time is rarely available at either the basic- or middle-education levels. Chilean teachers work from 33 to 44 hours per week; a teacher with a 33-hour schedule will spend about 30 hours in the classroom. There also are a large number of teachers who are working a full schedule at two or even three schools. Under these conditions, it is very difficult to find spare time to examine the proposed changes. If the government does not address this issue there will be major problems in implementing the reforms.

There are other problems related to the involvement of teachers in reform. Investments need to be made in teacher inservice training to help teachers understand the new curriculum requirements. A related issue is the need to ensure that changes occur in teacher preparation programs at the universities so that future teachers will graduate prepared to participate in reform.

Teachers are an integral part of the reform process. Yet, the teachers' associations complain that they were not considered during development of the reforms and that there was not an open debate about the implications of the reforms for teachers. In *El Mercurio* college president Jorge Pavez stated that there was not much participation by teachers in the reform of basic education but that teachers were consulted about the reforms of middle education. The extent of teacher participation may be debatable; it does appear that the reform development process did not fully study the impact of reform on the teacher in the classroom.

In the article mentioned above, Pavez also expressed his concern that the flexibility of the curriculum framework could work against the establishment of national identity. Yet the number and specificity of the minimum mandatory content are also considered a problem. As indicated before, the specific objectives were determined by groups consisting mainly of subject matter specialists. The tendency was to add required content to ensure the comprehensive coverage of each discipline. As a result, the minimum mandatory content is considered by many to be overloaded with too many requirements.

Finally, there is a need to provide more resources (libraries and computers) to schools. Schools with infrastructure and human resource scarcity problems are in a precarious position. They may need even more additional help from the government if they are to implement the new plans and programs.

Dr. Manuel Martinez is a professor in the Faculty of Chemistry and Biology at the University of Santiago de Chile. A former president of the Division of Chemical Education of the Chilean Chemical Society, he is currently vice-president of the Society. He has published five chemistry texts and authored numerous scholarly papers in the field of chemistry education.

Dr. Raúl Cerón is an associate professor in the Faculty of Chemistry and Biology at the University of Santiago de Chile with a background in curriculum development and science education. He is the author of two textbooks and numerous papers related to science education.

References

Allard N., R. 1997. "Los Programas de Fortalecimiento de la Formación Inicial y Continua de Profesores en el Marco de la Reforma Educacional Chilena." Paper presented at an international seminar on the preparation and continuing education of teachers, Santiago, Chile, March.

Arellano M., J.P. 1997. "Reforma en Marcha: Para que Tengan un Tiempo a su Medida." Speech delivered by the Minister of Education, March 10.

Cox, C. et al. 1997. *160 Años de Educación Publica: Historia del Ministerio de Educación.* Santiago, Chile: Ministry of Public Education.

Donoso, S., and G. Hawes, eds. 1994. *Veinticinco Años de la Prueba de Aptidud Académica.* Santiago, Chile: Ministry of Public Education.

Ministry of Public Education 1998. *Curriculum de la Educación Media: Objetivos Fundamentales y Contenidos Mínimos Obligatorios*. Santiago, Chile: Ministry of Public Education.

———. 1994. *Compendio de Información Estadística.* Santiago, Chile:Ministry of Public Education.

———. 1969. *La Superintendencia de Educación y la Reforma Educacional Chilena.* Santiago, Chile: Ministry of Public Education.

The Science Teachers Association of Nigeria: Forty-One Years of Service to Science Teaching

Samuel Bajah

This paper gives a brief overview of the development and organization of the Science Teachers Association of Nigeria (STAN) over the past 41 years. The Association's programs are described including its role in textbook development, its conferences and workshops for teachers, its journal, and its programs to promote excellence among high school students. Funding for STAN activities largely derives from its active publication program (more than 80 percent of the annual budget).

Introduction

The Science Teachers Association of Nigeria (STAN) is the nation's professional association for science teachers working at the three educational levels of: preprimary and primary, for ages 3–11 years; secondary, for ages 11–17; and tertiary, for ages 17–21+. STAN, now a household word among science teachers throughout Nigeria, was initially established in 1957. It is a nonpolitical, nonreligious, and nonprofit professional association with the following aims:

- To promote cooperation among science teachers in Nigeria with a view to raising the standard of science education in the country.
- To provide a forum for discussion by science teachers on matters of common interest.
- To help science teachers keep in touch with developments in science and its applications to industry and commerce.
- To popularize science.
- To do or perform such other functions incidental to or necessary for the realization of these objectives.

In 1996 the Association commissioned a study by Bajah and Bello, which culminated in the publication of a book documenting the many activities of STAN over the years. This paper is based on the overview of STAN found in the book. Over the past 41 years STAN has regularly conducted lectures, seminars, workshops, and conferences for teachers as well as developing a series of user-friendly textbooks. More details on these activities can be found in the book.

Well over 80 percent of the funds expended by STAN come from royalties and from books published by STAN. Member dues account for about 15 percent of the annual budget, while federal and state grants account for about 5 percent. Some special grants are received from oil firms operating in Nigeria, notably Mobil and Shell Petroleum. Also, there is sometimes income from sales of conference proceedings.

Organization

Membership

Right from its inception, membership in the Association has been open to all science teachers at the secondary level and to science educators in Nigerian universities. The Association began with 16 members, and today there are 2,435 active, paid members. There are seven categories of membership—student, associate, full, fellow, life, institutional, and honorary life.

- Student members are science-teachers-in-training at the colleges of education and polytechnics and at universities.
- Associate members include graduate science teachers in active teaching; science graduates who, in the opinion of the Executive Committee of the Association, are interested in the advancement of science education; and nongraduate science teachers actively involved in teaching of science.
- MSTAN designates a full member of the Science Teachers Association of Nigeria. The MSTAN is accorded to members from time to time, whenever the Executive Committee approves a list submitted by the Membership Committee.

  MSTAN is attained by members who satisfy the following conditions:
  - Associate members with at least five years of continuous membership in the Association
  - Those who apply and complete the appropriate forms and pay the prescribed application fees
  - Those who are favorably considered by the Membership Committee with such recommendations being approved by the Executive Committee on behalf of the Governing Council.
- Science teachers and educators who have distinguished themselves in science education may be recognized as worthy of the award of Fellow of STAN (FSTAN).
- The category of Life Member is open to members who have reached the age of 50 and who have applied to the Executive Committee after paying the prescribed fees.
- All educational and research institutions with an interest in science education may become institutional members of STAN. These currently include education publishers, industries, science equipment manufacturers, and suppliers.
- Finally, individuals (both with and without a major background in science) who have contributed significantly to the growth of STAN may be awarded an Honorary Life membership. To date, two distinguished Nigerians who have contributed significantly to science education, either by funding projects, conferences and workshops or by publishing science textual materials, have been so honored.

During the early years of the Association, the membership list was maintained on card files containing details of each member. However, with the growth of the Association and the need to maintain a modern, easily accessible file of members, a computerized membership system is now in operation. The Membership Secretariat annually receives membership information from each state and from the federal capital.

Administration of Science Teachers Association of Nigeria

STAN is administered by three separate but mutually supportive bodies—the Annual General Assembly, the Governing Council, and the National Executive Committee. The Annual General Assembly is the supreme body of the Association. Some of its functions are delegated to the Governing Council. The Assembly (of all members of STAN) accommodates the annual conference and holds meetings of the Executive Committee, the Governing Council, and the fellows of STAN. The Governing Council consists of representatives from a large number of national and international organizations—the All Nigeria Conference of Principals of Secondary Schools, the Early Learning Science Series for Africa, the Forum of African Science Educators, the Ministry of Education, the Joint Admissions and Matriculation Board, the International Council of Associations for Science Education, the National Business and Technical Education Board, the Nigerian Educational Research and Development Council, the National Educational Technology Centre, the News Agency of Nigeria, the National Agency for Science and Engineering Infrastructure, the National Board for Educational Measurement, the National Board for Technical Education, the National Commission for Colleges of Education, the National Commission for Nomadic Education, the National Manpower Board, the National Primary Education Commission, the National Teachers Institute, the National Universities Commission, and the West African Examinations Council.

Growth of the National Secretariat

The National Secretariat was initially established during the earliest days of the Association. The general secretary's office became the nerve-center of the Association's activities, with all correspondence emanating from and directed to the general secretary's contact address. The Association has been fortunate enough to get talented individuals to fill this important position, originally in a volunteer capacity. We were also fortunate in initially obtaining office space at the University of Ibadan. As the activities directed by the general secretary grew, it became necessary to establish a Permanent Secretariat with paid officers. By 1980 the growing STAN moved into its own accommodations on the Government College campus, Apata, Ibadan.

The building houses a conference room-library, the general secretary's office, a general office, the administrative secretary's office, the account's office, and a storeroom. The office equipment available includes computers, electric and manual typewriters, and duplicating machines. The Association has two vehicles—a station wagon and a pickup van.

STAN began to establish a library from the beginning. There was a time in the history of STAN when its library was located in the Institute of Education at the University of Ibadan. The books, journals, and materials belonging to the Association are still in the Institute's science laboratory, but a new STAN library is now located in the National Secretariat but the number of books therein is still very small. There needs to be a more aggressive search for materials for the new library, since STAN can contribute significantly to the popularization of science and research through its resources.

The recruitment of staff is usually based on existing regulations in government service and the needs of the Association. Any vacant position is advertised internally, in a daily newspaper, or both. A selection committee headed by the general secretary does the recruitment. An Executive Committee interview panel recruits the administrative secretary.

All Association staff members enjoy the same welfare packages as contained in the federal government regulations. Junior staff are trained in how to use new equipment or are allowed to undergo in-service training after office hours. The administrative secretary has benefited from the mutual cooperative assistance of both the Association for Science Education (in the United Kingdom) and the National Science Teachers Association (in the United States). The STAN
administrative secretary has attended the national conventions of both organizations and has shadowed their officers to learn more about the management of large teacher conferences. The administrative secretary has also been granted day-release to pursue post graduate studies.

At the recent STAN annual conference in August 1998 the Annual General Meeting ratified the decision of the STAN Governing Council to upgrade the position of administrative secretary to that of executive director. The first executive director, Mr. Ben Akpan, has just been appointed. The Governing Council of STAN has also made another major decision—to build an appropriate STAN Secretariat at the national capital, Abuja. The proposed new building, which will cost several million naira, will be named after the founding father of STAN, Mr. F.I. Ajumogobia.

Currently, the permanent Secretariat staff of STAN consists of the executive director, the assistant administrative officer, two accounts clerks, five secretaries, two drivers, and two gardeners-night guards. The staff strength fluctuates mainly in the secretarial pool, where there is a rapid turnover.

Activities of the Science Teachers Association of Nigeria

STAN has spearheaded major science curriculum development and reform in the country and has introduced science to at the grassroots level by publishing of low-cost books on science subjects. When funds permit, the Association also publishes *STAN Journal* twice a year. The journal is considered a "learned journal" so university lecturers publish their work in it. The articles are usually geared to the university audience—way above the immediate needs of elementary and secondary school teachers. Ten percent of the contributions to the journal come from outside Nigeria. At times Nigerians who are studying for higher degrees abroad contribute articles. The assessment fees charged to contributors do not pay for the cost of the journal, which is subsidized by STAN. The journal is distributed free to all STAN members from inside and outside the country and to corporate bodies registered with STAN. To meet the needs of high school teachers, STAN publishes a newsletter and a bulletin (each twice a year). Both contain "Teaching Notes" for classroom teachers.

Our teacher training efforts through workshops and conferences have been specially designed for our particular circumstances. Only recently, in response to national aspirations, an

environmental education panel was established. This panel promotes an awareness among Nigerian citizens of issues such as environmental pollution and protection and biodiversity. All STAN conferences focus on a theme. For example, at the just-concluded conference at Osogbo, the theme was "Communicating Science, Technology and Mathematics."
At the STAN annual conferences, (which usually last five days), contributed papers are presented at plenary and subject panel meetings; and science teachers are given an opportunity to exhibit teaching materials and posters.

In addition to the conferences, each subject panel organizes one workshop every year, during which problems of teaching science and mathematics in the schools are discussed. Panel workshops are rotated around the country, and usually last three days. Money to support these workshops is provided by the Executive Council of STAN. While annual conferences are open to all STAN members and staff from the ministries of education (both federal and state), the panel workshops are primarily attended by high school teachers and lecturers from faculties and education institutes at the various universities.

STAN branches in all 36 states and Abuja prepare high school students for an annual quiz competition and science fairs. The climax of these two major events occurs at the STAN annual conferences. State branches arrange to bring their competing students to the annual conference, and the central Executive Committee arranges accommodation and provide food for the students and their teacher chaperones. In addition, each STAN branch organizes several state workshops annually for their teachers as well as social gatherings where teachers can interact in a more relaxed environment. The branches also organize public lectures on scientific topics of general interest.

International Support

STAN has benefited from formal agreements to train STAN administrative secretaries at the main offices of the NSTA in Washington, D.C., and at the ASE in Hartfield, England. This training has provided the STAN administrative secretaries with greater insight into how to run a large science teachers association. To date, two STAN administrative secretaries have benefited from such overseas training. STAN is also a very active participant in the International Council of Associations for Science Education, for which it has run regional conferences and workshops for teachers.

STAN has developed and maintained strong regional links with the Ghana Association of Science Teachers (GAST) and across the African continent with other science teachers associations through the Forum of Associations for Science Education. These links have involved academic exchanges and participation in each other's programs. Most recently, STAN and GAST held a weeklong workshop on Project 2000+ (Scientific and Technological Literacy for All) under the auspices of the United Nations Educational, Scientific, and Cultural Organization (UNESCO). STAN sent a delegation of seven representatives to Winneba, Ghana, to attend the workshop. STAN would like to hold more workshops with GAST, but the usual problem is funding. Neither STAN nor GAST has adequate funds, but both can contribute the human resources that will benefit from such workshops.

The Curriculum and School Science Textbooks

Teachers who participate in curriculum reform in Nigeria usually do so on the platform of STAN. STAN is often asked to nominate those who will attend workshops where new educational policies in science education (elementary and secondary schools) are discussed. The majority of those who wield a strong influence at such workshops are STAN science educators from the universities. We would certainly like to include more high school teachers in curriculum reform, but we would first need to build up their confidence in participating in such activities.

There is no dearth of good science textbooks being written and published in Nigeria. Nigerian authors are being encouraged to write more science textbooks to reflect both the contents of the national curriculum and the Nigerian culture. All the authors write from one reference point, which is the approved core curriculum for all the secondary schools in the country. Any author whose book is adopted for use must have derived the contents from the national curriculum. The differences between one adopted text and another, for example in chemistry, are mainly found in differing formats and teaching strategies adopted. While some chemistry books incorporate both theory and practical work into one volume, others may adopt a completely theoretical approach in one volume, and provide an accompanying practical textbook. There is a preference for the former, as we believe here that chemistry must be taught with experiments integrated with theory.

Nigerian education policy stipulates six years of secondary schooling, during which period the three major sciences are presented concurrently to students. Thus a student may be taking physics, chemistry, and biology for three years prior to entering a tertiary institution (a university, polytechnic, or college of education). The science content mandated in the national curriculum for secondary school students is both preparatory and an interface with what is taught during the first year in the tertiary institutions. Physics, chemistry, and biology are taught to students as if they will all be science students at the university.

It is this emphasis on treating all secondary students as future scientists that has been challenged by some curriculum developers who claim that secondary school science students should be allowed to study alternative science programs, for instance, chemistry for nonchemistry majors. As of today, the national core curriculum from which the science content is derived does not make room for such alternatives. Since all the secondary school students take a national examination at the end of their course, there is not much room for deviation.

Textbook publishers who want their books approved and adopted for use in the secondary schools must go through a specified selection procedure. Secondary school textbooks are largely presented in two stages: at the school level and at the state or national level. At the school level, teachers are given the opportunity to select books in their area of specialization. Where more than one book is selected in one subject, such books are ranked. On the whole, the major criterion used for selection is content validity, with the core curriculum as reference. Other criteria used include sequence of topics, eye-catching appeal to the reader, and the credibility and popularity of both the authors and the publisher. The list of books selected at the school level is passed on to a special book selection committee at the state level, which in turn, use similar

criteria for selection. This entire process of assessment leading to the selection of textbooks at both the primary and secondary school levels is highly influenced by local politics.

The Association has attempted to have an impact on science education reform in Nigeria through the development of model textbooks. STAN publishes primary and secondary school textbooks in collaboration with some commercial publishers, across a wide range of subjects. The Association also publishes its own books. As indicated previously, the royalties from sales of books contribute significantly to the annual budget. The STAN books are written by the cream of science teachers drawn from different parts of the country. They focus on the relevant syllabuses and boast of an excellent presentation of the subject matter to suit both the teacher and the student.

STAN authors are brought together by the STAN Executive Committee and the subject panels. They are then introduced to an international commercial publisher. STAN-sponsored books are eagerly sought by all publishers who know that, with the stamp of approval of STAN, classroom teachers who are mainly members of STAN will recommend the STAN books, thus enhancing sales. The Association normally receives a 10 percent royalty for each book sold.

Writing workshops are jointly run by STAN and a publisher. Workshops usually last a whole week in a retreat setting; it normally takes 10 such sessions to develop a text. STAN authors are usually paid a one-time honorarium determined by STAN. They do not receive a royalty payment—all royalties go to STAN.

STAN has been highly supportive of integrated science programs at the lower secondary level and has produced a series of three volumes of integrated science student textbooks and workbooks, with associated teachers guides. We have also developed textbooks in biology, physics, and chemistry for upper secondary school students. All these curriculum materials are published by Heinemann Educational Books (Nigeria). STAN members have also developed a six-volume primary science program that is published by University Press; a three-volume mathematics series; and a science teachers handbook. Our agricultural science three-book series is published by Longman Nigeria.

Secondary school science textbooks, either written by a professional association like STAN or by single or multiple authors through a local publisher, are all subjected to the politics of the textbook selection process. Over the years studies have been conducted to show how the performance of secondary school students in science correlates with the approved textbook used by their school. More comprehensive studies are needed to determine the impact of specific textbooks on the learning of science in Nigeria.

The STAN Secretariat is kept busy all year round—news about the latest curriculum developments within Nigeria and abroad are sent to members. The Secretariat is the clearinghouse for information flow. Unfortunately, in recent years financial constraints have severely hindered the activities of the Association. This lull in activities is reflected in a decline in the effectiveness of our science, technology, and mathematics (STM) teachers and, consequently, in the quality of STM education in Nigeria. In order to arrest this decline, the

Association has been attempting to obtain additional funds from the government, the business sector, and privileged individuals.

In spite of this decline, co-opted professional bodies such as the West African Examinations Council (WAEC), the Joint Admissions and Matriculation Board, and the National Teachers Institute all involve STAN members in their own curriculum development activities. For example, STAN members constitute the largest single group of examiners of the WAEC. Over the 41 years of its existence, the Association and its individual members have compiled an impressive record of support for science education in Nigeria. Despite current financial difficulties, we fully anticipate that the next 41 years will be as productive.

Professor Sam T. Bajah is currently the Director of the Institute of Education at the University of Ibadan. Professor Bajah was Editor-in-Chief of the STAN Journal and later President of STAN for four years. Professor Bajah was educated at the University of Ibadan, Nigeria; Oxford University, United Kingdom; and at the University of South Dakota, United States. He is a Fellow of STAN.

School Laboratories in Developing Countries: Are They Worth the Effort and Expense?

Erik W. Thulstrup

The view held by almost all natural-science-based educators, that hands-on activities (laboratories, experiments) are essential for successful science education at any level, is not shared by all educational economists and other social scientists. Some claim that laboratory-based education is expensive and has few, if any, positive outcomes. This paper argues, illustrated by examples from developing countries, that hands-on science education does not have to be expensive. On the contrary, use of low-cost equipment, which is transparent to the user, may improve pedagogical outcomes. It is also shown that claims that the benefits from hands-on instruction are insignificant tend to be based on evidence that does not address some of the expected major outcomes of hands-on activities.

Introduction: Hands-on Science

Among all school subjects, science is particularly fascinating because it relates our experiences of the physical world around us with theoretical, scientific knowledge that frequently is formulated in comprehensive and elegant mathematical language. Thereby, it places individual pieces of knowledge about our environment in a knowledge framework that enables us to explain new phenomena and react efficiently to new situations in the physical (as well as chemical and biological) world that surrounds us. In addition, the outcomes of good science education have a large content of practical skills included that makes it possible for the students not only to "know" science, but also to "do" science. This paper argues, contrary to the beliefs of some, that practical (hands-on) activities in science education are worth both the effort and the expense. Specifically, it is argued that hands-on activities, including both laboratory work and other practical activities:

- Provide important components of the skills and cognitive learning objectives of science education.
- Have essential affective outcomes, for example, by reducing the fear of technology and by motivating students (female as well as male) to pursue careers in science-based fields.
- Can be both effective and inexpensive at the same time.

School science subjects, including environmental science, are dynamic subjects to a larger extent than most other school subjects. They change with society and, in particular, with the technologies used at any time and place. Therefore, it is not surprising that science and environmental education have experienced a fast rate of change during the past few decades, in both industrial and developing countries. Partly as a reaction against the Sputnik-inspired interest in science for its own sake, dating back to the 1960s, there is now a trend toward science "for all" or "for the citizen." This trend, which was visible

already in the 1970s, has continued, relying increasingly on everyday materials, problems, and experiences of a scientific nature to illustrate science in the classroom. Today, teachers and curriculum designers in most countries have realized that the majority of both primary and secondary school students are not often motivated by the inner beauty of science itself. They are motivated by the need to understand their physical surroundings, including numerous technological applications of science, as well as by the positive or negative consequences of science-based actions, especially on the environment. In many countries, this has already had a strong impact on both educational curricula and materials and, most of all, by the inclusion of everyday environmental issues in both primary and secondary school as well as in college science courses. This can be done with a minimum cost to the traditional science subjects, since many of these issues provide excellent illustrations of important scientific concepts.

Also, the strongly increased availability and affordability of personal computers is having an impact on science education in industrial countries. If the present trend in decreasing the costs of educational technology continues, PCs may also become useful tools in schools in developing countries. Distance education based on radio, television, and satellite transmission, and on other new technologies, offers opportunities for reaching audiences that would otherwise be difficult to reach, sometimes even at low cost. An important issue in connection with distance science education is the question of how to organize hands-on activities for remote students. While the older and more established distance teaching activities often have found ways to solve this problem (Kirschner and others 1991), new initiatives in the field may not fully realize the need for inclusion of hands-on activities in the teaching of the sciences themselves, as well as engineering and other science-based subjects. Also, they may be unaware of the practical difficulties involved in this task.

School science is widely accepted as an important ingredient for economic development in the poorest countries. Unfortunately, the way science subjects have been dealt with in school development projects in developing countries has sometimes been superficial. One important example is the treatment of hands-on activities for students. These activities have been traditionally included as a major ingredient of science education, at least at the secondary level (table 1). The need for special physical facilities for these activities, such as school laboratories and science equipment, makes science education different from most other school subjects and, in particular, makes unit costs less uniform. In developing countries, facilities for hands-on activities have often been very expensive compared with other costs such as teacher salaries. Iin several cases, this has led economists to question the cost/benefit value of hands-on science teaching. One example is found in the latest strategy paper on education from the World Bank (World Bank 1995), which argues that the outcomes of hands-on science teaching are not worth the required investments and that, therefore, laboratory teaching should be reduced or eliminated in primary and lower secondary schools.

The main arguments voiced by such persons outside the science community against hands-on teaching are that the research evidence of the benefits of laboratory teaching is quite limited, and laboratory teaching is very expensive. To make matters worse, a comprehensive

review of more than 100 World Bank projects that contained secondary school science components (el Hage et al. 1992) demonstrated some severe problems. The study seemed to indicate that provision of expensive laboratory buildings and imported, state-of-the-art science teaching equipment—was the highlight of most secondary school science education components in World Bank projects—have often failed, at least initially. Although the World Bank (1995) does not specifically refer to this review, it is hardly surprising that these and other similar observations have led some to doubt the value of the inclusion of hands-on activities in science education projects. However, these doubts have primarily been expressed by nonscientists, with little insight into the nature of science or science education. On the contrary, the vast majority of scientists and science educators do not question the value of student experiments; they support hands-on activities wholeheartedly (Haury and Rillero 1992; Black and Atkin 1996). This broad support among practitioners in the field of science education goes back to the 19th century (for a historic review of this support in the United Kingdom, see Gee and Clackson 1992). In the United States support for hands-on activities also goes back to the 19th century; in 1893 the National Education Association wrote:

> "The study of simple natural phenomena ... must be pursued by means of experiments carried out by the pupil. The study of books is well enough... but the study of things and phenomena by direct contact must not be neglected" (National Education Association 1993).

Today, support for hands-on science education among science teachers goes far beyond industrial countries; it seems to be global. In a study covering widely different countries in Eastern Europe, the Middle East, East Asia, and North America (Doran, Tamir, and Bathory 1992) teachers in all countries agreed that access to laboratory facilities was essential. Even the new, improved opportunities for simulations of experiments on a computer screen have not changed this support. It would appear to be arrogant to take such a unanimous conviction among practitioners in the field lightly.

This almost spontaneous support by scientists and science teachers is shared by many others. The U.S. Secretary of Education during the Reagan administration, William J. Bennett expressed it like this:

> "Seen only as a laundry list of theorems in a workbook, science can be a bore. But as a hands-on adventure guided by a knowledgeable teacher, it can sweep children up in the excitement of discovery. Taught by the regular classroom teacher, it can illustrate the point that science is for everyone—not just scientists" (Bennett 1986).

Haury and Rillero (1992) provides an excellent summary of the wide support for hands-on teaching, with useful references to research in the field.

The nature of the disagreement between some economists and the science education community may be better understood on the basis of a thorough analysis of the economists' arguments against hands-on science teaching. Although these arguments may seem convincing to some, they do not hold. For example:

- One obvious reason for claims that the benefits of hands-on teaching have not been clearly demonstrated in educational research projects is that surprisingly few serious attempts have been made to measure such benefits. Almost all larger tests of science ability among students have concentrated on the theoretical knowledge of the students—to what extent they know science facts and concepts, not to what extent they are able to use their scientific knowledge for practical purposes. Nor do most tests measure how the teaching has influenced student attitudes toward science. When theoretical knowledge is tested the test is often directed toward students' vocabulary, rather than their understanding of scientific concepts. Clearly, the understanding of scientific concepts should rank at the top among the cognitive outcomes of science education, which attempts to form a foundation for lifelong learning in the sciences.
- In contrast to the knowledge targeted in most tests, some of the main benefits of hands-on teaching are related to the ability of the students to "do" science, rather than to "know"(or even memorize) science. The reason that the ability to do science is rarely tested may be that this would require procedures drastically different from those used for testing in other school subjects—in fact even the weak emphasis on concepts in many tests may also be related to the fact that school subjects other than science concentrate on facts and have a low concept teaching content. So far, no large tests have been able to measure, in a reliable fashion, the ultimate outcomes of science education in schools. These outcomes include the ability and willingness of the students to use their science knowledge and skills in the workplace or in further studies, as well as in everyday life. Essentially, all science educators agree that these goals can only be reached through science teaching that includes hands-on activities.
- The negative experience in some World Bank-financed science education activities, especially failures in connection with the provision of equipment, seems to be related to a traditional reliance on expensive equipment, imported from industrial countries, and a lack of proper teacher training and support in relation to the new laboratories and equipment provided. Equipment imported from industrial countries has often turned out to be unsuitable for use in schools in developing countries (el Hage et al. 1992; Musar 1993).
- Even the last argument against hands-on activities in schools, the high relative costs, no longer holds. Since the early 1980s a movement toward new, inspired hands-on teaching strategies, which at the same time provide high-quality education and are affordable and sustainable, have increasingly been visible in both industrial and developing countries (Thulstrup and Waddington 1984; Dock 1984). These strategies are often based on everyday materials that are readily available at low cost in grocery or hardware stores worldwide.

The Importance of School Science

Numerous applications of research-based scientific knowledge have changed the lives of most inhabitants on Earth. Science-based technologies have been developed and have created new opportunities for increased production, efficient environmental practices, fast global communications, better health and longer lives, and improved access to information. Science has also transformed our social structures—the ability to apply science-based knowledge has become the key to wealth. For example, in many developing countries, new, educated middle classes have appeared as a result of science-based production. Today, the educational standards of the

workforce in a country, rather than its natural resources, have become the route to national economic success.

The new science-based opportunities have primarily benefited populations in industrial countries, while inhabitants of developing countries largely have been unable to take proper advantage of these opportunities. This is the reason that some countries are labeled developing countries: the inability of the workforce in a country to use science-based knowledge effectively will leave the country out of global competition. The recently recognized importance of science-based knowledge may help explain the striking differences in the pace of economic development among different countries. Cultures that value (scientific) knowledge tend to make fast economic progress, while cultures that have relied on traditional products, with much lower value added, are unable to take advantage of the new science-based opportunities. Therefore, one of the keys to economic success today is the provision of high-quality science education.

It is widely recognized that in order to be economically successful nations must be able to create and maintain a labor force that is competitive in the international market for science applications. In addition, it is also becoming increasingly important for countries to be able to contribute actively to the international development of science and science applications in order to gain access to the international knowledge pool. Today, science-based technology changes are so fast that only a highly qualified workforce with research training in the respective fields is able to evaluate and modify such technologies for local use.

The situation has become even more critical because of the new, Internet-driven dominance of informal networks within the scientific information exchange system. Today, production of scientific knowledge has become a necessary admission ticket to such networks, which represent the most useful markets for new information in specialized fields. In other words, in order for a country to be competitive, most citizens must be able to apply science and science-based technologies, and some must know how to create new scientific knowledge. The import of science talent and science-trained labor, on which some rich countries rely, is not feasible for developing countries. Therefore, school science programs, which provide a strong motivation for science- and technology-based careers, have become a necessary condition for the creation of an internationally competitive workforce. It is hard to imagine that such motivation may result from science education without hands-on activities.

Finally, it must be kept in mind that school science provides contributions beyond those directly related to economic development. Environmental insight is one important example. In order to create (even preserve) environmentally sound behaviors by the population of a country, large numbers of the population must understand fundamental scientific concepts related to the environment. If this is not achieved to a reasonable extent, the population as a whole is not likely to behave in an environmentally responsible fashion. In democracies politicians will be less inclined to introduce efficient environmental measures. As a result, a country may endanger its own—and maybe even the world's—long-term environmental future.

Other important political decisions in both developing countries and high-technology societies require scientific insight among the voters; strong school science programs may help

the students and adult citizens to make the best possible decisions for the community. The present standards and practices in science and environmental education in most developing countries (and in many industrial countries) do not address such demands. Nor do they provide sufficient incentives for careers in science and technology fields. In particular, science education in developing countries' schools is often weak and unable to present a convincing case to the students for further studies in science-based fields. This occurs in spite of the fact that the future of their country, to a considerable extent, depends on the students' willingness to study science, agriculture, health, engineering, and other science-based fields. Even for those who enter such studies, low-quality training in secondary school mathematics and science, together with insufficient communication between secondary and tertiary institutions, frequently lead to high dropout rates among students in science, engineering, and several science-based disciplines.

Scientific Competence and Hands-on Activities

Today, hands-on science activities at the secondary level are part of the curriculum in essentially all countries. Nevertheless, there are considerable differences among countries in the time they allot to these activities; differences may even be large among schools in the same country. Ware (1992) reported that, worldwide, around 20–30 percent of the time given to science education was used for hands-on activities in secondary schools, but in some countries this figure was reported as 50 percent or even higher. In the United States some schools reported that no time at all was allotted to laboratory science, while other U.S. schools spent 50 percent of the science education time in the labs (see table 1). International tests performed by the International Assessment of Educational Progress (IAEP 1992; see below) revealed similar trends. It is interesting to note that several economically successful East Asian countries report that a high share of the time is used for practical work.

Table 1 Percentage of Science Education Time Used for Hands-on Activities in Secondary Schools

Less than 20 percent	Approximately 20–30 percent	Approximately 50 percent
China	Bolivia	Australia
Lao P.D.R.	Hungary	Guyana
United States (some schools)	India	Malaysia
	Iran	Oman
	Jamaica	Thailand
	Japan	United Arab Emirates
	Malawi	United States (some schools)
	New Zealand	
	Nigeria	
	Sweden	
	Tanzania	
	Uruguay	

Source: Ware 1992.

Several international surveys of the science knowledge of teenagers have been carried out in recent years. The survey mentioned above was performed by IAEP on 13-year-old students in 20 different populations. It included science knowledge, and attempted to relate this to the teaching strategies used. It showed that the amount of time spent for hands-on activities was negatively related to the (theoretical knowledge) performance of students in more than half of the populations. It must be added that the study explicitly points out that the main outcomes of hands-on activities would not be detected in the tests, but such reservations are easily overlooked by readers with limited insight in the field. This study (with no inclusion in the test of the specific skills that may be acquired from hands-on learning) showed, for example, that students in Britain who were exposed to the highest relative amount of hands-on activities, performed below the international average. In contrast, some schools in the highest scoring countries (South Korea and Switzerland) reported that they never let the age group in question perform experiments.

However, other studies, applying a more comprehensive and balanced range of test questions, in addition to those directly related to theoretical knowledge, lend strong support to the belief that practical activities are beneficial for learning. One international study, reported by Young (1994), found that increased practical work components in science lessons led to improved science achievement by 14-year-old students in all 12 countries examined, including developing countries in East Asia and Eastern Europe.

During the winter of 1997/98 details and a series of analyses of a much larger international study performed during 1995 were being prepared for publication (NCES 1997). The study, usually referred to as TIMSS (the Third International Mathematics and Science Study) included about half a million students and their teachers from more than 40 countries, with a strong representation of Western and Eastern European countries, but, unfortunately, a much weaker representation of developing countries. In recognition of the difficulties in assessing the outcomes of hands-on teaching on purely theoretical tests, TIMSS students were also asked to perform hands-on activities, and some attempts were made to assess the often overlooked, affective outcomes of science teaching. Among the first results published, the simple rankings of countries, based on the scores of fourth and eighth graders in mathematics and science, caused considerable international interest. However, these rankings generally confirm the results of earlier tests (for example, Singapore scored in a class of its own, above all other countries, in both mathematics and science).

The true priority given to hands-on activities by decisionmakers may best be measured by the extent to which the activities are included in the final examinations. Ware (1992) discusses the role of practical work in external secondary school assessments; several countries include practical activities in these assessments and typically give them a weight of around 25 percent. In Denmark, which mistakenly was used as an example of a country that has "reduced or eliminated" hands-on activities in a recent World Bank report (World Bank 1995), such activities recently became an integral part of the final examinations for students graduating from lower secondary schools. At the same time, hands-on activities were introduced in Danish primary schools. The inclusion of hands-on activities in regular school assessments is very important. If

practicals are not included, students, teachers, and parents may give them low priority. In many countries this will drastically reduce the benefits to the students of the practical activities. According to Gardner (1990), "If "minds-on" is not included with the "hands-on," the latter will not lead to productive learning." A wider survey of the relationship between testing and learning in developing countries has been described by Capper (1996).

Obviously, students learn practical, technical skills in the laboratory, but most science educators agree that the benefits are seen beyond the laboratory. These benefits include the ability to work in teams as well as an enhancement of communication and analytical skills. Such abilities are rarely tested in traditional examinations, and they are not included in most larger tests. In addition, some cognitive skills are also believed to be developed through hands-on activities, for example, an understanding of the scientific method. However, claims that students learn problem solving through hands-on learning are difficult to prove (Ware 1992).

There have been some suggestions that hands-on science is especially helpful to girls and impacts upon their performance on later tests to a greater extent than boys. However, it is not clear to what extent hands-on science instruction is able to reduce gender and racial/ethnic differences in performance on standardized tests. Klein et al. (1997) reported on a study performed in an industrial country which found that practical science did not improve the performance of girls relative to boys on a standardized examination. However, a study from Papua New Guinea reported that girls performed significantly better than boys in practical science process tests in contrast to the common outcomes of traditional tests, where boys tend to outperform girls (Waldrip and Giddings 1993).

Other frequently quoted outcomes of hands-on science teaching are of an affective nature: improved attitudes toward science; an improved confidence with respect to the students' interactions with their own physical environment; and even a defeat of the students' fear of technology, which may be a serious problem, especially in developing countries and among girls.

Such outcomes of hands-on activities may be among the most important, in spite of the fact that they have only rarely been the subject of research. It has been shown that by making science experiments more "relevant" for students in grades 7 and 8, for example, by strengthening their social appeal, the motivation for science increased considerably more among girls than among boys (Sorensen 1985).

For teachers, increasing their self-confidence relative to science and reducing their fear of technology are important issues in developing countries. In a particularly successful teacher training strategy, which has been applied in several very poor countries, the student teachers combined their training with the production of complete hands-on science kits for use in their future schools (Schmidt 1984). The students started by constructing a wooden box for transporting the kits. All parts that went into the box during the course were produced from locally available, usually no-cost (or at least low-cost) materials (burned-out lightbulbs, old bottles, and the like). Thereby, it was made possible for the new teachers to resupply the kits. In addition, long before graduation from these courses, any fear of technology vanished completely among the future teachers.

A potentially important, but not widely known, observation is that hands-on science teaching has helped to reduce language problems in science classes. These problems may often be serious in school science, due to a large extent to the introduction of a new and extensive science vocabulary, which often is more extensive than foreign language courses at the same level. The problem may take on an additional dimension in developing countries, where the students speak local languages different from the language of instruction in the schools (Eisemon 1991).

Earlier World Bank Support for Hands-on Science

A survey of more than 100 World Bank projects between 1965 and 1990, which each provided funds for one or more secondary school science components, showed that World Bank lending for science education has covered a wide range of countries in all regions of the developing world (el Hage et al. 1992). The combined loan amount for secondary school science components during the period was more than $500 million. The projects contained a total of 184 components supporting school science—64 components were included in projects in Africa, 43 in Europe and the Middle East, 41 in Latin America, and 36 in Asia.

Among the different regions, total expenditures for science education projects were largest in Asia (about one-third of the total). This reflected the much larger average size of Asian secondary school science components. In general, the annual number of science education components increased over the years. In the last five years of the period covered by the study (1986–90) the number of secondary school science components in World Bank projects was an average of ten per year.

The expenditures for different budget items (el Hage et al. 1992; Ware 1992) show a heavy emphasis on hardware for hands-on activities, in contrast to the later World Bank recommendation (World Bank 1995). Civil works, primarily in connection with the construction of laboratory buildings, used 47 percent of the total budget, while 28 percent was spent on science equipment. The emphasis on hands-on activities in these investments is striking compared with the modest 20 percent of the total expenditures that were used for science teacher training (including both preservice as well as inservice training).

The emphasis on laboratories and equipment was particularly high in Africa, where only 10 percent of the projects included teacher training specifically related to the new hardware provided. In Asia such training was much more common (el Hage et al. 1992; Ware 1992). Over the years, the coordination between hardware provisions and teacher training has increased globally, from 5 percent among all projects in the 1960s to 26 percent in the second half of the 1980s.

Studies of World Bank documents on project performance, Project Completion Reports and the Project Performance Audit Reports do not provide detailed information on final project outcomes. However, some comments give insight into the problems that may severely influence the long-term performance of the projects. Based on these comments, school science components

seem to be consistently more successful in Asia than in Africa (el Hage et al. 1992). About half of the school science laboratories built in the African projects had already encountered problems at the construction stage. Later in the project life, African components often reported underutilization of the science equipment provided, a relatively rare complaint among projects in other regions.

The science equipment supplied under most World Bank projects was not only imported from industrial countries, it was also very expensive compared to local costs. This may be an important reason for the reports of underutilization of equipment. Teachers were afraid (sometimes not even allowed) to use it, especially when they had not been given any training in how to use it. The high costs and lack of related training are not the only problems encountered with such equipment. In a review of cost-effective equipment strategies, Musar (1993) lists the most commonly encountered problems with equipment imported from industrial countries as:

- High costs
- A lack of related teacher training
- Problems with procurement
- The technical unsuitability of the equipment
- The educational unsuitability of the equipment
- A lack of incentives to use the equipment
- Problems with local distribution of the equipment
- Difficulties in getting spare parts
- Inadequate supplies of needed consumables
- Inadequate service, maintenance, and repair facilities.

Low Cost, High-Quality Hands-on Teaching Strategies

Several of the numerous problems encountered with imported equipment are related to their high cost and "status." However, other stronger arguments than economic ones exist for the use of low-cost, locally produced (and much less scary) equipment in hands-on instruction. Low-cost strategies have obvious advantages far beyond those related to costs. In the proceedings from a recent international conference on low-cost science education (Towse 1997) it was emphasized that low-cost equipment and science education strategies based on locally available materials often have the following advantages:

- They are widely available and inexpensive.
- They are more familiar to the average student and teacher, which reduces the fear of breaking the equipment.
- The functions of the equipment are often transparent.
- They are more environmentally friendly.

In addition, local production may help provide important local income opportunities where they are most needed. Furthermore, several examples show that the design and production of teaching equipment is an area that may help promote important university-industry cooperation.

Another widely applicable cost-cutting method is to perform science experiments at a reduced scale (microscale). This limits the cost of consumables, the amount of waste, other harmful environmental effects, as well as risks to the students. Furthermore, positive student responses to microscale experiments have recently been reported (Bradley and Vermaak 1997). Numerous examples of the application of microscale experiments in developing countries exist (Towse 1997).

One cost-cutting strategy, which also increases the sustainability of the activities, is to rely only on materials that are available in local grocery and hardware stores and on equipment that can be made by the teacher and her students. There are several successful examples of such strategies in developing countries (Musar 1993). An excellent and very practical teachers guide to simple, low-cost, hands-on science education in elementary schools has been given by Haury and Rillero (1992). Although written for teachers in industrial countries, this paper includes not only practical advice, but also a comprehensive list of literature in the field, much of which will be useful anywhere in the world.

Low-cost electronic components are today available in all countries; they provide the basis for a wide range of opportunities for the local construction of low-cost laboratory teaching equipment (Thulstrup and Waddington 1984; Sane and West 1991; Musar 1993). Elsewhere in this publication Krishna V. Sane has provided a detailed account of the New Delhi-based Edutronics Group which, for more than 20 years, has produced teaching equipment based on low-cost electronic components available in developing countries. Another electronics-based opportunity is offered by personal computers, which, even in developing countries, lose most of their commercial value long before they are worn out. Personal computers more than ten years old may still be used effectively to enhance the outcomes of laboratory activities (Seth and Srivastava 1992; Towse 1997).

The use of standard sets of hand-on teaching materials for science (science kits) is widespread in the developing world. One of the best known kit-based science education projects in the developing world was established in Zimbabwe in the early 1980s, shortly after independence, in order to satisfy the needs for hands-on opportunities during a period when the educational system was expanding rapidly. Secondary enrollment grew from less than 10 percent to more than 50 percent during the early and mid-1980s. The "Zim-Sci" kits (Dock 1984; Musar 1993), which were based on experiences from an earlier distance education project, targeted primary and lower secondary schools. The kits were produced locally and were based on materials that were readily available almost anywhere. Typical costs were around $1,000 for a class of 40; resupply kits cost less than $1 per student. The Zim-Sci project was supported by the Ministry of Education in Zimbabwe as well as by foreign donors, including the European Union and the Swedish International Development Authority (SIDA).

Summary: Is Hands-on Science Beneficial and Affordable?

The World Bank strategy paper on education (World Bank 1995) stressed the importance of strong school science for economic development. Nevertheless, it only makes a single

recommendation in the field: that laboratory-based instruction should be reduced or completely eliminated in primary and lower secondary schools. As mentioned above, the main arguments for abolishing hands-on activities are the relative cost of laboratory facilities and the lack of proven benefits from hands-on activities. There is also the frequently unsatisfactory outcome of investments in school laboratory facilities in World Bank projects (el Hage et al. 1992). Additional claims in the strategy paper, for example that Denmark and other Organisation for Economic Co-operation and Development (OECD) countries are moving away from the hands-on teaching of science, are listed without references and do not hold. On the contrary, the international trend, specifically the development in science education policy in Denmark and other OECD countries (James 1997), has for some years been the opposite, increasing the emphasis on hands-on activities from primary schools on up.

The relatively few studies that have tried to assess the outcomes of hands-on science teaching have primarily concentrated on cognitive benefits, which most science educators agree do not represent the most significant benefits from hands-on activities. The apparent failures of equipment provisions in many World Bank projects are most likely related to insufficient teacher training in the use of the new equipment and the kinds of equipment provided as well as its high cost.

Hands-on science is not necessarily expensive. On the contrary, low-cost science teaching strategies exist and may have many advantages far beyond those related to the low costs. Good hands-on teaching may be based on small-scale experiments, inexpensive modern electronics, locally available materials and equipment, and local production and service of science teaching equipment. As an added advantage, the local production of teaching equipment may facilitate the development of local industries as well as university-industry cooperation in the developing world. It has been demonstrated in both developing and industrial countries that low-cost teaching strategies are feasible as well as effective (Thulstrup and Waddington 1983; Musar 1993; Towse 1997). Teachers will require preservice and inservice training, but implementing the new strategies will be affordable and sustainable (since repairs can be made locally with locally available parts). In addition, the use of low-cost, locally made equipment may reduce the fear of technology among both students and teachers.

None of the arguments against hands-on science survives a close inspection. While expensive and inefficient laboratory teaching is unacceptable anywhere, especially in developing countries, good hands-on science education may be affordable and deliver valuable and directly applicable knowledge and practical skills to the students. In addition, strong hands-on science education may have a positive influence on students' attitude toward science and technology and may encourage them to choose careers in science-based fields. This is true in both industrial and developing countries and may be of particular importance among girls in the developing world, who are often unaware of the opportunities offered by careers in expanding science- and technology-based fields.

Therefore, it is understandable that hands-on science activities in both primary and secondary schools are, almost intuitively, strongly supported by a majority of science educators, who agree that science instruction must include both content and process learning as well as

affective aspects. Also, many international organizations involved in science education emphasize hands-on teaching strategies. One example is provided by the United Nations Educational, Scientific, and Cultural Organization's (UNESCO's) "flagship" project in science education, Project 2000+. The World Bank, which is still responsible for large investments in school science in the developing world, is in a unique position to promote up-to-date, cost-effective, and sustainable teaching strategies that make hands-on science education accessible to all students, based on inexpensive, locally available materials, locally produced equipment, and environmentally sound procedures.

Dr. Erik Thulstrup has returned to academic life as Professor of Chemistry at Roskilde University. He was formerly a Senior Science and Technology Specialist at the World Bank and managed a work program on science and technology for development. He has been a visiting professor at several universities in Europe and North America and is the author of the leading monograph in his research field, polarization spectroscopy.

References

Bennett, W.J. 1986. *First Lessons: A Report on Elementary Education in America.* Washington, D.C.: U.S. Department of Education.

Black P., and J.M. Atkin eds. 1996. *Changing the Subject. Innovations in Science, Mathematics, and Technology Education.* Paris: Organisation for Economic Co-operation and Development.

Bradley, J.D, and I. Vermaak. 1997. "Microscale Chemistry from an African Perspective." In W. Beasley ed. *Proceedings of 14th International Conference on Chemical Education.* Canberra: Royal Australian Chemical Institute, Education Division.

Capper, J. 1996. *Testing to Learn—Learning to Test: Improving Educational Testing in Developing Countries.* Washington, D.C.: International Reading Association and the Academy for Educational Development.

CSTEEP (Center for the Study of Testing Evaluation and Educational Policy). 1997. *Third International Mathematics and Science Study.* Boston, Mass.: Boston College. (See also: http://wwwcsteep.bc.edu/TIMSS1)

Doran, R.L., P. Tamir, and Z. Bathory. 1992. Conditions for Teaching Laboratory Practical Skills. *Studies in Educational Evaluation* 18: 291.

Dock, A. 1984. *The Essentials of Zim-Sci Methodology.* Harare, Zimbabwe: Ministry of Education.

Eisemon, T.O. 1991. *Language Issues in Scientific Training and Research in Developing Countries.* World Bank, PHREE Background Paper 92/47.Washington, D.C.

Gardner, M. 1990. *Laboratory Assessment Builds Success.* Berkeley, Calif.: University of California, Lawrence Hall of Science.

Gee, B., and S.G. Clackson. 1992. "The Origin of Practical Work in the English School Science Curriculum." *School Science Review* 73 (265): 79.

el Hage, D., R. Rinaldi, S. Ware, and E.W. Thulstrup. 1992. *World Bank Lending for Secondary School Science.* World Bank, PHREE Background Paper 92/58R.Washington, DC:

Haury, D.L., and P. Rillero. 1992. *Hands-on Approaches to Science Teaching: Questions and Answers from the Field and Research.* Washington, D.C.: Office of Educational Research and Improvement.

IAEP (International Assessment of Educational PROGRESS). 1992. *Learning Science.* Princeton, N.J.: Educational Testing Service.

James, E. 1997. Private communication, November. OECD, Paris.

Kirschner. P. and others 1991. *Learning Objectives for Practicals in Institutes of Higher Distance Learning.* Heerlen, the Netherlands: Open University.

Klein, S.P., J. Jovanovic, B.M. Stecher, D. McCaffrey, R.J. Shalelson, E. Haertel, G. Solano-Flores, and K. Comfort. 1997. "Gender and Racial/Ethnic Differences on Performance Assessments in Science." *Educational Evaluation and Policy Analysis* 19: 83.

Musar, A. 1993. *Equipment for Science Education. Constraints and Opportunities,* ESP Discussion Paper 11.Washington, D.C.: World Bank.

National Education Association. 1993. *Report of the Committee of Ten on Secondary School Studies, (NSB91-1).* Washington, D.C.: U.S. Government Printing Office.

NCES (National Center for Educational Statistics). 1997. *Third International Mathematics and Science Study.* See http://nces.ed.gov/TIMSS/report/97255-01.html

Sane, Krishna V. and D.C. West. 1991. *Locally Produced Low Cost Equipment for Teaching of Chemistry.* Delhi: University of Delhi, Publication Division.

Schmidt, H. 1984. "Producing One's Own Teaching Aids." In E.W.Thulstrup and D. Waddington, eds., *Locally Produced Laboratory Equipment for Chemical Education.* Paris: United Nations Educational, Scientific, and Cultural Organization.

Seth, C.K., and P.K. Srivastava. 1992. *PC in Chemistry Education, an Introduction.* Delhi: Centre for Science Education and Communication.

Sorensen, H. 1985. "Differences in Girls' and Boys' Attitudes Toward Science—A Study Among Thirteen-Year-Old Pupils." In E.W. Thulstrup, ed., *Proceedings of the Nordic Conference on Science and Technology Education: The Challenge of the Future*. Copenhagen: Royal Danish School of Educational Studies/UNESCO.

Thulstrup, E.W., and D.Waddington, eds. 1984. *Locally Produced Laboratory Equipment for Chemical Education*. Paris: UNESCO.

Thulstrup, E.W. 1998. "Science Education for Development: Is Quality Affordable?" In L. Buchert, ed., *Education Reform in the South.* Paris: UNESCO.

Towse, P. ed. 1997. *Cost Effective Chemistry. Ideas for Hands-on Activities.* Madison, Wisc.: University of Wisconsin, Institute of Chemical Education.

Ware, S.A. 1992. *Secondary School Science in Developing Countries*. World Bank, Background Paper 92/53. Washington, D.C.

Waldrip, B.G., and G.J.Giddings. 1993. "Educational Productivity and Science Education within a Developing Country." Paper presented at the annual meeting of the National Association for Research on Science Teaching, Atlanta, Georgia.

World Bank. 1995. *Priorities and Strategies for Education.* Education and Social Policy Department. Washington, D.C.

Young, D.J. 1994. "The Effect of the Science Learning Environment on Science Achievement and Equity." Paper presented at the Meeting of the International Congress for School Effectiveness and Improvement, January 3–6, Melbourne, Australia.

Science and Technology Education in Developing Countries: Low-Cost, Locally Made Instrumentation

Krishna V. Sane

This paper presents some thoughts (based on the 20-year experiences of the author) on developing locally produced low-cost equipment for improving science education in the developing world. This includes initial identification of the major factors required to initiate the reform process in science and technology education. This is followed by a discussion of a pilot project, which was supported by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the International Council of Scientific Unions, and the International Union of Pure and Applied Chemistry (IUPAC). The successes and failures of the pilot project are examined, in particular, the inability of the pilot project to become self-sustaining. Finally, steps are identified to overcome the failures and to consolidate the gains of the pilot project.

Introduction

Since the importance of science and technology (S&T) for improving the quality of life in the developing world is well recognized, a high priority status should have been accorded to improving the quality of S&T education in developing countries. Unfortunately, generally this has not happened. Most developing countries continue to cling to an education system that is a relic of the colonial era and is ill-suited to the needs of the present, fast-changing world. The single-biggest weakness of this system is that it is essentially driven by the need to pass memory-testing examinations rather than the need to acquire skills.

Of course, it can be argued that S&T education is also far from perfect in industrial nations. However, this shortcoming is less serious because the industrial world enjoys the historic advantage of establishing an interactive process in which S&T developments and economic progress have catalyzed each other. S&T education in industrial countries has fueled this process as well as benefited from it—particularly through the many centers of educational excellence like Massachusetts Institute of Technology, the California Institute of Technology, Oxford, Cambridge, the Sorbonne, Munich, and the like. The loss of this historic advantage, however, can be offsetting to some extent if a strategy is evolved that, through hindsight, avoids the pitfalls of the Western model. It is also essential for the strategy to focus on the key question: how to shift progressively from the present "examination-driven" system to a "skill-development-driven" system.

Any skill development-driven S&T education system has to be based on a hands-on approach. Unfortunately, the hands-on component of science and technology education in India and other developing countries is deteriorating because of:

- The continual rise in the cost of equipment, chemicals, glassware, software
- The lack off suitable inservice teacher training programs
- A "black-box" attitude toward equipment, resulting in poor maintenance.

The diminishing quality of laboratory work is preventing the learning of manipulative skills and producing scientists ill-prepared for research, teaching, and industry. What is the solution? Rapid advances in electronics, computer science, and material science are offering exciting opportunities to develop cost-effective tools for teaching and self-learning. Equally rapid advances in multimedia and communication technologies now offer several options to revamp teacher-training and student-training methodologies.

However, a problem can seldom be solved by technology alone. If education systems in the developing world are to shift progressively from the present examination-driven system to a skill-development-driven system, strong two-way linkages have to be developed between innovation and dissemination and teacher development and curriculum changes. Good coordination also needs to be established between the development of cost-effective teaching tools and their mass production and academic institutions, government agencies, and the industrial sector.

Case Study

In 1979, to test the feasibility of changing the system to a skills-driven approach, a pilot project was initiated by the Edutronics Group in the Department of Chemistry, University of Delhi. The project was sponsored by the Committee on the Teaching of Chemistry (CTC) of the International Union of Pure and Applied Chemistry (IUPAC) in association with UNESCO and the erstwhile Committee on Teaching of Science of the International Council of Scientific Unions. Valuable assistance was also received from the Commonwealth Foundation; the Committee on Science and Technology for Developing Countries; the International Development Research Council, Canada; and a number of other regional and international agencies.

The Indian component of the pilot project was carried out under the auspices of the Department of Science and Technology (DST), New Delhi, and the University Grants Commission, New Delhi, who provided extensive support for developmental work as well as for field work within India. The pilot project had five objectives:

- To develop reliable, locally produced low-cost (LPLC) equipment that would be easy to fabricate and maintain
- To find experiments compatible with the equipment that illustrated the principles and practice of modern chemistry
- To transfer the know-how to teachers through hands-on workshops, manuals, videotapes, and multimedia modules

- To set up a production unit to supply the kits and assembled equipment without a significant escalation of cost
- To encourage curriculum changes using the equipment and activities that would better prepare students for a career in chemistry.

It should be noted that the pilot project focused on teaching chemistry because IUPAC was the principal sponsor. However, the approach of the project can be applied to all areas of S&T education.

Development of Reliable Locally Produced Low-Cost Equipment

Development of the LPLC equipment progressed in several well-defined stages. The first phase was an exploratory one, where a number of circuits for measuring pH and conductance were tried and analyzed. This work was carried out via college-level student projects supervised by teachers. One important achievement was to establish the utility of a carbon rod, extracted from a discharged dry cell, as a zero-cost electrode material for pH and conductance measurement. In April 1981 an international workshop was held in Madras, India, to review the work completed during this phase. The proceedings of the workshop were published by UNESCO/IUPAC (1981).

The second phase included the design of a colorimeter, perhaps the single most useful instrument for teaching chemistry. This phase also saw the development of several accessories (for example, an OVA source, a magnetic stirrer, timer, thermostat, and centrifuge) to complement the equipment. The OVA source, which is a combination of a resistance box and a variable voltage or current source, was greatly useful for calibrating and troubleshooting the LPLC equipment. In December 1985 a second international workshop was held in Bombay to review the work done during this phase. Again, the proceedings of the workshop were published by UNESCO/IUPAC (1985).

All the equipment developed during the first two phases was of the analogue variety because, during the early 1980s, a moving coil meter was significantly cheaper in India than a digital panel meter. When this situation started changing in the late 1980s, development of digital instruments was initiated. A "meterless" version of the equipment was also developed based on the use of a comparator circuit. This enabled the design of a very cheap display system to replace the more expensive, moving coil panel meter or digital panel meter. Such meterless instruments seem ideally suited for senior secondary level work, since the cost is extremely low and the maintenance is almost nonexistent.

A multi-purpose kit was designed because a large number of chemistry teachers felt that they would like to acquire more familiarity with the principles of basic electronics. The kit uses plug-in-type solder-less connectors that enable quick assembling and dismantling of circuits. Several experiments illustrating key characteristics of electronic components like resistors, capacitors, diodes, transistors, and opamps have been developed, along with experiments involving basic opamp circuits of utility in chemical and biological applications.

Computerized instruments have become ubiquitous in research and industrial laboratories. To initiate students in modern methods of data acquisition, a microprocessor-based data logger (DL) was developed. A DL version based on the 8085 microprocessor has been successfully tested with sensors, such as a glass electrode, as well as for off-loading and on-loading data to and from a personal computer. A low-cost interface based on the work done at the Inter American University of Puerto Rico permits a direct coupling of any instrument to a personal computer. Thus the user has three options:

- To couple a sensor with the DL
- To couple the DL with a PC
- To couple a sensor with a PC.

The options provide enormous flexibility in devising teaching and learning strategies and for carrying out specialized experiments (for example, the kinetics of moderately fast reactions, field-based pollution monitoring, and the like).

Another computer-based activity was the development of simulation software to permit a user to carry out dry runs of experiments that are either expensive, dangerous, or time-consuming. Packages for colorimetry, potentiometry, and conductometry were developed in Basic, Pascal, and C languages.

Under the Indian program the research and development work sponsored by the Department of Science and Technology, resulted in production models of four prototype instruments (a pH meter, a colorimeter, a conductometer, and a thermometer) in three versions (meterless, analogue, and digital). The three versions meet the requirements of cost and accuracy at the school, undergraduate, and postgraduate levels, respectively. A low-cost computer interface, which can either be built-in or attached from outside, is an optional item for all three versions. (Sane and West 1994.)

Over the past 35 years there has been a tremendous escalation in the cost of chemicals (for many common chemicals, as much as a 50 to 100 percent increase). Together with the rising prices of commercial equipment, this is having an adverse effect on laboratory curriculum. For equipment, initial high costs are compounded by a lack of maintenance; for chemicals the problem is recurring costs.

A three-pronged attack: introduction of a microscale (or small-scale) approach, inclusion of a recycling step as an integral part of student experiments, and, substitution of expensive chemicals, provides an alternative that is cost-effective and pedagogically advantageous. To facilitate the introduction of the microscale approach, a microchemistry kit (costing about US$12 for use by one to five students over one semester) was designed by adapting the work of groups from elsewhere in the world.

Finding Experiments Compatible with the Equipment

The design of cost-effective equipment can become a means of improve the teaching of chemistry, if suitable experiments and activities are developed that illustrate the principles and practice of modern chemistry. Thanks to the enthusiasm of a large number of teachers and students, more than 100 experiments—a blend of pure and applied chemistry—have been standardized to date. This collection contains examples from agricultural, biochemical, clinical, environmental, and industrial applications of chemistry and from thermodynamics, kinetics, and titrimetric analysis. It was published by UNESCO/CTC as part of a series of low-cost resource books in chemistry for teachers and students (Khanna, Sane, and Seth 1996). Similar compilations are also available (for example, Serafimov 1992; Blume and Bader 1996).

Supporting the Teachers

Simultaneously with the developmental work, a systematic attempt was made to propagate the project philosophy around the world. In 1983 the first Senior Visiting Practitioner Award, given by the Commonwealth Foundation, enabled the dissemination of the project methodology through a 47-day lecture-demonstration tour of five Commonwealth countries. Since an educational innovation remains an abstraction unless it is accepted and practiced by teachers and students, the Edutronics Group has placed great emphasis on hands-on workshops to evaluate and disseminate the project. The modus operandi has consisted of inviting selected teachers from a particular region for a weeklong workshop at which participants fabricate and test the equipment designed at Delhi University. Out of the nearly 90 workshops held so far, three (Madras 1981, Bombay 1985, and Delhi 1993) have been international. Selected specialists and teachers from all over the world have reviewed and tested the prototype models. From 1981 to 1997 some 37 UNESCO-sponsored workshops were held outside India to generate core groups in various countries and regions that are now adapting the Delhi designs to suit local needs. UNESCO and IUPAC/CTC have now setup an international network to coordinate the activities of the core groups operating in different countries.

The network organizes training courses in the fabrication, use, and maintenance of low-cost equipment, and provides kits, equipment, and spare parts to institutions needing such equipment. The head office of the LPLC equipment network was located at the Department of Chemistry, University of Delhi, from 1991 to 1995. Beginning in 1996 the head office shifted to the Department of Chemistry, Inter American University in San Juan, Puerto Rico.

In 1991 a massive countrywide teacher training program was launched in India by the University Grants Commission, New Delhi, under the title "Regenerating the Teaching of Chemistry." This program was conducted by the Centre for Professional Development in Higher Education (CPDHE), University of Delhi.

The popularity of the hands-on program necessitated the preparation of instructional materials for use by the participants during and after the workshops. This resulted in the development and subsequent publication of *Low-Cost Chemical Instrumentation,* a monograph by Sane and West (1994). The monograph give a step-by-step description of the fabrication, use, and maintenance of the analogue pH meter, colorimeter, and conductometer. The Indian version of the monograph is published by the CPDHE and is used as a textbook by its all-India teacher training program.

If a picture is worth a thousand words, a movie is equivalent to more than a thousand pictures. The availability of extremely compact,user-friendly camcorders has opened up the possibility of amateur video shooting to develop "video clips" to supplement the monograph. Topics such as soldering and the calibration of instruments can be better understood by reinforcing the printed word with visual images.

The emergence of multimedia technology undoubtedly offers an exciting opportunity to revamp teaching-learning strategies. Exploratory attempts have been initiated to integrate the print material with graphics, animation, video, and audio materials. In addition, work has started on developing CD-ROM multimedia diskettes based on the publications from the project.

Production and Costs

The typical cost of assembling any instrument or accessory developed by this project is in around US$ 20–30, if an ordinary casing (about US$3) and an ordinary moving coil meter (about US$6) is used. If instead of building a power supply (about US$3) into every instrument, a central power supply is built into the laboratory, the effective cost for classwork can be brought down further.

The items in the test package (continuity tester, transistor tester, I.C. tester, OVA meter, OVA source) typically cost around US$ 6-12, while most of the sensors cost virtually nothing. The interface for coupling any of the instruments to a PC costs about US$8. The only relatively expensive item is the data logger (about US$150), but it can be used as an instrumentation package as well as a computer with modest capabilities.

The combination of inexpensive, reliable instruments with a hands-on teacher training program should initiate the process of making progressive changes in laboratory curricula. (These curricula have remained basically stagnant for three decades in India and many other developing countries.) Unfortunately, the matter is not straightforward because changes in laboratory curricula in the developing world cannot be sustained unless teaching-oriented instruments, accessories, test packages, and the like are manufactured on a large scale without a significant escalation in cost. This is a "chicken and egg" dilemma because curriculum changes require that affordable items are available. However, a commercial unit will not find it attractive to manufacture such items unless laboratory curricula are already based on their usage. Further, the costs of manufacturing drop only when large orders are placed for equipment. Thus without "economies of scale"

change comes only to a few progressive institutions with the necessary financial resources.

One promising solution to this dilemma was provided by the decision of the Indira Gandhi National Open University, New Delhi (IGNOU), to use the low-cost equipment designed at Delhi University in distance education courses in chemistry. Given both budgetary and time constraints it was necessary to find an inexpensive, timely way to deliver the equipment. It was decided to hire untrained, but needy, individuals and pay them minimum wage to develop the equipment. This exercise proved that a group consisting of the handicapped and school dropouts could be trained to deliver the IGNOU package on time. The coupling of social objectives (providing training and a livelihood to individuals in need) and educational objectives (manufacturing high-quality, affordable items for education) added a new dimension to the work.

The encouraging success of the IGNOU initiative led to the next step. Delhi University and DST signed a technology-transfer agreement with a company for the manufacture and supply of the low-cost equipment. By taking over the trained workforce, the company, headed by a disabled person, was able to keep the selling price of the equipment at about 10 percent above the cost price. The company was able to support 10 trainees from the disadvantaged sector for five years on a turnover of US$65,000.

It is hoped that this model, which joins technological innovation with social service and commercial viability, becomes a self-sustaining and self-evolving force for changing the educational pattern in countries with limited resources. In this context, the experience of the publication unit of the UNESCO/IUPAC project seems even more promising. It was organized to overcome an absurd situation—that documentation describing low-cost equipment cannot afford to be disseminated through high-cost publishing. The publication unit began by training destitute women for self-employment in desktop publishing. The hands-on training is provided through the use of educational material. Thanks to the generous donations of the necessary hardware and software by national and international agencies, overhead costs are now manageable, thereby allowing for the publication of useful educational materials at spectacularly low prices. (For example, a 250-page LPLC equipment monograph with 117 illustrations was produced in two colors for US$8, much less than the cost of airmailing it to Europe.)

The encouragement received from various agencies shows the popularity and the potential of this approach. For example, the Federation of Asian Chemical Societies, the South African Chemical Institute, and the Royal Society of Chemistry have all purchased multiple copies of the low-cost publications produced by the initial UNESCO/CTC project. The Indian edition of the monograph on low-cost equipment, used as a textbook for the teacher training program, has become a bestseller because of its low price.

Bringing About Curriculum Change

As mentioned above, the hands-on component of the curriculum in many developing countries needs radical change, because current syllabi are either inadequate or obsolete. The two key requirements for any curricular upgrading, namely the availability of affordable resource materials and trained teachers, have been the focus of the work described above. Within the past several years progress made in these directions could now catalyze changes in student laboratories. It is hoped that there will be some specific progress in this direction in the near future.

A Review of the Case Study: Successes and Failures

Although there are similar projects, this one is a special example of a systematic effort supported by several international, regional, national, and local agencies to simultaneously tackle a number of interlinked matters. The project has placed great emphasis on good coordination between its four facets:

- The development of cost-effective resource materials
- The training of teachers in the use of the resource materials
- The manufacture and marketing of the resource materials
- The promotion of curriculum change.

The importance of this coordination cannot be overemphasized, since progress in any single facet is meaningless without some progress in the other three.

Another significant feature of the project was its emphasis on the use of locally available materials, components, and devices through local initiatives and funding. Although this does not minimize the role of the foreign agencies, the foreign support was used purely as a catalyst to provoke internal action. Numerous studies (e.g., Musar, 1993) show that projects purely driven by foreign funds and foreign expertise seldom yield anything in the long run.

Yet another significant feature of this project is the emphasis on a multipronged approach to developing resource materials. Thus the resource packages developed under the project have used both hi-tech devices (such as a microprocessor) with zero-cost recycled items (such as carbon rods from discharged dry cells and glass from burnt fluorescent tubes). No contradiction is involved in using sophisticated and unsophisticated items side by side, since the underlying theme is how to improvise using low-cost, reliable, and locally available products.

Conclusion

To summarize, some of the more important achievements of the Indian project are:

- The development of several instrumentation packages with each package consisting of a piece of equipment (for example, a pH meter), accessories (for example, electrodes), peripherals (for example, a magnetic stirrer), and test equipment (for calibration and maintenance).
- The collection of more than 100 experiments from pure and applied chemistry and their standardization for each package. The experiments include traditional ones linked to present syllabi; they also include areas like soil chemistry, clinical chemistry, environmental chemistry, and pollution monitoring (Khanna, Sane and Seth 1996).
- The presentation of some 37 international teacher development workshops leading to the formation of national groups in Australia, Brazil, France, Germany, the Philippines, Puerto Rico, South Africa, and Thailand. The national groups are adapting the work done under the UNESCO/CTC project to the needs of their own country or region. In 1991 these groups also formed a LPLC equipment network to coordinate their work. In 1996, the network, headquartered in Puerto Rico, launched a vigorous and ambitious program to train teachers and technicians from 11 countries in southern Africa. This program will be extended to the entire African continent, if appropriate support becomes available.
- The presentation of more than 50 teacher training workshops all over India, where nearly 1,000 teacher participants have fabricated approximately 4,000 pieces of LPLC equipment. About 40 feedback reports have established the adequacy of the instruments for student laboratories.
- The signing of a technology-transfer agreement by the Indian Department of Science and Technology with a company (headed by a disabled person) in Delhi to undertake the manufacture and marketing of the packages in both kit and assembled forms. The kit will be priced at Rs.1,600 (about US$45) and the assembled forms at Rs.2,000 (about US$55). The company has absorbed the workforce trained under the project as employees. The workforce currently consists of handicapped personnel and school dropouts. This projects has successfully coupled educational objectives with social objectives—a gratifying feature.
- The development of a program for training low-income women in computer skills like word processing and desktop publishing. This has produced several low-cost educational publications, besides providing employment to the trainees. (Project SITA—Studies in Information Technology Applications: Training in Computer Skills for Low-income Women in India—based on this approach, is seeking funds from the World Bank.)

These achievements are very encouraging. However, some glaring failures of the project are a cause of great concern:

- The approach has remained confined to chemistry, although it can embrace any other area of S&T education. Extension of the project philosophy to the entire S&T spectrum is essential because reforms in S&T education are sustainable only if all S&T subjects follow a common approach.

- Even though 400 colleges in India have been equipped with LPLC items and 1,000 teachers have been trained, the laboratory curriculum has not incorporated any of the new developments. This means that LPLC equipment has not yet changed the way in which students are learning chemistry in India.
- As stated previously, the company manufacturing and marketing the equipment has had a turnover of US$65,000 in five years, providing employment for 10 disabled workers and school dropouts. The company has also exported US$15,000 worth of equipment. However, almost all the orders received by the company have come through the requirements of the teacher training program in India and abroad. The company has had little success in selling the equipment on their own, thus defeating their goal of self-reliance.
- The manufactured items are certainly affordable by any typical educational institution in the any typical developing country. However, they leave a lot to be desired in term of packaging and quality control. Unless these deficiencies are overcome, this equipment is unlikely to be able to compete in the marketplace.

It appears that this pilot project, despite its achievements, is doomed to die because it is neither self-evolving nor self-reliant. This conclusion is particularly sad when one realizes that:

- S&T education in the developing world urgently needs to switch to a hands-on approach based on cost-effective and locally available tools
- There is a worldwide need to train socially disadvantaged sectors in modern technologies for self-employment and regular employment
- It is essential to use the latest communication technologies to start preservice and inservice training programs for teachers and self-learning programs for students.

Directions for the Future: A Proposed New Model

It has been pointed out that educational reform in developing countries requires close coordination between academics, government agencies, and the industrial sector. The successes of the case study can be attributed to cooperation between the first two groups; the failures can be attributed to an inability to include industry in this cooperation. In most developing countries there are no linkages between the academic world and industry because it is more "profitable" for both sides to look toward the industrial world rather than to each other. A very practical way to overcome this reticence on both sides would be to initiate collaborative efforts in education. This ought to be welcome on both sides because, in any skill-development exercise, industry participation is a must for creating the infrastructure the content, and methodology of training and for monitoring and evaluating progress.

However, in spite of the advantages of such partnerships, it may be necessary to use "external" provocation to get the process off the ground. The UNESCO/IUPAC sponsorship of LPLC equipment was primarily responsible for bringing together academic and government agencies in India. Given that industry involvement in S&T

education is very important, how can it be achieved? One cooperative model is presented below, but there are a number of alternative mechanisms.

One way to consolidate the gains of the UNESCO/IUPAC project and overcome some of its failures is to establish a resource center to interface with academic institutions, government agencies, and the industrial sector. Such a resource center would facilitate the cooperative effort needed to improve S&T education in developing countries. Seed funds would be needed to start the initiative, but the center would be planned as a self-supporting unit over the long run. The feasibility of such a unit is currently being explored. The SITA project will test the sustainability of the women's publishing unit, but more initial funding is needed to prove the financial viability of the entire concept.

The primary objective of the resource center would be to initiate programs that would, directly or indirectly, help improve the quality of science and technology education in India and other developing countries. This would be done through the same kinds of activities that were a part of the UNESCO/IUPAC project (development of materials, the training of teachers, the use of employment-oriented empowerment programs), but would involve different kinds of collaboration among research and development institutions, educational institutions, government agencies, business and industry, international agencies, and voluntary organizations.

Dr. Krishna Sane was Reader of Chemistry at the University of Delhi and UNESCO–Nehru Professor of Science Capacity at the Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore. He is the Director of Project SITA and a recipient of the Albert Einstein Medal from UNESCO and the Brasted Award from the American Chemical Society.

References

Blume, R. and H.J. Bader. 1996. *Environmental Chemistry in Classroom Experiments.* Delhi, India: S.M.V. Traders and Printers.

Khanna, V.M., Krishna V. Sane, and C.K. Seth. 1996. *Modern Experiments for Introductory Chemistry*. Delhi, India: S.M.V. Traders and Printers.

Musar, A. 1993. *Equipment for Science Education. Constraints and Opportunities*. World Bank, ESP Discussion Paper 11. Washington, D.C.

Sane, K.V. and D.C. West. 1994. *Locally Produced Low Cost Equipment (LPLCE) for Teaching of Chemistry*. Delhi, India: S.M.V. Traders and Printers.

Serafimov, O. 1992. *Teaching of Environmental Chemistry*. Proceedings of the Uberlingen workshop, Germany. Delhi, India: S.M.V. Traders and Printers.

UNESCO (United Nations Educational, Scientific and Cultural Organization). 1981. *Low Budget Teaching of Chemistry, Volume 1*. Paris: UNESCO.

———. 1985. *Low Budget Teaching of Chemistry, Volume 2*. Paris: UNESCO.

Science Education at the RADMASTE Centre: The Role of University in Development

John D. Bradley

This report describes the work of the Centre for Research and Development in Mathematics, Science, and Technology Education (RADMASTE Centre) at the University of Witwatersrand. The Centre is actively involved in the coupling of educational research with educational development in South Africa. In particular, the RADMASTE Centre works with colleges of education nationwide to improve the education of future teachers and their continuing professional development. The Centre is also involved in curriculum development for grades 4-12, producing materials relevant to the South African sociocultural context. The costs of practical work in science education are being addressed through the development, manufacture, and use of inexpensive, microscale kits.

Introduction

The Centre is located at the University of Witwatersrand, Johannesburg, South Africa. Since its establishment 76 years ago the University, has had strong faculties of science, engineering, and medicine. In 1986, the University added a School of Science Education to the Faculty of Science that offers postgraduate studies in this field. Since its establishment, the school has made a significant contribution to the long-term development of science, mathematics, and technology education in South Africa, with several of its graduates now occupying national leadership positions.

The contributions of the school have been valuable but, in the context of national development, not sufficient. This context demands the active dissemination and application of some of the university's resources of knowledge and skills to community issues and the coupling of educational research with development. In 1990, the RADMASTE Centre was established to address these two broad goals, initially in South Africa but, increasingly, in other parts of Africa. The idea was presented to the university by the present directors of the Centre as a logical extension of the activities of the School of Science Education, which had proved successful in attracting a steady stream of master's and doctoral candidates to the university. From the university's perspective, the centre fit convincingly within its existing broad commitment to community outreach.

The RADMASTE Approach

Science, mathematics, and technology are closely-related fields of knowledge that together underpin the economic development and competitiveness of a country. Thus, it makes sense to address all three areas when planning an educational initiative for development. Since education

is a continuum, it also makes sense to include primary, secondary, and tertiary education in any such initiative. Without a balanced and coherent program, an initiative targeted at one level and in one field can be handicapped by weaknesses or contradictions at another level, or in another field. Thus, the RADMASTE Centre has projects at the primary and secondary school levels, as well as at the colleges of education. For example, the Relevant Maths project and the More Relevant Science Curriculum project, both span the primary and secondary levels. The Microscience project, the Environmental Education project, the Maestro Audio-Visual Physical Science project, and the Eskom Mathematics and Science Colleges of Education project involve both the secondary schools and the colleges of education.

In 1990, the RADMASTE Centre personnel comprised only the three directors (Professors John Bradley, Paul Laridon, and Margaret Rutherford), who still remain at the Centre. Each director still holds a tenure-track university post in the Faculty of Science, contributing to departmental teaching in chemistry, mathematics, and physics respectively. The remaining staff of the Centre (about 45 individuals) are normally employed on a one-year contractual basis, funded by external grants. The majority of the academic staff are graduates with one or more post-graduate qualifications in science or science education.

Until very recently, the funding for most RADMASTE projects had been obtained from donors and from government or private sector contractors in South Africa. Some donors have supported basic resource development work, but many have sought to fulfil social responsibility objectives through the educational enhancement of employee communities. These two types of activity make a fruitful combination. Newly developed resources often find application in teacher enrichment programs in local communities, while the application provides real feedback to guide ongoing resource development projects.

In addition, research projects are funded, usually by the national, statutory bodies: the Foundation for Research Development (FRD) and the Human Sciences Research Council (HSRC). These research projects are always linked, formally or informally, with the developmental projects described above. Thus, research, development, and application are in a continuing dynamic relationship, but draw financial support from different sectors. Relatively recently, the centre attracted funds from outside South Africa, for example from United Nations Educational, Scientific, and Cultural Organization. The Centre is now designated as a UNESCO-associated Centre for Mathematics and Science Education.

RADMASTE Projects

From the outset, given the Centre's limited financial resources, programs have focused on school teachers, college lecturers, and school inspectors. The university location makes it easier to communicate effectively with adults than with children. A considerable number of nongovernmental organizations in the science, mathematics, and technology education were active at the individual classroom level, sometimes on a nationwide basis (for example the Science Education Project, the Primary Science Programme) (Levy 1992). Thus, the Centre's

role as a university group is in teacher enrichment, lecturer development, and inspector guidance, coupled with innovation of teaching and learning resources that is informed by research and international trends. This policy has ensured that the Centre contributes according to its strengths.

During the relatively short history of RADMASTE, significant political change has occurred in South Africa. The new regime, naturally, has wanted to make significant changes in education. Unfortunately, it has been attempted to change everything in a very short time, and the consequent turbulence could implode the fragile educational infrastructure. The general policy of RADMASTE has been to be neither too close nor too remote from the government of the day, attempting to focus on real needs as identified by interactions with educators themselves. The following selected examples of major RADMASTE projects in science, technology, and environmental education elaborate on the Centre's role as a university group in national development.

Colleges of Education

In South Africa, the majority of teachers at both the primary and secondary levels qualify by completing a three-year diploma at a college of education. Many of these colleges (about 70, but decreasing) are quite small and located in rural areas. Under the previous regime, these colleges were segregated, serving primarily black students, and were administered by different departments of education. The culture at most of these colleges was authoritarian and traditional, and they lacked basic resources. Sometimes they were housed in converted schools and were operated more like secondary schools than tertiary institutions. The colleges often seemed to offer training rather than education, for example, drilling science student teachers on using the prescribed school textbooks rather than helping them to reach a deeper and wider understanding of science and science education. Many of the staff were demoralized and frustrated by this situation, but some were really not equipped to deliver the kind of education to which a student teacher should be exposed (Selepe 1997; Bradley and Mosimege 1998).

In 1991, the Centre's directors ventured into this appalling situation as a result of a chance invitation to participate in drafting new science syllabuses for these "black" colleges. In general, the directors' approaches and suggestions were similar to trends in many developed countries but were contrary to the previous practice—and to the Department of Education and Training is expectations. Nevertheless, in cooperation with a committee of brave college lecturers, the Centre's reforms were accepted. However, the department had no plans to explain the revolutionary changes to the college lecturers, who would simply receive a copy of the new syllabuses when they returned from vacation to start the new academic year. Thus, the directors committed themselves to working with the college science lecturers on an ongoing basis to exploit opportunities provided by the new syllabuses to prepare better science teachers for the future. Right or wrong, the directors' status as university staff was influential in achieving this intervention.

What was the Centre trying to accomplish? It sought to design a curriculum that would enable the student teachers to understand each science concept they would have to teach in school. Furthermore, the students would learn about the many pitfalls that young learners encounter when introduced to new science concepts, pitfalls that result in predictable common misconceptions. The student teachers would develop confidence in using learner-centered methodologies and practical work. Finally, they would reconceptualize their scientific worldview through science-technology-society studies, which should be undertaken in their first year.

In some ways, the Centre been busy with this agenda ever since. The strategy has included biannual workshop courses for college lecturers lasting four to five days, and usually located at the RADMASTE Centre. The courses include a variety of activities and inputs from many different sources. Regular features include a plant or site visit, practical work, and the development of new teaching resources, primarily by RADMASTE staff. The educational changes initiated by the new government include the introduction of outcomes-based education (OBE) (National Department of Education 1996). Outcomes-based education takes different forms in different countries, but a common feature is that outcomes are government designed but inputs are designed by teachers, which gives greater responsibility to teachers and places explicit, rather than implicit, demands on their knowledge and skills. Because colleges of education seem to have been informed about this new philosophy at a very late stage, instruction in outcomes-based education has been included in the Centre's agenda and workshops.

As a result of this sustained involvement with college science lecturers from the majority of colleges throughout South Africa, the Centre has developed good relations with the lecturers and their colleges, and a sound understanding of their situation. For better or for worse, the Centre has influenced the knowledge, skills, and attitudes of college science lecturers and, by implication, on their students.

Several further lines of development have emerged as a result of this program, sustained over a seven-year period:

- Firstly, science lecturers at clusters of colleges have been communicating and cooperating with each other more extensively than before. This mutual support and encouragement adds strength to the Centre's efforts.
- Second, colleges are giving renewed attention to schools in their region from the viewpoint of both recruiting students and improving teaching practice. The fact that RADMASTE itself is directly involved in both primary and secondary science education means that the Centre is also able to help colleges improve their school-related interests in science.
- Thirdly, the desperate state of practical science work in the colleges soon came to light as one of the major weaknesses of science teacher preparation. This and other school-based experiences led RADMASTE to initiate a major program of development and research into low-cost equipment for science education.

- Fourth, the need to develop scientifically sound environmental education programs has led to an environmental education project at the colleges of education.

School Curriculum Development

When the RADMASTE Centre was inaugurated at the end of 1990, the South African school science syllabuses were similar to those of the United Kingdom in the 1950s. They were supported by approved science textbooks that were relatively inexpensive but lacked visual appeal and credible strategies for meaningful learning. Few science teachers had horizons much beyond those offered by these textbooks, reflecting the training that the majority of the teachers had experienced in the colleges of education. Teacher knowledge and understanding of science was often inadequate to the tasks they had been allocated as teachers (Bradley et al 1990).

Against this background, the RADMASTE Centre has devoted a great deal of effort to the development of a more relevant science curriculum for schools. This has been the task of the More Relevant Science Curriculum project, which has attempted to develop a curriculum covering the same science concepts as the existing traditional syllabus, but to present the material in a more everyday context familiar to the students through learner-centered methodologies. Such features are characteristic of new courses developed in the past 10 to 15 years by leading science educators in a number of countries, for example, Salter's Science in the United Kingdom (Campbell et al. 1994) and ChemCom in the United States (American Chemical Society 1998). While such courses developed outside South Africa are useful models, they are not written for the South African cultural context, nor do they cover all the topics required by the syllabus.

The Centre addressed science content from grades 4 to 12 through a framework of five themes: air, earth, water, life, and change. Teaching and learning resources were prepared by project staff and tested at teacher workshops over a period of four years. These workshops provided valuable feedback to the authors, while teachers gained useful resources from which they could select material as appropriate. A formal classroom trial and evaluation would have been very valuable, but this was not possible within the budget. However, in parallel with this project, but independent of it, two doctoral studies were completed in which similar teaching resources were evaluated in classroom trials (White 1998; van den Hoek 1997). These studies contributed valuable insights to the project team during the development of their resources.

The impact with these materials has been limited by:

- The other substantial changes with which teachers have had to cope during the last five years.
- The Centre's lack of capacity to conduct more extensive workshops and to disseminate the resources more widely.

Nevertheless, the Centre's work has likely contributed to the outcomes-based education natural sciences curriculum framework, which was published in 1996. This framework has four themes: matter and materials, planet Earth and beyond, life and living things, and, energy and

change. The Centre's resources are readily adapted to this framework. However, the other requirements of the outcomes-based education philosophy—statements of learning outcomes and provision for continuous assessment—are onerous. In order to adapt resources to meet these requirements, the Centre has sought financial support through association with a commercial publisher of textbooks and other educational materials. This may not solve the problem, as government funds for textbook purchases are very limited and many traditional suppliers to the schools have been losing a great deal of money.

Overall, through the More Relevant Science Curriculum project the Centre has had some success in disseminating new ideas and a sound understanding of science concepts with local contextualization. New opportunities are emerging to disseminate much of the resources generated by the project in a modified form.

Practical Work in Science Education

For some time it has been apparent that practical work in science education is widely endorsed but little used. Despite the statements in official curricular documents, many South African schools do no practical science (Lynch et al 1994). Universities in South Africa accept into science a significant percentage of students with no personal experience of the subject gained through hands-on activity. Some school teachers consider practical work to be drawing, and describing experiments on the blackboard. As already noted, colleges of education often provide only limited practical science experiences for student teachers, thus perpetuating the unsatisfactory school classroom situation.

Of course, there are many reasons for this situation, but one basic consideration is cost. Equipment, consumables, and laboratory facilities add up to a cost barrier that seems insuperable to many educational institutions. In addition, there are numerous other reasons as to why no practical work is done, even when the school has some resources to support laboratory activities. For example:

- Practical work means extra work for the science teacher.
- Technical assistance is unavailable to the teacher.
- Safety is a concern.
- An overcrowded syllabus doesn't allow sufficient time for include practical work;
- Class periods are too short.
- Students break everything and make a mess.
- Broken equipment cannot be replaced.
- There is no practical examination.

Of course, deep down there is also the teacher's lack of confidence. There is some truth in all these claims but, unless the cost barrier is overcome, it is pointless to dwell on them. While the majority of teachers do no practical work through lack of resources, the minority with

resources have the basic excuse that they do not need to do practical work. When the majority have resources, it is a natural expectation that the majority will do practical work.

Drawing upon the earlier innovations of others, the Centre's directors designed a microscale chemistry kit for individual student use (Cros 1988). It is easy and safe to use and promotes pride and responsibility of ownership on the part of students. There are various permutations of the kit concept, but the Basic Microchem Kit permits a range of simple chemistry experiments at low cost. (This kit costs about US$6.) The items in the kit are almost all plastic; they are durable and should last for many years with reasonable care. The quantities of chemicals used are about 1 percent of traditional scale, bringing down the cost of consumables to a few cents per student per experiment. Beyond all this, it is not essential to use the kit in a science laboratory, so there are very substantial further savings of capital investment.

The management of the activity is made as convenient as possible for the teacher. Microchemical kits with preprepared solutions, books of worksheets, and teacher notes all contribute to this convenience. The use of individual student kits is highly motivating for the students. The classroom environment is supportive of both teacher and students, allowing the teacher to engage the students in meaningful learning. Many remarkable lessons have emerged by using the kits. Furthermore, formal research confirms that both attitudes and knowledge can improve significantly to an extent depending on the teacher's competence (Bradley and Vermaak 1996; Kolobe, 1998). However, it remains true that many teachers need guidance on how best to exploit the learning opportunities now presented.

The concept of affordable, individual student kits with a very convenient set of resources at the disposal of the teacher has been very well received both in South Africa and elsewhere (Bradley et al. 1998). Secondary schools, colleges of education, universities (including technikons in South Africa) have all found merit in the system. In response to requests from physics and biology educators, the Centre is starting to develop kits to address their needs—food testing, enzyme experiments, and direct current circuit experiments can now be done cost-effectively on a microscale. Appeals from primary science educators have also been heard and partially addressed through development of a "kiddies' kit" that is already being piloted in a number of schools with encouraging feedback so far. Finally, in response to requests for more advanced chemistry kits, the Centre has developed a microtitration kit—yet much remains to be done. The kits have been very well received, a finding confirmed through research studies—both a doctoral and a master's degree thesis have been completed (Vermaak 1998; Kolobe 1998). These confirm the enormous potential for enhanced student learning through hands-on practical work, which can be successfully exploited given competent teachers. Of course, the competence of the teacher is a basic limitation in all aspects of education.

Technology Education

In the new South African school curriculum, technology is identified as one of the essential "Learning Areas" with the same status as the "Natural Sciences Learning Area." The Natural

Sciences Learning Area is the familiar cognitive domain that covers traditional school subjects such as biology, physical science, and earth science. Technology, however, is a new, uncharted domain. Although guidelines have been published, there are no substantial classroom resources available for teachers or college lecturers. There is also no significant basis of experience in teaching technology within the country on which these educators can build.

At RADMASTE, some modest contributions to developments in technology education have been made. The Centre's science and mathematics strengths have been used to develop six substantial modules for grades 7 to 9. They have been used in workshops and classroom trials and, given the favorable outcomes, are now in the process of being published by a commercial publisher. In addition, the urgent need to provide both pre-service and in-service teacher preparation in order to teach technology is receiving our attention in association with the Israel Institute of Technology-Technikon, Haifa, and our own Faculty of Education.

Environmental Education

In the new South African school curriculum, environmental education is seen as a crosscurriculum responsibility. It is also a required component of teacher education provided by the colleges of education. The Centre's strength in the natural sciences and the colleges of education has been the basis of our involvement in developing resources to teach environmental education. The Centre is working with college lecturers to develop the college curricula, and is also developing cost-effective teaching and learning resources for use in schools and colleges.

A range of water quality testing kits is prominent among these resources. These kits consist of a simple student field kit and a more advanced student kit for classroom use, both of which are supported by materials for the teacher. The kits are microscale and come supplied with preprepared chemicals and appropriate printed instructions. Many of the resources were developed under a government contract (from the Department of Water Affairs and Forestry) related to a national water awareness campaign, in association with a consortium of nongovernmental organizations.

Some Collaborative Efforts

The growth of RADMASTE has been due to the successes and growth of its projects led by enthusiastic educators. However, opportunities for individual projects to join forces, especially on particular regional efforts, have always been eagerly sought. An early example of an ongoing collaborative effort is the Toyota Teach Primary Schools program. This effort focuses on improving primary school education in an area close to the company's manufacturing plant in Durban. RADMASTE has contributed mathematics and science expertise both in the classroom and through the local colleges of education.

With growing maturity and size, RADMASTE is taking a greater interest in larger projects that use its resources across educational levels and the fields of science, mathematics,

and technology. The most ambitious project is taking place in the Eastern Cape province, one of the poorest of the nine provinces in South Africa. A special presidential project sought science, mathematics, and technology educational inputs at grades 1, 4, 7, and 10, as well as at the college level. The project is being conducted in association with the University of Transkei, which is located in Umtata, the provincial capital.

Retrospect and Prospect

The Centre's directors started the RADMASTE Centre with the belief that they had something valuable to contribute to their country's development. By one crude measure—growth in size—the directors have been justified in their efforts. The directors have drawn heavily on their own substantial experiences, and concentrated their efforts into working with school teachers and teacher educators. A variety of people have been attracted to the work: old, young, of different genders and races, and with different formal and informal qualifications. Together they have thrived in a work environment where they are given the space to follow their own inclinations. They have been able to draw upon the substantial resources of a major university, to keep in touch with national and international trends, and to engage in research that is strongly focused on development. This success has earned RADMASTE a sound reputation for good quality, enduring commitment, and realistic innovation.

The role played by RADMASTE in South Africa should be seriously considered by universities in other developing countries. It is a role that can uniquely be played by universities where appropriate staff are found. The Centre's directors intend to continue playing this role within South Africa and extending it to other parts of Africa.

For many years, Dr. John Bradley has been on the staff of the Chemistry Department at the University of Witwatersrand, where he was instrumental in establishing the School of Science Education. He is currently serving as the Chair of the Committee on theTeaching of Chemistry of the International Union of Pure and Applied Chemistry.

References

American Chemical Society. 1998. *ChemCom: Chemistry in the Community*, 3rd Ed. Dubuque, Iowa: Kendall/Hunt Publishing Company

Bradley, J.D., S. Durbach, B. Bell, J. Mungarulire, and H. Kimel. 1998. "Hands-On Practical Chemistry for All—Why and How?" *Journal of Chemical Education* (75).

Bradley, J.D., G.C.Gerrans, and G.C. Long. 1990. "Views of Some Secondary School Science Teachers and Student Teachers about Chemical Equilibrium." *South African Journal of Education* 10 (1): 3-12.

Bradley, J.D. and M.D. Mosimege. 1998. "Misconceptions in Acids and Bases: A Comparative Study of Student Teachers with Different Chemistry Backgrounds." *South African Journal of Chemistry* 51 (3).

Bradley, J.D., and I.Vermaak. 1996. "Microscale Chemistry from an African Perspective." In W.F. Beasley, ed. *Proceedings of the 14th International Conference on Chemical Education.* Brisbane: Royal Australian Chemical Institute.

Campbell, B., J.Lazonby, R. Millar, P. Nicholson, J. Ramsden, and D.J. Waddington. 1994. "Science: The Salters Approach—A Case Study of the Process of Large Scale Curriculum Development." *Science Education* 78 (5): 415-477.

Cros, D. 1988. *Expériences de Chimie Utilisant du Matériel Miniature*. Montpellier: Université de Montpellier II, Centre Internationale Francophone pour l'Education en Chimie.

Kolobe, L. 1998. "The Introduction of Small-Scale Chemistry in Some Disadvantaged Schools in Gauteng. M.Sc. diss., University of Witwatersrand, Johannesburg.

Levy, S. 1992. "Projects Speak for Themselves." S. Levy: Johannesburg.

Lynch, P.P., J. Smit, and B. Tema. 1994. *Cluster Studies of the Laboratory Situation in South African Schools*. Pretoria: Foundation for Research Development.

National Department of Education. 1996. *Curriculum Framework for General and Further Education and Training*. Pretoria: National Department of Education.

Selepe, M.C. 1997. "Conceptual Difficulties about Some Chemical Thermodynamic Concepts among Student Teachers and Lecturers at Colleges of Education." M.Sc. research report. University of Witwatersrand, Johannesburg.

van den Hoek, A.K. 1997. "Instructional Materials in Science Curriculum Change in South Africa." Ph.D. thesis. University of Witwatersrand, Johannesburg.

Vermaak, I. 1998. "Evaluation of Cost-Effective Microscale Equipment for a Hands-On Approach to Chemistry Practical Work in Secondary Schools." Ph.D. thesis. University of Witwatersrand, Johannesburg.

White, M.D. 1998. "Designing, Implementing, and Evaluating a Science-Technology-Society (STS) Teaching Resource Package on Air Pollution." Unpublished Ph.D. studies. University of Witwatersrand, Johannesburg.

Meeting the Needs of Science Teachers and Students: The Philippines Experiment

Warren Beasley

This is a discussion of an on-going teacher continuing education program in the Philippines involving the participation of the University of Queensland. The science teacher component is directed to teachers in grades 5 and 6 in the elementary schools and the first two years in secondary school. Some 500 Filipino principals and teachers were trained as inservice facilitators at the University of Queensland in order to run workshops for teachers in their own region. The local workshops will operate from a series of teacher support units attached to lead schools in five different regions of the Philippines. The support units will contain a variety of teaching resources, including media equipment, videos, and reference texts. The intent is to prepare teachers who can reflect on their own teaching practices and become better teachers as a result.

Introduction

The Philippines-Australia Project in Basic Education (PROBE) is a partnership between the governments of the Philippines and Australia to support the education of Filipino elementary and secondary school students in English, mathematics, and science. PROBE is involved with 588 elementary schools (involving about 12,000 teachers and 420,000 students) and 300 secondary schools (10,400 teachers and 300,000 students).

Within the science inservice education initiative PROBE focuses on grades 5 and 6 in the elementary school and years 1 and 2 in the high school. This account of the teacher inservice education component draws upon the experiences of teachers, principals, consultants, and inservice education providers associated with junior school science for its data.

The history of educational assistance to the Philippines through successive Australian aid projects has been characterized by the provision of in-country resources such as laboratory equipment and reference textbooks. In Australia it has also included the training of subject specialists to enhance their subject matter knowledge. The Philippines-Australia Science and Mathematics Education Project (PASMEP) is one example of a project that preceded the current PROBE initiative. This previous project concentrated on upgrading the content backgrounds of chemistry, physics, and mathematics teachers, as well as providing student reference books and laboratory equipment. Much of this material remains unused, locked away in laboratory cupboards.

The distinctiveness of PROBE, compared with earlier projects, is the emphasis placed on providing professional development in Australia for Filipino teachers and principals to enable them to become inservice facilitators (ISFs) for their local regions in the Philippines. Most of the $AUD 45 million to be invested over the period 1996–2001 will be spent on supporting the professional development of these facilitators and their regional teachers. The program is not

about buildings and equipment per se, but about the enhancement of human capital. The PROBE designers believe that high-quality training is delivered close to the teachers' work situation; is seen by them as meeting their needs; and is characterized by follow-up support and effective monitoring. ISFs will operate both reactively to teachers' requests and proactively through regular visits to the schools to discuss the concerns and needs of the teachers and to provide on-site advice and assistance.

Project Design

The project requires the cooperation of the national, regional, and divisional organizational levels of the Philippines Department of Education, Culture and Sport (DECS). The Philippines is divided into 13 administrative regions, each of which oversees the delivery of educational services through a number of divisions that work very closely with the schools. The divisional superintendents are the people most visible to the schools. Thus this discussion will mainly focus on the divisional level, where the schools and the ISFs are directly involved. The overall design of the project can be conceptualized as interlinking cycles of the classical action research model. At each of the three levels, the design can be described in terms of a challenge or need or research question to be met through the continuous cycle of action research:

→ Planning → Acting → Observing → Reflecting →

At the national level the action research cycle can be exemplified as follows. In the "planning" phase of the project a team of Australian consultants first undertook a training-needs analysis of Filipino lower secondary science teachers in five regions of the country. This analysis was used to plan the program for the ISFs in Australia between October 1997 and July 1998. In the "acting" phase teams of inservice providers at the University of Queensland ran four two-month training sessions for 500 Filipino principals and teachers. The "observing" phase will be undertaken by Australian long-term advisers in the Philippines over the next three years, using data provided by Filipinos trained in monitoring and evaluation techniques. The subsequent process of "reflecting" will be undertaken by Australian advisers, local subject supervisors, and divisional superintendents to ensure that, in the future, appropriate modifications will be made to the inservice design.

At the divisional level each school with trained ISFs (called a "lead school") will work with their own teachers and those of six satellite schools to meet the needs of local students. Lead schools were selected according to a number of criteria, including experience of staff and principal, physical facilities to house a teacher support unit (see below), and geography. There are 150 lead schools, each with six satellite schools, located across five administrative regions. These schools will serve 20,000 teachers and will have an impact on about one million students.

It is anticipated that the "action research model" of professional development will also be the framework from which the ISFs will design their inservice initiatives with local teachers. The emphasis is on the development of reflective practitioners through ongoing inservice opportunities. Teachers are required to "reflect" upon their classroom actions using the cycle of responsibilities introduced above.

The training needs analysis conducted by the University of Queensland staff examined both contextual factors (see below) and identified teacher needs. The data collected resulted from studies that were conducted at DECS (Manila), and at lead schools in regions II, VII, IX, X, and XIII of the Philippines. This involved:

- An analysis of DECS policy documents
- Observations of schools and classroom lessons
- Interviews with principals and teachers in district lead schools
- Meetings with Bureau of Secondary Education staff at DECS.

The research undertaken for the project addressed the following three questions:

What were the training needs of the district lead school principals and the teachers of science that should be addressed in the inservice facilitators' training course at the University of Queensland?

What major conceptual ideas and teaching strategies should be enhanced during the ISF course for secondary science teachers?

What action learning plans and resources should ISFs develop to facilitate the effective operation of the local teacher support units? (These resource centers to deliver teacher inservicing locally are described in detail below.)

Contextual Factors

Filipino students experience 10 years of schooling—6 years in elementary school and 4 in secondary school. However, access to education at the high school level is not universal across the Philippines. Of those students who enroll in grade 1 in elementary school, about two-thirds complete grade 6. About one-third of the students who enroll in grade 1 go on to secondary school; and about three-quarters of this cohort complete four years of secondary instruction.

The national government regards science in the secondary schools as a priority subject for all students in years 1 through 4. Along with mathematics and English, students study science for 80 minutes per day, Monday through Friday. In total, secondary school students study eight subjects per day for four years. Students attend school for about 180 days per year. The designed curriculum requires about 240 hours of classroom time per year.

Although school science is highly regarded, this does not result in high enrollments in tertiary teacher education institutions. In 1992 only 8 percent of Filipino physics teachers studied physics as their major or minor during preservice training; 21 percent studied chemistry, 41 percent studied biology, and 40 percent studied general science. As is the case in many countries, high school graduates in science would rather study engineering, medicine, or other courses leading to more financially rewarding opportunities.

National Priorities

The DECS Master Plan for Basic Education (1996) states:

"Inservice teacher training is hampered by a weak institutionalised pedagogical support system. While past interventions have initiated the establishment of teacher in-service training on a continuing basis, these suffered from inherent deficiencies in educational supervision, such as the presence of many unqualified supervisors in science and mathematics, and the control-oriented type of supervision as distinguished from a facilitative or supportive type."

As well as recognizing the need for different types of inservice programs to enhance the professional skills of science teachers, the national government, through its long-term development vision for the Philippines up to the year 2025, has identified a number of broader issues for the basic education sector to address. Three of these national priorities are directly related to science education and are stated as follows:

Gearing tertiary education for high tech industries and services, and building an adequate pool of science and technology manpower in light of the shift of competition from military-ideological to trade-technical.

Implication: The basic education sector must contribute by providing a strong foundation in the sciences and languages, as well as by developing critical thinking skills in students.

The need to take advantage of the explosion of information access and exchange.

Implication: Learning can be enhanced by accessing knowledge available outside the confines of the classroom.

Developing and promoting environmental ethics.

Implication: Education will have to promote a reorientation of values and lifestyles toward more environmentally sensitive alternatives.

The Defined Curriculum

In the Philippines the defined curriculum for science and technology education over the four years of secondary schooling is contained within nationally prescribed documents such as the New Secondary School Curriculum (NSSC). The curriculum design is "outcomes based" and is conceptualized in terms of student competencies, for example:

Relate how science and technology affect man's beliefs, practices, and ways of thinking. Apply the processes of science in solving simple problems in daily life.

The general objectives for the four years of science education are categorized under six headings as follows:

- Knowledge of science in the environment
- Scientific thinking
- Effective communication
- Scientific attitudes
- Knowledge of the relationships among science, technology, and society
- Appreciation of the contribution of scientists to the quality of life and levels of thinking.

These general objectives or major goals are developed over four years in year-long courses with the following discipline emphasis:

Year 1 General science and earth science
Year 2 Biology
Year 3 Chemistry
Year 4 Physics.

For the two years of secondary school covered by this project, the major topics studied are, for year 1 (general science):

- The nature of science and scientific contributions to society
- Force and motion
- Energy
- Matter
- Naturally occurring changes
- Earth's place in the universe
- Man's effects on and changes to the environment.

And for year 2, the biology topics are:

- The nature of biological science and biologists' contributions to society
- Ecosystems
- Biological diversity
- Life energy
- The cellular basis of life
- Organ systems
- Reproduction
- Genetics
- Life on Earth—changes through time.

The Developed Curriculum

The developed curriculum (the interpretation of the syllabus in learning materials) manifests itself in the form of nationally written textbooks that are distributed to schools by the DECS. These textbooks are written explicitly to the nationally mandated list of competencies and use the

same headings and organizational framework. Each unit is broken down into a "lesson" sequence (subtopic) with the typical structure being:

- Introduction to topic
- Concept description and explanation
- Activity
- Summary
- Self-test.

This structure is repeated for each subtopic or "lesson." In year 2 the 357-page textbook is structured into the nine competency units described previously and 22 subtopics.
From 1998 the developed curriculum in the textbooks will no longer be produced by the national government. Private publishers will be invited to produce textbooks that meet the government-mandated competencies framework.

The Taught Curriculum

The curriculum that is actually taught in the schools (the teachers' praxis) is influenced directly by the teachers manual that accompanies the student textbook. The manual, which is produced by DECS, is sequenced along the same lines as the student textbook "lesson" framework. Each "lesson" is explained through a sequence of headings, such as:

- Topic introduction
- Specific objectives (derived from the "competency" statements)
- Science ideas
- Processes and skills
- Teaching hints and strategies
- Answers to developmental questions on the student self-test.

However, textbooks are usually in short supply, with two to four students sharing a class copy. Large class sizes are the norm and are anticipated for the foreseeable future, with 50–70 students per class being common. These factors impact upon every aspect of the "taught curriculum." When combined with the nonavailability of laboratory resources (teaching laboratories, equipment, and consumables), the choice of learning settings becomes severely limited. Schools are more likely to have one or two conventional classrooms in which science classes are scheduled, rather than dedicated spaces for each of the science discipline areas.

According to DECS documents (for example, DECS Order No. 73, August 31, 1993), there is a standard equipment and supplies list for each year of high school science. This list suggests that enough equipment should be available for a class of 50 students divided into 10 groups. However, a recent 1996 report by an Australian short-term adviser connected with the preservice education of science teachers in tertiary education institutes suggests that "basic equipment for activity-based science teaching is in short supply in the secondary schools, with laboratory schools always much better equipped than regular schools." (The term "laboratory schools" refers to those schools that have been allocated specially constructed teaching

laboratories funded by the Department of Science and Technology.) Former PASMEP schools do have a supply of chemicals and equipment, but its use appears to have been very limited. During our inspections all the equipment still looked new.

All teachers are expected to produce substantial lesson plans. Prototype lesson plans kept at regional offices require teachers to identify in advance the following lesson features and formally integrate them into a standardized plan:

- Topic
- Objective
- Resources
- Concepts
- Questions
- Explanations
- Self-test items.

The Assessed Curriculum—That Which Is Tested in Formal Examinations

The existence of the nationally mandated competencies for science education as well as the National Secondary Assessment Test (NSAT) together exert a huge influence on the taught curriculum and the formative assessment of learning outcomes in the science classroom. The NSAT is the nationally administered external examination taken in the final year of secondary school. It counts for 20 percent of the final grade awarded to a student. The NSAT assesses directly the competencies listed in the nationally prescribed syllabus (the designed curriculum). The NSAT does not measure higher-order cognitive skills such as critical thinking and decisionmaking. At best, it encourages the recall of knowledge and its simple application. The assessment of laboratory outcomes and project or field works is not addressed by the NSAT instrument and, therefore, is not emphasized in the classroom.

The existence of "grading periods" every three months reinforces an assessment-driven curriculum process in schools. These grading periods provide a measure of student performance that is monitored at the school, regional, and divisional levels.

Other public accountability measures also influence the taught and assessed curriculum. For example, principals and teachers sign a performance contract each year that indicates the level of proficiency expected of at least 75 percent of the students. These testing results during grading periods at the regional and divisional levels are publicly displayed in reception areas within the school administrative center.

The results of the Third International Study in Mathematics and Science (TIMSS) are public knowledge. The Philippines ranked 37 of 39 for 13- and 18-year old students in science. This performance was discussed at a cabinet meeting of the national government and was reported in local newspapers. There is a sense of urgency about improving student outcomes, with the teachers feeling that they are being blamed to some extent by government and department officials for the poor results. However, students are expected to learn a longer list of

competencies at least two years younger than their western counterparts. Reform of the curriculum, an increase in resources available in classrooms, much smaller class sizes, a refinement of the NSAT instruments, and massive inservice education initiatives could perhaps reverse the current trends in student achievement.

One additional issue is that the official language of instruction in science classes is English. However, it is recognized that for most teachers and students, a mixture of English and Filipino dialects is used in classroom instruction and conversation. The impact of this on meaningful verbal learning at the high school level is not clearly understood. Filipinos generally believe that if the medium of instruction were their first language, then more meaningful learning might be forthcoming. Government policy would suggest that this is unlikely to occur in the foreseeable future.

The contextual background to this report, as discussed above, provides some illustration of the societal and educational dimensions of the classrooms that teachers must face each day. These factors are clearly identified and articulated by the education profession in the Philippines. It was clear to the providers of inservice education at the University of Queensland that there was little that PROBE could do to change the context in which the Filipino teachers must work. What the program can and must attempt to do is produce 500 talented individuals who have new skills to influence the professional actions of thousands of additional teachers in the areas supported by the teacher support units. Professional teachers are the ones in the best position to make decisions about appropriate learning settings to enhance student understanding and enthusiasm for science. In summary, "*There are no simple solutions, just intelligent choices.*"

Designing Professional Development Courses for the ISFs

The training courses at the University of Queensland have concentrated on:

- Inservice education skills and strategies
- Teaching, learning, and assessing science
- Developing an action plan and identifying resources for the operation of teacher support units.

Research by the Bureaus of Secondary and Elementary Education (1996) into the training needs assessment for science has revealed particular areas of concern on the part of the teachers. These areas were prioritized in a study of 243 teachers in the PROBE institutions across the five regions. The teachers identified the following as being of particular concern:

- Upgrading teachers' competencies through inservice training that should include hands-on operation of modern technologies such as computers and laboratory equipment (51 percent).
- Developing specific teaching strategies in physical science and biology, as well as the process approach to science teaching (28 percent).
- Preparing materials such as low-cost instructional aids, prototype lesson plans, and constructing assessment instruments (11 percent).

In addition to these responses the teachers also identified topics, such as ethics in science teaching; conducting experiments; developing questioning techniques; and the safe storage, handling, and disposal of chemicals. More background knowledge of specific topics was also valued. In year 1 teachers identified the following topics: the solar system, plate tectonics, forces, and environmental problems and solutions. In year 2 teachers mentioned genetics, respiration, reproduction, and molecular biology.

The challenge to refocus the teachers' teaching away from the teacher instruction to student learning was immense. However, unless classrooms become more student-centered and less teacher-directed the problems associated with the contextual factors discussed above will be unsolvable. Thus it was appropriate that the inservice education courses enhance teacher thinking about the following:

- How students think about scientific ideas
- Teaching models that emphasize student-centered behaviors
- The role of formative and summative assessment in learning science
- Authentic assessment techniques
- Classroom management skills for small groups and individual activity settings for large class sizes.

These topics are not unique to the Filipino context but, at present, the taught curriculum is entrenched in a "teacher-telling" approach to learning rather than a student-centered learning approach. The courses at the University of Queensland had to engage the ISFs with alternative methodologies that make sense of the reality of the large classes, the lack of resources, and the external examination system. This was accomplished by introducing the following strategies:

- Small group techniques
- Meaningful learning from text
- Concept mapping for students
- Group project work in science
- Field-based learning
- Peer teaching.

For a developing economy like the Philippines, it is especially important that the usefulness of science learning is made central to the classroom experience. Thus the teachers must place the teaching-learning processes in a context that makes sense of the students' daily tasks, informs the students' attitudes about environmental degradation, and encourages critical thinking and decisionmaking strategies. These outcomes can be partially achieved if teachers are as concerned about "contexts for student learning" as "concepts to be learned."

Operation of the Teacher Support Units

Each teacher support unit (TSU) will be a resource center where a variety of inservice initiatives will be available. Each facility will be housed in a district-lead school and be provided with video replay equipment, an overhead projector, a video camera, and a mimeographic copier.

They will also house reference texts, science demonstration equipment, and training videos recommended by the PROBE lecturers and the Australian advisers who undertook the original needs analysis. The role of the principals will be crucial in providing the TSUs with leadership and legitimacy in the wider educational community. Each TSU must operate as a stand-alone resource that can be accessed independently by district teachers. Therefore, the effective operation of each TSU will require that ISFs are prepared with the following competencies:

- The skills to enhance teacher development in group settings
- The skills to produce stand-alone materials to be accessed by the teachers
- Management and technical skills to operationalize the TSU as an effective learning resource for teachers
- Generic adult learning skills.

In the Philippines inservice education has focused on modeling teacher-student interactions consistent with the teaching or coverage of the major concepts contained in the national competencies framework document. The Department of Science and Technology provides the majority of inservice initiatives to a limited number of teachers each year. This is usually a one-day event and includes the demonstration of laboratory equipment. This type of inservice has been directed at the content to be taught and has not taken into account the needs, beliefs, and personal practical knowledge of teachers in the process. It is different in content and philosophy from that envisaged in PROBE, but because of the Department's willingness to continue to invest in science education in all regions, that model of inservice will still be available to schools and teachers.

When teachers are given specific lesson plans to follow in order to teach specific concepts and do not know how to develop the lessons themselves, this is akin to giving teachers the fish rather than teaching them the "skills of fishing." For the ISFs to become reflective practitioners (that is, to reflect before they teach, to reflect while teaching, and to reflect about their teaching) they need to develop generic adult learning skills.

The framework for designing appropriate learning experiences for the ISFs was developed using a number of learning models for teaching adults. The following guidelines and approaches were identified and incorporated into the courses at the University of Queensland:

- Help teachers identify and clarify the problems they experience in the classroom and that they wish to overcome.
- Accept each teacher as of worth, respect their feelings and ideas, and develop a relationship of mutual trust.
- Encourage cooperative activities and refrain from competitiveness or making judgments.
- Contribute your resources as a co-learner in the spirit of mutual inquiry.
- Involve the teachers in a collaborative process of formulating the learning objectives, taking into account the needs of the school, society, and learners.

- Share your thinking with the group of teachers about the options available in the designing and articulation of learning experiences; they will then decide among the options jointly and collaboratively in mutual inquiry.
- Help the teachers use and understand their own experiences as resources for learning through the use of discussions, role playing, and simulations.
- Help the teachers apply the new learning to their own experiences, to make the new learning more meaningful.
- Help the teachers develop procedures for self-evaluation.

The experience of the ISFs in Brisbane has extended beyond their classroom experiences at the University of Queensland. Prospective ISFs have indicated their strong desire to interact and observe Australian teachers in local schools. Through the cooperation of local secondary schools, principals and teachers have observed the daily operation of a typical Queensland secondary school.

As well as school visits, the ISFs could visit and interact with staff at regional teacher support centers. This experience illustrated how inservice education support is managed in Queensland schools. Such opportunities have direct relevance to the management of the TSUs in the Philippines. Brisbane also offered visits to a number of community science education resource or activity centers, including:

- The CSIRO (Commonwealth Scientific and Industrial Research Organisation) hands-on science center for students
- The SCIENCENTRE, a public hands-on science center
- Field study centers at Nudgee Beach (mangrove and seashore ecology) and the Bunya Park Centre (open forest and stream ecology).

Conclusion

This project is an investment in the sustainability of the professional development of science teachers in five regions of the Philippines. At the national accounting level the principals and science inservice fellows have been given the skills to enhance science education in 888 schools. They will work out of teacher support units with other local teachers in their own classrooms. As emphasized earlier, the PROBE inservice initiatives in Australia have attempted to produce reflective practitioners by modeling for them the benefits of action research and action planning as the basis for catalyzing change in teachers' thinking and classroom practice.

The expectation is that the ISFs, on returning to the Philippines, are working closely with science teachers to produce large cohorts of reflective practioners. To get inside the heads of teachers, and to require them to change their professional practice, will always prove to be challenging. The following quote from an ISF following the formal evaluation of her course at the University of Queensland gives us hope that the new cycle of teacher development initiatives will be successful.

"Australia in general and PROBE in particular has caused a very big change in me. This I will always remember for I have a belief which runs this way:

'If you want to be remembered for 10 years, plant a tree; if you want to be remembered for 20 years, build an edifice; but if you want to remembered forever, build a person.'

The PROBE program is a part of what I am now."

Dr. Warren Beasley was the Course Director for the inservice programs at the University of Queensland in 1997/98. He is Associate Professor of Education at the University of Queensland, Australia, and was responsible for the training needs analysis (secondary science) for PROBE. He was formerly Director of Teacher Education within the Graduate School of Education.

Secondary Science Education in Thailand

Roger G. H. Downer and Karma Rana

In Thailand there is general agreement that the country's science and technology education programs are not adequately preparing young people for the demands of working in a technological society. Today, more than ever, a far deeper understanding of science and technology and their impact on society and the environment is needed by all students. The country is also not producing sufficient science- and technology-trained personnel to meet national needs. The Eighth National Education Development Plan of the National Education Commission has raised concern about the quality of science education in Thailand and has drawn attention to deficiencies among school-leavers in such essential skills as analytical thinking, creativity, initiative-taking, and problem solving, as well as a basic knowledge of science and mathematics. An inappropriate curriculum and a lack of qualified teachers are some of the reasons for this. While there has been an emphasis on student-centered learning for some 20 years, in practice this has been difficult for teachers to implement. This paper discusses the current status of the Thai education system for science and mathematics and actions that are being taken to improve the performance of students.

Importance of Science to Thailand's Future

Thailand, like many countries in Asia, is undergoing transformation from an economy that is based principally on labor-intensive manufacturing to one that is knowledge-based and dependent on technologically sophisticated production procedures. The availability of high-skilled labor is essential to this transition. Thus the scientific and technological literacy of those entering the workforce is of pivotal importance to the economic welfare of the country. Without a sound base of scientific and technological manpower, Thailand will be unable to take advantage of modern technologies and, as a result, will sacrifice global competitiveness in many vital industrial sectors.

Several factors impinge upon Thailand's national capacity to provide a technologically literate workforce, including the pool of students who are attracted to appropriate training programs, as well as the content and pedagogy associated with science and technology education. These issues will be addressed here. However, at the outset, it is useful to place them in context by outlining the education system within the country.

Organization of the Formal School System

Thailand has a 12-year schooling system divided into six years of elementary education and six years of secondary education. According to the 1977 National Scheme of Education, the education system was changed from a 4-3-3-3 system to a 6-3-3 system wherein six years of compulsory primary education are followed by three years of lower secondary school and three years of upper secondary school.

A diversion from general education into vocational education only starts at the upper secondary level, after nine years of general education. Graduates from three years of vocational education (a total of 12 years of schooling) receive a certificate of vocational education. Students at this point may enter the labor market as skilled workers or tradesmen, but the majority choose to continue their studies. Some study for another two years for a diploma of vocational education. Another route to becoming a technician is to take a two-year course after 12 years of general education to receive a diploma of technical education. Workers with these qualifications are usually employed as technicians or assistants to engineers.

In addition, some tertiary institutions still enroll certificate of vocational education graduates for a four-year course leading to a bachelor's degree. However, for some it is possible to attain a bachelor's degree in engineering by investing in only two more years of study.

The usual path to becoming a scientist or engineer is to complete a four-year course of study in university, after 12 years of general education, to receive a bachelor of science or bachelor of engineering degree. A master's degree requires another two years; a post-graduate certificate takes one additional year; and a doctor of philosophy degree another three years after having received a master's degree.

Changing the Investment in Primary and Secondary Education

While the primary and tertiary enrollment ratios are fairly satisfactory, it is at the secondary level that Thailand has been behind some of the other Asian countries over the past years (table 1). The percentage of students who complete lower secondary and go on to upper secondary still remains very low (table 2). In 1997 the estimated enrollment ratio at the lower secondary level was about 75.8 percent. At the upper secondary level it was approximately 26.9 percent for the general education stream and 20.9 percent for the vocational stream. Since the implementation of the government's policy to extend basic education from six to nine years, covering lower secondary education, the number of public lower secondary schools has increased from 5,661 (1993) to 7,911 (1996). At the upper secondary level the number of both public and private schools has increased from 2,048 in 1993 to 2,817 in 1996 (ONEC 1997a).

Table 1 Enrollment Ratios in Selected Asian Countries, by Level of Education, for Selected Years

Country	Primary				Secondary				Higher		
	1970	1975	1980	1985	1970	1975	1980	1985	1975	1980	1985
Indonesia	80	86	107	118	16	20	29	42	2.4	3.9	6.5
Korea, Rep. of	103	107	109	96	42	56	76	75	10.3	15.7	31.6
Malaysia	87	91	95	99	34	42	49	53	2.8	4.3	6.0
Philippines	108	107	114	106	46	54	62	65	18.4	27.7	38.0
Singapore	105	110	108	115	46	52	58	71	9.0	7.8	11.8
Thailand	83	83	99	97	17	26	29	30	3.4	13.1	19.6

Source: Tan and Mingat 1992.

However, there is a disparity in enrollment ratios among the provinces. A number of the disadvantaged, such as primary school graduates in remote areas and children of poor families, still do not have access to secondary education. In 1996 the transition from primary to lower secondary was 91.1 percent of the total graduates, for the upper secondary level the ratio was 49.6 percent, and for the vocational stream 41.5 percent (ONEC 1997a).

Table 2 Percentage of School-Age Population who are Students, by Grade and Education Levels: Academic Years 1991–95

Age	Percentage of school-age population who are students					Education level
	1991	1992	1993	1994	1995	
3–5	38.09	39.30	45.78	49.11	56.86	Pre-elementary
6–11	93.72	92.58	90.37	86.86	83.02	Elementary
12–14	41.43	46.82	53.39	59.66	64.35	Lower secondary
15–17	23.64	25.29	28.20	31.53	35.30	Upper secondary
12–17	32.62	36.12	40.76	45.46	49.69	Total secondary
18–21	9.98	20.52	22.01	22.56	24.81	Higher education
3–21	47.96	51.02	53.14	54.35	55.85	Students as percentage of total population

Source: Ministry of Education, Thailand 1995.

Thailand compares reasonably well with its neighbors in terms of public spending at different education levels (table 3). Government funding has been the main source of financial resources for education development in Thailand. On the average, during 1987–97 total government spending on education equaled 3.16 percent of gross domestic product or 18.64 percent of the total expenditures. These percentages increased from 3.18 percent and 18.18 percent in 1987 to 3.80 percent and 20.47 percent in 1997. Total education expenditures increased from 42,888 million Baht (1987) to 216,318 million Baht (1997). Education expenditures in the central government budget were 18.85 percent in 1987, which increased to 22.0 percent in 1997. The education sector has received the largest share of the total public expenditures since 1991, with 16.49 percent of the 1997 budget allocated for secondary education and 3.17 percent for teacher education (ONEC 1997a).

Table 3 Share of Public Spending on Education in Selected Asian Countries, by Level, 1985 (percent)

Education level	Country				
	Indonesia	Korea	Malaysia	Philippines	Thailand
Primary	61.8	57.1	37.4	64.0	58.1
Secondary	27.1	33.5	33.3	16.0	23.6
Higher	9.2	9.4	24.7	20.0	12.4
Other	2.0	0.0	4.6	0.0	5.9

Source: Tan and Mingat 1992.

Enrollments in Science and Technology

In 1992 science and technology graduates in Thailand accounted for only 13 percent of those graduating from public universities, compared with 56 percent in Taiwan and 47 percent in Malaysia. Although the figures have improved in recent years, the pool of school-leavers who elect a career in science or technology remains much lower than in neighboring economies and is substantially less than that required to satisfy national needs (ADB 1995).

According to science and technology (S&T) workforce demand forecasts, Thailand will have an S&T workforce stock ratio of about 60 engineers and scientists per 10,000 population in 2001. This is far below that of industrial countries like the United States, which had a S&T stock ratio of 200 per 10,000 in 1990. Korea had about 100 engineers or scientists per 10,000 population in 1989. This forecast indicates large and growing workforce supply gaps in occupations that are regarded as critical for continued, rapid industrial development and change (ADB 1995). The failure of the education system to encourage a greater number of students to study science and technology warrants examination.

Science Education in Thailand

Sequence of the Curriculum: Primary School Level

According to the 1990 revised edition of the 1978 primary school curriculum, the principal goals at this level are to provide basic education for all; experiences applicable to students' daily living; and education for national unity, with common purposes and opportunity for local authorities to develop part of the curriculum suitable to their conditions and needs. The total time allotment for completion of the primary curriculum is six academic years, comprising not less than 40 weeks of teaching each year, with not less than 25 hours or 75 periods per week (table 4). The time allotted for each period is 20 minutes. Thus altogether the learning periods should not be less than 200 days or 1,000 hours. For grades 5 and 6, another 200 hours in the area of "Special Experiences" is provided according to the students' interests.

The curriculum provides learning experiences in the following five areas:

Area 1: *Tool subjects*, comprising the Thai language and mathematics.
Area 2: *Life experiences*, dealing with the process of solving social and daily life problems, with an emphasis on scientific process skills for better living.
Area3: *Character development*, dealing with activities necessary for developing desirable habits, values, attitudes, and behaviors that will lead to a desirable character.
Area 4: *Work-oriented experiences,* dealing with general and practical work experience and basic knowledge for career preparation.
Area 5: *Special experiences*, dealing with activities based on learners' interests is provided for students in grades 5 and 6 only. These may include knowledge and skills selected from the other four areas or activities such as "English for everyday life." Schools may select as many activities as desirable.

Table 4 Time Allotment for the Five Areas in each Grade at the Primary School Level

Areas of learning experiences	Approximate time allotment					
	Grades 1–2		Grades 3–4		Grades 5–6	
	Percent	Periods per Year	Percent	Periods per Year	Percent	Periods per Year
Tool subjects	50	1500	35	1050	25	750
Life experiences	15	450	20	600	25	750
Character development	25	750	25	750	20	600
Work-oriented education	10	300	20	600	30	900
Total	100	3000	100	3000	100	3000
Special experiences	–	–	–	–	–	600

– Not available.
Note: One hour is three periods with 20 minutes for each period.
Source: Ministry of Education, Thailand 1995

At the primary level there are no separate science or mathematics courses. They are included and form part of the topics covered in the different areas of learning experiences, such as "tool subjects" or "life experiences." The following are emphasized at this education level:

- Basic learning skills—the retention of literacy and mathematical skills
- Knowledge and understanding about self, the natural environment, and social changes
- The ability to take care of personal and family health
- The ability to identify causes of personal and family problems and to apply scientific reasoning skills in suggesting ways and means to solve them
- Developing the habit of reading and lifelong learning.

Curriculum Sequence: Secondary School Level

Secondary education in Thailand has become more diversified and comprehensive since the curriculum reform and change of the school system in 1977–78. In 1975 the Ministry of Education initiated a drastic change of the upper secondary school curriculum. The credit or unit system was introduced, whereby all coursework could be given credit and accomplished in one semester. Such a credit system was intended to give more flexibility and efficiency to the learning process. It was intended to promote more freedom of choice and do away with the annual repetition of a grade. Another drastic change was the abolition of the terminal grade examination centrally administered by the Ministry of Education. Every school would evaluate its own student and, in order to promote standards of testing, schools were clustered into groups for close collaboration on testing (ONEC 1997a).

According to the 1992 National Scheme of Education, lower secondary education aims to promote learners' knowledge, ability, and skills beyond the primary level; to enable students to identify their needs and interests, and to be aware of their aptitudes in both general and vocational education. Students also develop work skills and occupational practices relevant to their age.

Upper secondary education aims to enable learners to make progress according to their aptitudes and interests, acquiring the knowledge and skills either for continuing on to higher education or for going directly into employment. Students learn morality, ethics, and the social skills necessary for working, pursuing a career, and leading peaceful social lives.

Lower secondary level—The lower secondary school curriculum consists of 39 units of core courses; 18 units of compulsory elective courses; 33 units of free elective courses; and noncredit activities (table 5). Each academic year is divided into two semesters, with 20 weeks per semester. Each week consists of no less than five learning days, and at least seven periods per day (one period=50 minutes), with at least 30 periods per week. One credit unit is given per semester to any subject requiring two learning periods per week.

While students are expected to gain knowledge and skills in general education subjects, specific objectives are defined for science and mathematics. For sciences, these are to enable learners to develop the following characteristics:

- An understanding of the principles and basic theories of science
- An understanding of the characteristics, scope, and limitations of science
- Skills in scientific and technological studies, discoveries, and inventions
- Rational thinking, open-mindedness, accepting others' opinions, belief in and making use of the scientific method in problem solving
- Love, interest, and eagerness to learn about science and technology
- A realization of the relationship among science, technology, human beings, and the environment concerning their mutual influences and impacts
- A knowledge of the application of scientific and technological knowledge and understanding to society and in daily life.

Table 5 Structure of the 1990 Revised Edition of the 1978 Lower Secondary School Curriculum

Subject areas	Number of periods per week per semester								
	First Year (Grade 7)			Second Year (Grade 8)			Third Year (Grade 9)		
	Compulsory		Free elective	Compulsory		Free elective	Compulsory		Free elective
	Core	Elective		Core	Elective		Core	Elective	
1. Languages									
1.1 Thai	4	–		4	–		4	–	
1.2 Foreign	–	–	10[a]	–	–	10[a]	–	–	13[a]
2. Science-mathematics									
2.1 Sciences	3	–		3	–		3	–	
2.2 Mathematics	3	–		3	–		–	–	
3. Social studies	2	2		2	2		2	2	
4. Personality development									
4.1 Physical education	1	2		1	2		1	2	
4.2 Art education	1	–		1	–		1	–	
5. Work and vocation									
5.1 Work-oriented education	–	2		–	2		–	2	
5.2 Vocational education	–	–		–	–		–	–	
Total	14	6	10	14	6	10	11	6	13
	30			30			30		
Activities									
– Boy Scout, Girl Scout, Red Cross Youth, Girl Guide	1			1			1		
– Extracurricular activities	1			1			1		
– Guidance and remedial teaching or academic development activities	1			1			1		
– Independent activities	2			2			2		
Total	35			35			35		

a. Learners who are Buddhists are required to chose one Buddhism course in each semester in social studies throughout the three-year course of study.

Source: Ministry of Education, Thailand 1995

For mathematics, the specific objectives are to enable learners to develop the following characteristics:

- A knowledge and understanding of mathematics and the use of data apparent in the environment
- The ability to think rationally and use reasons to express opinions in an orderly, clear, and thoughtful manner
- Calculating skills
- An awareness of the usefulness of mathematics, both in daily life and as a knowledge seeking tool
- The ability to apply mathematical knowledge, understanding, and skills to daily life and as a basis for studying higher mathematics and other subjects requiring mathematical knowledge.

Students are required to take two compulsory science courses of 1.5 units each in all three grades at this level (grades 7, 8, and 9). However, for mathematics there are two compulsory courses of 1.5 units, each which must be taken in grades 7 and 8 only. There are no compulsory elective courses in either science or mathematics at the lower secondary school level, and interested students must then chose from the free elective courses. There are ranges of free elective courses of one unit each in the science option from which the students may wish to select. These courses include topics such as science through toys, problem solving in science, mechanical and electrical toys, beginning a science project, heredity, electronics for fun, science projects for the quality of life, light and visual equipment, solar energy at work, fibers and dyeing color, science and beauty, and the environment around us. Although the free elective courses can be chosen in any order, certain courses such as heredity must be taken in grade 8, while electronics for fun, science projects for the quality of life, light and visual equipment, and solar energy at work must be taken in grade 9.

There is a similar range of free elective courses for students interested in mathematics, which includes four courses of one unit each, covering mathematical skills at levels 1–4. Students are free to study all the four skill levels or only some of the electives. However, students who wish to continue their studies at the upper secondary level with an emphasis on mathematics are urged to choose certain electives through which they can build a stronger mathematical understanding.

Upper secondary level. The upper secondary school curriculum consists of 15 units of core courses, 15 units of compulsory elective courses, no less than 45 units of free elective courses, and noncredit activities (table 6). The specific objectives of science education at this level are the same as that of the lower secondary school, with the differences being in the structure of the compulsory and free elective courses. There are no core compulsory courses for either science or mathematics, which are offered as part of the compulsory and free electives.

For students wishing to emphasize science, the curriculum consists of two structures, with Structure 1 focusing on biological and physical sciences and Structure 2 on physics, chemistry, and biology. Topics under Structure 1 in the physical science grouping include

sunlight and energy, the world of colored lights, synthetic materials, electricity and electrical appliances, sound in daily life, invisible rays, the earth and the stars, natural resources and industry, and colored objects. Topics under the biological science grouping include eating right and living well, medicine and life, genetic heritage, our body, and life and evolution.

Within Structure 1 four compulsory elective courses are selected with two topics for each course. From all the selected topics, five are to be taken from the physical science and the biological science groups. Under Structure 2 the compulsory electives include three courses, one each in physics, chemistry, and biology of two units each.

Table 6 Structure of the 1990 Revised Edition of the 1981 Upper Secondary Education Curriculum

Subjects	Number of units Grade 10–Grade 12		
	Compulsory		Free electives
	Core	Elective	
1. Thai language	6	–	Select from other subjects not less than 45 units. (All Buddhist learners have to select one Buddhism course each semester throughout the three years)
2. Social studies	6	–	
3. Physical education	3	3	
4. Science	–	6	
5. Vocation-oriented education	–	6	
6. Mathematics	–	–	
7. Foreign languages	–	–	
8. Art education	–	–	
9. Vocational education	–	–	
Total number of units	15	15	
Activities			
1. Extracurricular activities	1 period / week / semester		
2. Guidance or remedial teaching or academic development activities	2 periods / week / semester		
3. Independent activities			

Source: Ministry of Education, Thailand 1995

The objectives of mathematics education are also more or less the same as that of the lower secondary level, except that there are no compulsory elective courses. Students wishing to emphasize mathematics are required to select from the free elective courses under Structure 1, which offers six mathematics courses of two units each, in addition to a one-unit course and six other courses of 0.5 units. Students who desire to study mathematics as basic knowledge are offered another set of free elective courses under Structure 2 and can choose from among the available six courses of 1.5 units each.

Assessment of the Current Situation

The Eighth National Education Development Plan of the National Education Commission raises concern about the quality of science education in Thailand and draws attention to deficiencies

among school-leavers in such essential skills as analytical thinking, creativity, initiative-taking, and problem solving as well as basic knowledge in science and mathematics. The report recognizes several contributing factors to this situation, including ineffective processes of teaching and learning, inappropriate curricula, and a lack of qualified teachers. Of particular concern was the continued emphasis on rote learning and direct transfer of information by the teacher, rather than on the stimulation of inquiry and problem-solving ability (ONEC 1997b).

Another study from the National Education Commission recognizes the poor achievement of primary school students in mathematics, science, and vocational skills as well as a considerable disparity in education quality between schools in rural and urban areas. Schools in remote areas suffer from a lack of resources and, consequently, are short of instructional materials and qualified teachers. Undoubtedly, underfunding, together with serious social problems, contributes to the high dropout rates in many rural primary schools. Academic achievement at the lower secondary level is also not satisfactory, partly due to the expansion of basic education, which led to the rapid increase in the number of students resulting in a lack of qualified teachers, especially in mathematics and science. The efficiency of upper secondary education provided in large schools in urban areas and smaller ones in rural areas still differs due to the inequality in allocation of educational resources, including qualified teachers (ONEC 1997a).

Implementation of the 1978 curriculum required that teachers adopt a more student-centered approach to instruction. However, this approach is fundamentally incompatible with the traditional classroom role of Thai teachers. Thailand's education system has been dominated by teacher-centered methods of instruction in which teachers lecture and students learn by rote. It was found that adherence to this method of instruction, in the absence of innovation in teaching style, inhibits the realization of many of the objectives of the revised curriculum (Thailand Development Research Institute 1992).

There is general agreement that science and technology education in the country is not adequately preparing young people for the demands of working and maintaining community in a technological society. A far deeper understanding than has been necessary in the past of science and technology and their impact on society and the environment is needed today by all students. Traditionally, science education has been part of the formal, institutionalized education system. There is frequently a considerable gap between the outcomes of the learning process as envisaged by curriculum developers (the "official" curriculum) and those achieved in the typical science classroom (the "actual" curriculum). Whenever a gap of this nature exists there is the likelihood of children developing negative attitudes toward science and technology, and this can have serious implications. Traditionally, the content of science education has been drawn from within science itself, rather than from the needs of society for science-literate citizens. Even science curricula that include social issues and work experience still emphasize conceptual and theoretical knowledge. For many students, this approach to science has little relevance outside school in their daily lives (Singh 1986).

Actions

In an effort to correct many of the problems identified above and improve scientific awareness among school-leavers, a number of reforms have been introduced in recent years. These are outlined in the Eighth National Education Development Plan (1997–2001) and include the following (ONEC 1997b):

- Expansion of both lower secondary education and upper secondary education in order to increase the enrollment ratio of the age groups 12–14 and 15–17 to not less than 95 percent and 70 percent respectively in 2001 and the extension of 9 years of basic education to 12 years for all.
- Increasing the production of teachers in the areas of science and technology to meet the demand; continuous development of inservice teachers; provision of fellowships for study-visits for technical teachers at least once a year; provision of various types of social benefits to teachers to facilitate their well being.
- Increasing the proportion of university first-degree graduates in science and technology to 40 percent of total graduates by 2001. There is also an emphasis on increasing the rivate sector's role in the production and training of personnel in science and technology and strengthening cooperation with foreign education institutions.
- Improving the curriculum and adjusting the teaching and learning process to focus on the learner; preparing diversified educational media.

The application of a student-centered approach requires innovations that extend beyond the classroom. In particular, it will be necessary to help teachers develop schemes of work and use new teaching and learning strategies and assessment methods for classroom activities that develop critical skepticism, open-mindedness, thoroughness in rational inquiry, and respect for the viewpoints of other. The mode of instruction should encourage learners to appreciate the tentative nature of scientific knowledge and allow learners to develop an understanding of the generation and evaluation of evidence. Science knowledge should be introduced in contexts that are personal and relevant to the learner and that help the learner view science as a creative, imaginative activity (ASE 1998).

The professional development of secondary science teachers should include the learning of science content through the perspectives and methods of inquiry. It should also integrate the knowledge of science, learning, pedagogy, and students, and apply this to instruction. For teachers to be successful facilitators of children's science learning, a great deal of support must be made available to them, both within the school and from the broader professional community. Teachers cannot develop the needed expertise without support from professional colleagues. They must have opportunities to exchange ideas and experiences with other teachers and with colleagues from the science and education communities, to reflect on their teaching, and to read the research literature and contribute to its development as part of a research team.

Universities and corporations should also endeavor to help in every way they can and not sit back complacently and admonish the school system for its "failures." Collaborations among scientists, teachers, businesses, colleges, and universities must be built to support secondary

science. This could be achieved in numerous ways, for example, by inviting students into university laboratories; by organizing summer science camps for bright students; offering a weekend lecture series delivered by interesting, exciting speakers; producing news bulletins in simple, easy-to-understand language; and working with teachers to improve their access to and understanding of the latest developments in science and technology, both in Thailand and around the world.

Acknowledgments

Special assistance was provided by Dr. Passawalee Nitikasetsoontorn, School of Communication Arts, Sukhothai Thammathirat Open University, Bangkok, Thailand.

Professor Roger G. H. Downer is currently President of the University of Limerick in Ireland. From 1996–98, he was President of the Asian Institute of Technology in Bangkok, Thailand. For most of his professional career Dr. Downer served as professor of biology and chemistry at the University of Waterloo, Canada. He has served as President of the Canadian Council of University Biology Chairs and Vice-President of the Biological Council of Canada.

Karma Rana has a background in both mechanical engineering and business administration. He has been employed at the Asian Institute of Technology since 1991, and is currently the Executive Assistant to the President of the Asian Institute of Technology in Bangkok.

References

ADB (Asian Development Bank). 1995. *Higher Education Development Project in Thailand, Volume 4, Science and Technology Manpower aand Labor Market Issues in Thailand.* ADB Technical Assistance Project T.A. No. 2104-THA. Bangkok.

ASE (Association for Science Education). 1998. *Education in Science*, February.

Ministry of Education, Thailand. 1995. *1995 Education Statistics in Brief.* Bangkok: Ministry of Education, Bureau of Policy and Planning.

ONEC (Office of the National Education Commission). 1997a. *Education in Thailand, 1997.* Bangkok: Office of the Prime Minister.

ONEC (Office of the National Education Commission). 1997b. *Synopsis of the Eighth National Education Development Plan (1997–2001).* Bangkok: Office of the Prime Minister.

Singh, R.R. 1986. *Education in Asia and the Pacific, Retrospect: Prospect.* Bangkok: UNESCO.

Tan, J.-P., and A. Mingat. 1992. *Education in Asia: A Comparative Study of Costs and Financing.* World Bank, Regional and Sectoral Studies. Washington, D.C.

Thailand Development Research Institute. 1992. *Educational Options for the Future of Thailand, Year-end Conference 1991*. Bangkok.

Toward a Comprehensive Strategy for Science Curriculum Reform and Teacher Development in Southern Africa

Leo P. de Feiter and Kenneth Ncube

This paper examines the needs, directions, and requirements to accomplish sustainable reform in science education in southern Africa. It does so on the basis of experiences with inservice science teacher education and teacher professional development programs in the region. The majority of these projects took place as interuniversity cooperation projects involving various universities throughout the region and the Vrije University, Amsterdam. In particular, project experiences in Zimbabwe will be used to reflect on a few key issues.

Introduction

Calls to reform science education can be heard worldwide, including in the developing countries in southern Africa where "change is in the air." Still, as history has shown, sustainable education reform is difficult to accomplish. As Lewin (1995) states:

"The developing world is littered with educational reform proposals that either have not been seriously implemented or that were overtaken by events before their effects were transparent."

This paper will first examine the science education curriculum in southern Africa and identify the main direction of the changes now taking place. These changes will be illustrated by a discussion of practical laboratory work and the problems inherent in implementing alternative solutions to laboratory instruction requiring appropriate local ownership of curriculum solutions.

In a consecutive section implementation problems are analyzed and the need to adjust efforts to the actual state of practice is discussed. The level of knowledge and confidence of teachers is seen as key to reform. Then, there is an overview of the problems commonly found in science teaching, followed by the conclusion that improving teacher supply alone cannot solve the problems inherent in the system. More direct efforts in school improvement and leadership development are required.

The final sections of the paper describe some experiences with implementing change in the schools and with leadership development. There is clearly a need to strengthen all levels of the system, including the teacher education institutions.

The Need for Change

The science curriculum that still dominates educational practice in many developing countries originated in the wave of curriculum reform that took place beginning in the 1960s (Lewin 1992; Ware 1992; de Feiter, Vonk, and van den Akker 1995; van den Akker 1998). These curricula stemmed from a concern with scientific workforce development, and emphasized the disciplinary

knowledge of science and scientific inquiry through laboratory work. Currently, in the industrial world, the new wave of curriculum development is emphasizing "scientific literacy for all."

The general direction of this movement is toward more "student-centered" education and the development of useful skills. It is recommended that less emphasis be put on learning ever-increasing amounts of information and conceptual knowledge, and more emphasis be put on the development of inquiry skills and the gathering and processing of information—that is, "learning how to learn" (Keeves and Aikenhead 1995; van den Akker 1998). Also, there is an emphasis on learning about the relationships between science, technology, and society (including environmental issues) and a de-emphasis on individual science disciplines.

In developing countries the need to develop a new vision for science education for the majority of students is urgent for a variety of reasons:

- *Pedagogic concerns*: Many people believe that science should become more meaningful and relevant to life outside school for those not likely to take up further studies in science. Even at the lower secondary and primary levels the disciplinary perspective often strongly influences the curriculum and instruction, as it does in nonscience streams at the senior secondary level.
- *Socioeconomic concerns:* Global economic competitiveness appears to be influenced by the general level of scientific and technological literacy in the population. Technology (particularly computer technology) is a part of many areas of economic activity. Clearly, science and technology education should be part of every student's education. Current curricula, with their emphasis on understanding science for its own sake, are considered too difficult and abstract by many. Students tend to avoid science classes whenever possible (Walberg 1991; Lewin 1992, 1995; Caillods, Göttelmann-Duret, and Lewin 1997).
- *Financial concerns:* More students now participate in secondary education than in the past. Many education systems cannot sustain the type of high-cost science education that requires laboratory work—which characterizes many curricula that were developed in the 1960s and 1970s.

In their recent comprehensive review of planning and policy issues in science education and development, Caillods, Göttelman-Duret, and Lewin (1997) analyze in detail the complex issues that are involved in reconciling the different demands of "science for all" and scientific workforce development within the secondary curriculum (Lewin 1992). These issues include the time of specialization, ways of streaming the students, the curriculum structure, and various assessment systems.

In southern Africa the different demands of "science for all" and "science for further studies" are strongly felt. The curriculum structure in southern Africa stems from the British

system, the main former colonial power in the region.1 A brief overview of the science curriculum structures found in the southern African region follows.

Overview of Secondary School Science Education in Southern Africa

In all countries science is a compulsory part of the curriculum up until junior secondary level (grades 9 or 10), but the curriculum is primarily a preparatory phase for senior secondary education. Subject specialization takes place at the senior secondary level, but within the framework of a general education curriculum, except in the case of Zimbabwe's A(advanced)-level system.

In Botswana, Lesotho, and Swaziland, the Cambridge Overseas Examination Board is still in control of the final examinations and thus, in practice, of most of the secondary curriculum. The final examination is the traditional O(ordinary)-level General Certificate of Education, originally meant for the top 20 percent of the ability range, but the only well-developed school program in these countries. The growth in enrollments at the secondary level, together with resource problems (particularly in Lesotho and Swaziland), leads to an examination of the extent to which the curriculum meets the needs of all learners. Growth in enrolments has also caused changing patterns of subject choice (weaker syllabus options) and declining examination results (de Feiter and Thijs 1996).

After gaining independence in 1990, Namibia adopted the new version of the O-level examinations, the IGCSE system (International General Certificate of Secondary Education) appropriate for about 80 percent of the ability range. Before independence Namibia took part in the South African matriculation system. Botswana is also now changing over to the IGCSE system, and Swaziland is considering the same move. One of the major difficulties experienced in implementing the IGCSE curriculum is in carrying out the continuous assessment component that normally forms part of the examination system. Another difficulty faced by many schools is the need to provide differentiation of teaching according to student ability level.

In the British system O-level work is normally not considered adequate preparation for university, but it gives students access to intensive specialization work at A-level for another two years. Contrary to other countries in the subregion Zimbabwe has included A-level in its education system. The A-level examination is still administered by the Cambridge Examination Board, but the O-level examination is fully localized in Zimbabwe. The content and structure of the O-level science curriculum has been fully determined by Zimbabwe and focuses on social fields, for which science is relevant, although backwash effects from the prestigious A-level examinations ensure that, in practice, disciplinary science knowledge still dominates.

---

1. Geographically, Mozambique and Angola also could be considered as southern African countries. Their background and education systems are influenced by Portugal and are therefore different from the rest of southern Africa. The situation in these two countries will not be considered further here.

The South African matriculation system does not follow the O/A-level pattern and is fully local in content and organization. It has different parallel exit levels (lower, standard, and higher grade), where only the highest level normally gives access to university studies. Science and mathematics at the senior secondary level are, at present, only taken by a relatively small minority of students. South Africa has recently embarked on a major curriculum reform toward nine years of basic education for all (Curriculum 2005). Implementation starts in 1998 for grades 1 and 7. The consequences of curriculum reform at the senior secondary level have not yet been clearly articulated.

Those countries that do not have a separate tier in the educational system to prepare for higher education (like A-level), have to perform this function in parallel with general education functions and other specialist preparation. The consequence is often that not enough adequately prepared candidates for higher-level science studies are produced. In Botswana, Lesotho, and Swaziland, special bridging programs for science streams have been in operation through the 1980s and into the 1990s to provide appropriate preparation for university studies (Cantrell and others 1993). Programs of this type have also recently become popular in South Africa, due to the very small number of students who qualify to pursue science studies on the basis of their secondary school results, especially from disadvantaged sections of the population (Volmink 1996). These programs are generally considered emergency solutions to be used until examination results have improved (they have been largely phased out now in Botswana, Lesotho, and Swaziland). Namibia adopted, on top of the IGCSE curriculum, a more demanding option for some schools (Higher IGCSE) in order to prepare students for university. It is too early to tell whether this solution works well.

Although the situation varies somewhat in different countries, the state of the science curriculum with regard to "science for all" and "science for further studies" may be characterized as follows:

- The disciplinary perspective (science for further studies) is dominant.
- The curriculum is not relevant to the majority of students, leading to poor learning results and a lack of interest in science.
- There are multiple resource problems (books, equipment, supplies, laboratories, teachers) due to the rapid growth of the secondary system and budgetary constraints, leading to further problems in learning outcomes (rote learning).
- In spite of the dominance of the disciplinary perspective, and largely because of implementation problems in schools, there are continuing problems in preparing enough students for higher education in science-related fields, particularly for teacher education streams.

Curriculum innovation and further curriculum localization are being considered by most countries in the region, and, in some cases, are already under way. Curriculum solutions will need to cater both to the science for all functions, as well as for the preparatory function for higher studies in science. It will also need to pay special attention to streaming problems in schools. However, in most countries, there is only one dominant secondary-school-leaving examination giving access to higher studies and the job market. Thus the community is more

comfortable staying within the safety of an established (and internationally recognized and accredited) examination.

These factors are strong forces acting against streaming, and the development of local curricula. As Ware (1992) notes curriculum reform should only take place if the need for reform is widely accepted by all stakeholders, and it should go hand in hand with examination reform. This can be illustrated by the difficulties often encountered when attempts are made to introduce simple practical work as an alternative to the traditional full-fledged laboratory.

Practical Work and Curriculum Change

Although the emphasis on inquiry and "hands-on science" is still very strong in current thinking on the science education curriculum, this does not necessarily imply a similar strong emphasis on traditional laboratory work. On the contrary, traditional laboratory work has often been criticized for its complex aims (concept learning, inquiry skills, manipulative skills) and many doubts have been cast on its effectiveness (Caillods, Göttelman-Duret, and Lewin 1997). It is often argued that simpler and more natural contexts can be more effective when a skills-oriented approach is advocated (van den Berg, Lunetta, and Finegold 1994; van den Berg 1996). Also, for a thorough understanding of basic scientific concepts, a constructivist design of lessons based on developing and challenging students' alternative conceptions can be effectively accomplished with the use of teacher-led demonstrations (Dekkers 1997).

Practical work in the laboratory can be made more effective, for example, by making more careful distinctions between different learning objectives (van den Berg and Giddings 1992). However, it may be questioned whether complex laboratory experiments are absolutely necessary, other than for the preparation of students who intend to become scientists. Furthermore, the experiences of bridging programs between school and university in southern Africa indicate that an intensive half-year or one-year course of study, with carefully designed practical experiences, can effectively prepare students for successful university education. This is true even if their secondary school background has hardly introduced them to practical laboratory work (Cantrell and others 1993).

A pattern that most countries may be adopting is one in which science is studied by all up to junior secondary level, emphasizing scientific literacy and including simple and inexpensive practical work, not necessarily in a laboratory (compare Caillods, Göttelman-Duret, and Lewin 1997). Furthermore, for a more student-centered emphasis on scientific literacy, other cost-effective alternatives to laboratory work (for example, thought experiments, simulations, demonstrations, video presentations, excursions) could also play an important role. Laboratory work could be introduced at the senior secondary level for the science stream, thus saving considerably on costs and freeing time for more effective activities to be undertaken with other students. The nonscience students could also study some science as a further extension of the scientific literacy curriculum started at the junior secondary level.

Attempts to provide more cost-effective and simple alternatives to the traditional fully equipped laboratory have been made in the southern African region through the development

of science kits (for example, in Zimbabwe (ZimSci project) and South Africa (Science Education Project) (Rogan and MacDonald 1985, Ross and Lewin 1992). Although effective instruction can be accomplished using such kits, they are often considered second-rate alternatives by teachers and schools, Thus they have generally not proved very popular (Ross and Lewin 1992). In Zimbabwe replenishment funds for science kits within the ZimSci project have been exhausted. Consequently, hardly any practical work is done in O-level schools anymore. This is so despite the fact that all O-level students have to sit for a practical science examination (but, in most cases, a paper and pencil version of this examination is taken).

If alternatives to a disciplinary emphasis in the science curriculum are to have any chance of being accepted and implemented in schools, they should be seen as an improvement on the current situation. They should not be considered a second-rate option. Apart from a clear stakeholder recognition of the need for reform, ownership of the content and methods of reform should also be established, especially in the professional community. However, this presupposes the existence of a professional community and professional leadership to drive the processes of reform. As will be further discussed below, the leadership capacity in individual countries necessary to develop and sustain local systems is insufficient.

The State of Practice and the Demands of Change

If we look at the stated ideals of student-centered education and inquiry-based approaches to science education, then a study of curriculum implementation and educational practice in schools worldwide provides a rather gloomy picture (van den Akker 1998). Whole-class instruction, sometimes supplemented by teacher questioning, is still the dominant mode. This is the situation even in circumstances where resource problems do not prevent alternative forms of instructional delivery. Of course, resource problems are a key characteristic of education systems in developing countries and need not be reiterated here. The majority of southern African schools are no exception to this. Under these circumstances it may come as no surprise that the gap between the ideal of introducing more student-centered education in schools and the actual practice found in most schools is enormous. The typical classroom practice includes (de Feiter, Vonk, and van den Akker 1995):

- An overdependence on the lecture method ("chalk and talk")
- Passive learners
- Only correct answers accepted and reinforced by the teacher
- A lack of learner questioning
- Whole-class activities of note taking.

Beeby (1996) pointed out that the actual state of practice in schools in developing countries limits the amount and type of change that can be introduced effectively (Beeby 1966). To systematize his experiences, he proposed a model that described several stages of development. Verspoor and his colleagues at the World Bank (Verspoor and Leno 1986, Verspoor and Wu 1990) further developed this model by using ideas from studies on teacher concerns and organizational change. Both Beeby and Verspoor focused mainly on primary education. De Feiter, Vonk, and van den Akker (1995) have adjusted this model to focus on secondary science education (table 1).

Table 1. An Adaptation of Verspoor's Stage Model Distinguishing the Main Elements of the School System, by Level of Development

Level of development	**Teachers** • Teacher background • *Teacher professionalism* • Teacher reaction to innovation	**Curriculum** • Curriculum • Teaching techniques	School organization • Textbooks and other materials • Supervision/support	**Possible change** • Teacher development • School development
Unskilled	• Questionable mastery of subject content; little or no professional training. • teachers often isolated, poorly motivated. • ignorance, confusion, and nonapplication.	• Narrow subject content, emphasis on basics; • low standards; high wastage accepted. • Recitation, rote learning & memorization; students copy from blackboard; no individualization.	• one textbook per class used by teacher; near total absence of instructional materials. • sporadic supervision, focused on administrative control and compliance with regulations.	• simplify structure and provide structured teachers' guides, textbooks, and minimal instructional materials. • train teachers in subject matter & a few basic *teaching techniques; help teachers perceive need* for improvement. • strengthen school supervision and support; bring order to the school.
Mechanical	• moderate subject mastery; • limited professional training. • incidental contact with colleagues through in-service training; some interest in professional improvement but easily discouraged. • uncertain about use; focused on personal *mastery; dilution of innovation to adapt* to personal, professional capacity and motivation.	• Highly structured, emphasis on basics; little or *no curriculum differentiation; standards imposed* by examinations; repetition accepted as a means to maintain uniformity. • Memorization; slavish adherence to curriculum, short-term activities and objectives; rigid application of one instructional technique.	• one textbook per student in core subjects. • *supervision occasional; focused on compliance;* in-service training infrequent –focused on dissemination of structured programs; emphasizes standardized application of curriculum & materials.	• broaden curriculum; teachers' guides and *textbooks set standards enforced by exams.* • increase subject mastery training; introduce a few simple techniques to make teaching more effective and varied; increase confidence of teachers through training and school-level support. • train headmasters in development of basics of school curriculum, staff, and organization; stimulate department building and teacher cooperation in and between schools.
Routine	• adequate subject mastery and training. • incidental contact with colleagues. • *interested in improving student perform-*ance if adequate incentives are provided. • sceptical about immediate effects; willing and able to make honest effort; will try to adapt innovation for ease of classroom management & standardized application.	• Curriculum goals broaden, but syllabus still dominated by examination; some curriculum *differentiation* and tracking of students present; opportunities for adaptation & experimentation exist; little attention to career guidance of students; concern is preventing failure. • Memorization still dominant; increasing attempts to introduce learning by doing. • Medium-term planning using textbooks & materials in a more goal-oriented way; limited variation.	• additional texts available; deviations and selective use of available text begin to occur; supply of materials adequate; small school library. • supervision more frequent & less oriented toward compliance; in-service training more frequent - emphasizes the application of innovations in class-room teaching; role of principal as source of knowledge becomes more important.	• teaching more focused on understanding; • some diversity and flexibility can be introduced to the curriculum; objectives can be broadened to include attention to process skills, science and society issues and career guidance. • introduce more complex forms of teaching; • promote professional exchange between teachers and career development of teachers. • train headmasters as educational leaders; • stimulate collaborative work-culture in schools & school/ subject development plans.
Professional	• good subject mastery; well-trained. • frequent contact with colleagues; reads professional publications; interested in *improving student performance.* • needs of students is central focus; willing to try and test alternative approaches; • confident about own ability to master and adapt innovation to fit needs of particular group of students.	• Meaning and understanding stressed in wider curriculum; allowance for variety of content and methods; considerable attention to the role of the *school for students' future life.* • self-generated habits of learning: reflective practice; ability to investigate new ideas; longer-term instructional planning allows teacher to adapt use of materials and curriculum sequence to student needs; individualized or multi-group discussion instruction.	• broad availability of textbooks, supplementary reading materials & reference books; well-stocked school library; variety of instructional materials. • the principal becomes source of pedagogical support; external support & assistance are available on a contingent basis; training emphasizes the development of professional skills, allowing teacher to select appropriate instructional approach in each situation.	• innovation becomes permanent feature. • teachers can be encouraged to behave and perceive themselves as professionals; offer diverse staff development opportunities. • make schools more independent in their operation and responsive to the needs of society.

Source: de Veiter, Vonk, and van den Akker 1995.

The respective models all take as their premise that when conditions are ill-resourced, teachers are not well-trained, and the school organization is weak, different actions are required than in situations where these variables are further advanced. Failing to take this into account will worsen the situation not improve it when innovations are attempted (compare Lewin 1995). Van den Berg (1996) takes up this idea and proposes concrete improvements in science teaching for different levels of development. Improving conventional teaching is potentially a more effective improvement strategy at lower development levels. More student-centered methodologies can be introduced at higher levels of school development (de Feiter, Vonk, and van den Akker 1995; van den Berg 1996).

The validity of the Beeby stage model has been heavily criticized, especially by Guthrie (1980 a, b; 1990) as a typical product of Western dominance (de Feiter, Vonk, and van den Akker 1995). It presents student-centered education as the ultimate form of good education, in line with the individualistic Western culture. In fact, this may not necessarily be the best teaching strategy in all cultures. Also, a recent analysis by Tabulawa from Botswana points out that rather deep sociohistorical factors work more against student-centered methods than merely technical ones (Tabulawa 1997). He rightfully points out that teacher-centered teaching is also underpinned by a philosophy of knowledge and learning that is embedded in a wider cultural context; it can be considered as a paradigm in the Kuhnian sense. Attempts to change the pedagogy of classrooms conflict with the value systems of both teachers and students.

Discussions of "student-centered" versus "teacher-centered" tend to focus on teaching methods and on the types of relationships and interactions found in classrooms. Other methods the classroom should be considered because many learning outcomes are considered important. Higher order outcomes related to reasoning processes and the application of theoretical knowledge are extremely important. Certain learning outcomes are more difficult to achieve than others; and certain methods, depending on the context, can better reach certain outcomes than others. Also, some teaching methods are more difficult to implement than others. Higher order outcomes require a higher level of teacher knowledge and skills, and more difficult methods require more teacher confidence. This is conveniently pictured in a stage model, although this should not be interpreted mechanistically. Of course, this presupposes that other outcomes are valued and thus measured by the examination system. This serves to strengthen the view that ownership of the curriculum, along with associated materials, teaching styles, and assessment practices, should ultimately rest within individual nations and a professional community.

The stage model also effectively portrays change as multidimensional and requires the simultaneous addressing of different factors, such as teacher education, school management, curriculum and materials development, examination systems, and resources for the schools. Furthermore, the fact that a wide variety of school circumstances exist within an individual country complicates the identification of viable change strategies.

The most critical factor for successful change is the amount and quality of teacher knowledge and confidence present. The complexity of change will be illustrated further by a

more detailed discussion of teachers and teacher education strategies as a lever for science education reform.

Teachers and Teacher Education

As in many developing countries, the quality of the science education teaching force in southern African countries leaves much to be desired (Caillods, Göttelmann-Duret, and Lewin 1997). Depending on the particular country, many unqualified, underqualified, or expatriate teachers are present, or science education cannot be offered due to a lack of teachers (de Feiter, Vond, and van den Akker 1995). There are a few striking examples from different countries:

- In Botswana 56 percent of science and mathematics teachers are expatriates (Vonk and Kapteijn 1996).
- Only approximately 15 percent of Namibian junior secondary teachers and 50 percent of senior secondary teacher can be considered appropriately qualified (Benschop, Stoll, and de Feiter 1996).
- Nearly 60 percent of science teachers across seven provinces in South Africa have no accredited training in science (Arnott and others 1997).

Problems in the composition of the science teaching force usually involve a complex set of factors (Caillods, Göttelmann-Duret, and Lewin 1997). These factors include (de Feiter, Vonk, and van den Akker 1995):

- Insufficient teacher production due to the insufficient uptake of students into the teacher training streams
- Nonabsorption of qualified teachers due to the unpopularity of teaching, and the availability of many other career avenues for science graduates
- Inefficient deployment due to small school sizes and an inappropriate curriculum structure in the schools
- Inefficient deployment due to inappropriate curriculum structure in teacher education
- High attrition from the profession. The reasons for leaving the profession given by former teachers in a southern Africa study (summarized in Vonk and Kapteijn 1996) refer to motivational problems, teacher-status problems, and posting and transfer problems within education systems.

A variety of teacher education strategies can be employed to reduce the large gap between the actual composition of the teaching force and the ideals of a fully qualified professional teaching force, which is able to reform practice in schools (de Feiter 1998):

- Upgrade the knowledge and skills of serving unqualified and underqualified teachers to minimally acceptable levels through special certification programs.
- Reform initial teacher education in order to increase the supply of new teachers who are adequately prepared for the more demanding forms of teaching required in the schools.
- Improve absorption and early retention of new teachers, and also ensure the establishment of effective teaching routines for these new teachers through teacher induction programs.

- Provide on-the-job opportunities and support aimed at further professional development for all teachers. This will help them improve their teaching skills and provide them with the necessary skills to implement new forms of teaching and introduce new curriculum solutions into the schools.
- Provide opportunities and support for the development of leadership skills for selected expert teachers.

Most of the above strategies have been employed in various southern African countries in different circumstances and at different times. A detailed description and analysis of the variety of teacher education systems go beyond the scope of this discussion. However, generally teacher supply strategies (the first three of those mentioned above) usually are not sufficient to produce the required results. For example, in Lesotho, special programs were set up in the early 1980s to increase initial access to teacher education and to upgrade the qualifications of serving teachers. In the early 1990s, while these were seen to have had a significant impact on the number of qualified teachers available to the system, due to growth of the system coupled with high attrition, many expatriate teachers were still required (de Feiter, Vonk, and van den Akker 1995). These interventions had limited success.

A second intervention, set up in the second half of the 1980s, targets graduates from teacher training institutions and provides an induction program for this group of novice teachers. In the mid-1990s this intervention improved the absorption and early retention of graduates in the teaching force. However, it may not be having a significant impact on the total time spent in the profession by teachers (Mathot 1996). A comparative study in four countries—Botswana, Lesotho, Namibia, and Swaziland (Vonk and Kapteijn 1996)—found that 46 percent (Namibia) to 61 percent (Swaziland) of the mathematics and science teachers serve in the profession less than six years.

Another drawback of emphasizing teacher supply strategies can be that it produces academically weak teachers (de Feiter 1998; Nyagura 1996). Upgrading programs for unqualified or underqualified teachers serving in the schools are almost, by necessity, offered to candidates who originally did not qualify for initial entry into the programs at the college or university level. In Zimbabwe a heavy emphasis has been placed on producing teachers by teachers colleges. Due to the low quality of intake and the low academic standards in these colleges the standard of science education in O-level schools is quite low, although sufficient formally qualified teachers are now present (Nyagura 1996).

Teacher supply strategies can thus be seen to produce only limited results. Furthermore, although increased teacher supply may ensure that minimally competent teachers are present in the schools, it is insufficient to introduce a new pedagogic practice. Even if other pedagogic practices are promoted in preservice education and teacher upgrading programs, when they are absorbed in schools novice teachers tend to reproduce the pedagogic practices that are the norm in the schools. Reduction of this gap has to take place between theory and practice and teacher education and school policy. In line with a systemic view of educational change, the entire

teacher education system needs to be addressed by providing professional development opportunities for all teachers and educators.

The major challenge is to bring closer together a largely academic-focused culture in teacher education (offering little practical orientation in its programs) with a low-status and low-morale school culture, which emphasizes teaching as opposed to learning (Nyagura 1996). A genuine culture of "lifelong learning and development" can only be brought about by including direct efforts to support change and develop leadership in the schools and by building better links between teacher education institutions and the schools.

Supporting Change

The study of curriculum-change processes in the Western world has identified the pivotal role of teachers and their concerns during the adoption and implementation of curriculum innovations. Fullan (1991) presents a comprehensive overview of the complexity and demands of educational change for all stakeholders and, like many authors, emphasizes the importance of professional development opportunities and in-service teacher education.

In both industrial and developing countries inservice teacher education is a much-recommended strategy that is increasingly employed, but Caillods, Göttelman-Duret, and Lewin (1997) note that little is known about the effectiveness of the methods employed. As an example, they quote a study from Malaysia (Sharifah, Maimunah, and Lewin 1993), which found that although teachers there were generally satisfied with the content of the inservice education provided, little impact on actual practice in the classroom could be identified. The following criticisms emerged about the courses:

- They were too short to be effective
- They had little impact on teachers' actual practice, because the courses did not take into account the real situation in many schools
- They were ephemeral, with no follow-up or support materials provided
- They were sometimes run by those without adequate experience themselves
- They concentrated on description rather than the acquisition of new skills.

The lack of impact of inservice teacher education is not restricted to developing countries. Introducing innovations into teaching is now recognized as a complex undertaking, which is more difficult to achieve than initially realized. It usually involves a combination of changes in the following areas (Fullan 1991):

- New curriculum materials or a change in the use of existing materials
- New knowledge and skills required by the teacher
- New values and attitudes concerning student learning and new patterns of work in the classroom.

Many studies of attempts at innovation have reported the lack of sustained impact on classroom practice resulting from such attempts. However, it further appears from such studies

that successful implementation can be reached through the provision of intensive support scenarios in which the following strategies are employed (de Feiter, Vonk, and van den Akker, 1995):

- The use of well-tried exemplary materials that provide support for critical elements of the proposed changes, and that appropriately predict how proposed innovations will work out in classroom practice (van den Akker 1994)
- Ample opportunity for teachers to practice innovations in safe environments with feedback on performance and follow-up support (Joyce and Showers 1988)
- The creation of a supportive school environment and provision of in-school support for teachers when they try out changes in their classrooms (Joyce and Showers 1988; Fullan 1991).

In southern Africa the findings on the limited impact of traditional inservice education have also been confirmed in evaluation studies of the effects of inservice workshops on classroom practice (Boerma 1993). In recent years and in several countries in southern Africa (Botswana, Lesotho, Namibia, Swaziland, and Zimbabwe) more comprehensive inservice initiatives have been developed that try to use the lessons from the literature on innovation and apply them in various creative ways appropriate to the individual countries. Some specific lessons learned in developing these more comprehensive scenarios include the following (Stoll and others 1996):

- Studies in Namibia and Swaziland on the implementation of detailed lesson proposals, involving more practical work and employing student-centered methods, confirm that a number of basic teaching routines (for example, effective explanation and questioning, use of textbooks, use of homework) are often not well mastered by teachers. This hinders the effective implementation of more demanding forms of teaching (Boerma 1993; Ottevanger, Benschop and van den Akker 1995; de Feiter, Vonk, and van den Akker 1995).
- It pays to invest much time and effort in the development of teacher support materials that contain very specific guidelines and thereby exemplify the intended changes. The development of such materials should be in an iterative process. Through the intensive formative evaluation of materials, any implementation problems will be discovered and can be attended to in revised versions of the materials. The intimate involvement of experienced teachers in developing and piloting the materials is crucial for successful results (experiences stem from Namibia and Swaziland; see van den Akker and McKenney 1996).
- A system of regular inservice workshops needs to be organized (regionally or locally) to ensure regular participation by as many teachers as possible. Workshops organized at the national level will not normally provide sufficient opportunity for practice and for followup. The decentralization of inservice activities requires effort to be put into leadership development and the establishment of local resource centers, local teacher groups, school cluster networks, and the like (for example, Namibia, South Africa, Zambia, Zimbabwe; see de Feiter and Thijs 1996).
- Peer coaching is a promising strategy for the provision of more support in the school environment. However, teachers need appropriate training and support to implement

coaching, which is an innovation in itself. Furthermore, in order to be effective in improving classroom teaching, coaching support should be explicitly linked to proposed innovations in teaching (for example, Botswana and Lesotho; see de Feiter and Thijs 1996, Thijs and van den Akker 1997).

- In most schools management tends to focus on administrative issues and compliance with regulations. Educational leadership tends to be weakly developed, as in many instances are departmental structures, especially in small schools. Professional development strategies for teachers should therefore be coordinated with professional development programs for school leadership (for example, Botswana and Lesotho; see de Feiter and Thijs 1996).

Building Local Leadership

Local leadership capacity needs to be built for change to take hold and to enable on-going, local professional development activities to take place effectively. There are a number of strategies available to develop leadership roles for experienced teachers. For example:

- Tutors in schools involved in teaching practice for trainee teachers
- Mentors for beginning teachers in induction programs
- Developers of curriculum materials
- Peer coaching roles
- Master or resource teachers at the local or regional levels involved in setting up inservice support systems
- Heads of subject departments in schools.

Experiences in various settings with these various roles suggest the following guidelines:

- Explicit training programs need to be developed for such roles in order to equip teachers properly for them (de Feiter and Thijs 1996).
- In order for such roles to become appropriately established within the school system, they need to become embedded in personnel policies and career structures for teachers (de Feiter and van den Akker 1996; Thompson 1995). This may have the added benefit of improving teacher retention.

A supportive climate needs to be developed at local and regional levels and networks of schools and teachers need to be created, facilitated, and stimulated. The establishment of resource centers is also an appropriate strategy (de Feiter and Thijs 1996). One promising initiative is the comprehensive approach to set up a support system and to develop local leadership, teacher groups, and resource centers that was initiated in 1994 at the University of Zimbabwe.

Training Teachers for Effective INSET: The Case of Zimbabwe

Context

Starting in September 1994 a highly ambitious decentralized INSET project called Science Education In-service Teacher Training (SEITT) was launched in Zimbabwe. At the request of the Ministry of Education, the project was spearheaded by the Department of Science and Mathematics Education (DSME) of the University of Zimbabwe (UZ). DSME, with the help of the UZ administration, set up an inservice wing, complete with two full-time staff and three part-time staff—employees of UZ. This core staff was complemented by an INSET specialist seconded to UZ by Vrije University Amsterdam. Project funding was provided by the Dutch government.

The INSET team runs the resource teacher education program at the University; establishes effective communication channels with the Ministry of Education; facilitates the ordering and delivery of books and equipment; and provides technical and moral support. The strategy adopted was that of training A-level teachers as resource teachers (RTs). The RTs are trained to oversee and coordinate the implementation of INSET programs in regions and districts. They link into a system of regional and district resource centers for teachers, which is being developed by the Ministry of Education through the Better Schools program (an umbrella program that, among others, coordinates INSET programs within the Ministry of Education). Prior to developing the program, a thorough context analysis of what was required to establish an effective INSET program in the Zimbabwe education system was carried out.

The Post Graduate Diploma in Science Education (PGDipScEd-INSET)

The intending resource teachers are trained through a diploma course at the University. They are selected from practicing teachers, using criteria agreed to between the University and the Ministry of Education. Among other requirements, prospective RTs must be certified university graduates with at least two years of teaching experience, and they must be currently teaching their subject at a school. They must be individuals who show initiative and interest in their own improvement as well as that of other teachers. For this reason, the input of regional education officers is sought prior to accepting a teacher into the diploma program.

The diploma is a two-year, part-time program structured so that students come for two-week residential blocks at the University during all school vacations over the two years. The sudents have assignments related to developing INSET in their regional and local contexts between residential periods. During residential periods the RTs study curriculum development, professional development, and education innovation, with special attention to subject-specific teaching strategies, research methods, and general administration and communication skills. During school terms students do research and development assignments to apply the theoretical knowledge in their own classrooms. This involves interviews with regional directors, education officers, school heads, and fellow teachers on issues such as the quality of education and how each of the different stakeholders measures it; the quality of teaching INSET programs of the

Ministry of Education; and indicators of support for the INSET program. Teaching within the diploma program follows constructivist approaches. Theory is immediately followed by practice, so that teaching skills are developed in parallel with theory. It is hoped that the program will produce fully functional resource teachers capable of performing a variety of roles.

The resource teachers are educated to perform the following functions:

- Provide solutions to peers on professional matters, and help in the transition of peers to full professional status
- Identify local teacher needs and organize periodic workshops for fellow teachers to address those needs
- Organize and chair regular peer cluster meetings to address local pedagogical issues
- Act as general managers of science and mathematics centers
- Report to the management committee of the center and other interested parties on the activities of the science and mathematics centers
- Identify teaching materials as well as teacher professional journals through the University SEITT core team and from other sources
- Network teacher groups, both within Zimbabwe and outside, by e-mail.

Progress

The first group of 47 resource teachers finished the program in 1997. They have now taken up their positions in the regions as qualified INSET staff. On the whole, the trained resource teachers have met expectations. In 1998 alone they held at least four subject-based workshops in most regions. Peer evaluation of these workshops has been very positive, with many participants asking for more such workshops. A minority of the RTs in each of the 10 centers have not played an active role, primarily because they have overloaded teaching timetables. This has tended to reduce the frequency of teacher meetings and slow down the workshop program. Those who have worked hard providing INSET workshops need to be recognized for their efforts by the Ministry of Education through reduced teaching loads and additional remuneration. If rewards are not provided, the program will continue to slow down due to frustration among the RTs.

It is anticipated that every Science and Mathematics Center (SMC) in the regions will serve as a meeting place for teachers to discuss professional as well as social issues. The SMCs will also run workshops on teaching skills and curriculum development and serve as documentation centers. With time and money, they could also act as equipment loan centers. At present, each center has a photocopier, a computer (with e-mail facility), a printer, and a range of A-level textbooks to facilitate lesson planning.

For an SMC to function well, certain conditions need to be met:

- Appropriate accommodation for equipment and teacher meetings must be available.
- A trained RT must be accessible to teachers using the center.
- A technician should be available to assist with equipment operation and repair.

- An interested management committee must be in place to supervise the operation and maintenance of the center.
- The regional office of the Ministry of Education must fully support the program and must be convinced that it can succeed.
- For a center housed within a school, there must be an understanding with the head of the host school that the administration of the school and the center are separate.

The intention is that SMCs will be housed in a classroom-laboratory with an adjacent storeroom within a high school. Seven of the nine regions have met this provision. Due to a space shortage, two SMC host schools were only able to release a storeroom for equipment storage and make classrooms and laboratories available when RTs organize teacher workshops. Seven of the 10 SMCs (one region has two centers) have at least one resident RT and all 7 have run several teacher workshops since the graduation of the RT's. Those without resident RTs have yet to run workshops.

Ideally, a management committee is available to every center. It should include at least four RTs, a technician, a secretary, a school development association (parents') representative, the headmaster of the host school, regional science and mathematics education officers, and the Better Schools program coordinator. All the centers that have properly constituted management committees have come up with annual budgets for the center and mechanisms to raise funds. Three centers that have not involved all the stakeholders in management are having administrative problems due to a lack of guiding principles and funding.

Further Development

Networking. An important strategy already employed, but to be utilized further, is to link the resource centers to create networks of teachers. Using computer technology, the Zimbabwe Science Network gives teachers the opportunity to interact with each other and teachers in other countries via e-mail. An Internet capability will be added at each center in the future. There is an active interest in communicating across centers via e-mail. Some regions have already run computer training sessions for the management committees. However, most people (including the teachers) still have computer phobia.

SEITT sees further networking possibilities through subject associations of teachers, who can greatly facilitate interactions among teachers of science and mathematics. These associations do formally exist, but are rather inactive. So far, the project has not been successful in reviving these associations, which are very entwined with Ministry of Education structures and include teachers who are not part of the SEITT program.

Production of curriculum materials by teacher groups. Most schools have a shortage of teaching materials. The teachers are not yet ready to accept peer-produced teaching materials. Before this happens, the teachers must begin to collaborate and gain confidence in each other through interactions at regularly scheduled workshops. Then teachers can start forming a writers' group. This development is slated to start in the coming years. With the assistance of the

University of Twente in the Netherlands, a computer-support system is being developed for the production and evaluation of curriculum materials.

Extension and expansion. A proposal for the second phase of this project is now being prepared. This phase is designed to consolidate achievements and work toward a fully functional support system of resource centers and teacher groups. In 1998 there was a second intake of 50 teachers in the diploma program. In the future, satellite centers will be formed at the district level, also supporting O-level teachers. This is a much larger group of teachers with (partly) different needs; and this presents a formidable challenge to the project.

Capacity building and evaluation research. The new proposal also includes further capacity building within the SEITT team at UZ, especially related to curriculum materials development and evaluation research. Besides running the diploma program and possibly establishing new SMCs, the team will also have to: plan for growth of the SMCs, supervise the implementation of INSET activities; and, with support from subject specialists, help develop and edit teaching materials. The evaluation of research projects will have an impact on the future strategies employed and materials produced.

Higher Education Institutions, Teacher Educators, and Professional Communities

Caillods, Göttelman-Duret, and Lewin (1997) express concern over the lack of information on the advantages of different teacher education approaches. They also deplore the complete absence of data on cost implications linked to measures of effectiveness. They suggest that the use of printed materials and school-based sessions run locally are the cheapest form of inservice support. This will, of course, ultimately depend on the quality of the materials and the professional level at which local staff are able to function. We should not lose sight of the fact that interventions need to be effective in order to be cost-effective. The direction for development proposed in this paper is investment in problem solving and development capacity at various levels and in building effective links between various levels. Simple center-periphery cascade approaches usually do not work.

Investment in problem solving and development capacity will require setting the professional development of teacher educators as a high priority area and strengthening teacher education departments (Nyagura 1996). An apex institution is needed to deliver high-quality teacher education programs, to train leadership for schools and regions, and to provide the nucleus of a professional community. De Feiter and van den Akker (1996) argue that in order to develop systematic problem-solving capacity in the system, teacher educators and teachers must become involved in developmental research. This form of research (alternatively called action research, formative studies, design studies) examines the impact of on-going intervention strategies and materials development. It is a promising way forward (van den Akker and Plomp 1993; van den Akker, Ottevanger and Plomp 1994). The main aims of developmental research are:

- To reduce uncertainty in making development decisions
- To optimize the quality of interventions

- To generate principles and methodological guidelines for designing, evaluating, and implementing interventions
- To stimulate the professional development of all participants.

Networks and professional associations can play an important role in the further development of a professional community—both nationally and in the southern African region. Professional science and mathematics teacher associations sometimes cooperate regionally (de Feiter and Thijs 1996). The Southern African Association for Research in Mathematics and Science Education is increasingly becoming a regional platform for exchange of experiences for science teacher educators and researchers (de Feiter and van den Akker 1996).

Acknowledgments

The authors are grateful to all colleagues who have contributed their comments to this paper and to related earlier work. Special thanks to Ian MacFarlane and Coen Stoll of the Vrije Universiteit and Professor Jan van den Akker of the University of Twente for their extensive contributions to an early version of this paper.

Dr. Leo de Feiter is a staff member of the Center for Development Cooperation Services of the Vrije Universiteit Amsterdam, where he is involved with the development and supervision of science education programs in various African countries. He is also involved in international postgraduate programs and research on science education development in cooperation with the University of Twente, the Netherlands.

Kenneth Ncube is a Lecturer in physics and physics education at the University of Zimbabwe. He is a member of the Science Education Inservice Teacher Training (SEITT) team (a project with the Vrije Universiteit Amsterdam) and National Chief Examiner for Ordinary-level Physics and Physical Science. He is currently engaged in research in pursuit of his Ph.D. in science education from the University of Twente.

References

Arnott, A., Z. Kubeka, M. Rice, and G. Hall. 1997. *Mathematics and Science Teachers: Demand, Utilisation, Supply and Training in South Africa.* Craighall: Edusource.

Beeby, C.E. 1966. *The Quality of Education in Developing Countries*. Cambridge, Mass.: Harvard University Press.

Benschop, M., C. Stoll, and L. de Feiter. 1996. *The Composition of the Namibian Science and Mathematics Teaching Force: Baseline Study*. Windhoek, Namibia: INSTANT project, Ministry of Basic Education and Culture.

Boerma, S. 1993. *Biology In-service Training in Swaziland: An Evaluation of the Approach of IMSTIP for Biology.* University of Twente, Faculty of Educational Science and Technology. Enschede, the Netherlands.

Caillods, F., G. Göttelmann-Duret, and K. Lewin. 1997. *Science Education and Development: Planning and Policy Issues at the Secondary Level.* Paris: UNESCO/IIEP, Pergamon.

Cantrell, M., W. Kouwenhoven, T. Mokoena, and G. Thijs, eds. 1993. *Bridging School and University. The Pre-Entry Science Course at the University of Botswana.* Amsterdam: Vrije Universiteit Press.

de Feiter, L. 1998. "Teacher Professional Development Strategies as a Key to School Improvement in Southern Africa." Paper presented at the 11th International Conference on School Effectiveness and Improvement, January 4–7, Manchester, United Kingdom.

de Feiter, L., H. Vonk, and J. van den Akker. 1995. *Towards More Effective Teacher Development in Southern Africa.* Amsterdam: VU University Press.

de Feiter, L., and J. van den Akker. 1996. "Findings, Priorities, Promises and Prospects." In C. Stoll, L. de Feiter, H. Vonk, and J. van den Akker, eds., *Improving Science and Mathematics Teaching in Southern Africa: Effectiveness of Interventions.* Amsterdam: Vrije Universiteit Press.

de Feiter, L., and A. Thijs. 1996. "Strategies for System-wide Sustainable Change: Review of Strand Contributions." In C. Stoll, L. de Feiter, H. Vonk, and J. van den Akker, eds., *Improving Science and Mathematics Teaching in Southern Africa: Effectiveness of Interventions.* Amsterdam: Vrije Universiteit Press.

Dekkers, P.J.J.M. 1997. "Making Productive Use of Student Conceptions in Physics Education." Ph.D. thesis. Vrije Universiteit Amsterdam, the Netherlands.

Fullan, M G. 1991. *The New Meaning of Educational Change.* New York: Teachers College Press.

Guthrie, G. 1980a. "Stages of Educational Development? Beeby Revisited." *International Review of Education* 26: 411–38.

———. 1980b. "Response [to C. E. Beeby] from Gerard Guthrie." *International Review of Education* 26: 445–49.

———. 1990. "In Defence of Traditional Teaching." In V. D. Rust and P. Dalin, eds., *Teachers and Teaching in the Developing World.* New York: Garland.

Joyce, B., and B. Showers. 1988. *Student Achievement Through Staff Development.* New York: Longman.

Keeves, J., and G. Aikenhead. 1995. "Science Curricula in a Changing World." In B. Fraser and H. J. Walberg, eds., *Improving Science Education.* Chicago: University of Chicago Press.

Lewin, K. 1992. *Science Education in Developing Countries: Issues and Perspectives for Planners*. Paris: UNESCO/IIEP.

———. 1995. "Development Policy, Planning and Practice for Science and Technology." Paper presented at the annual conference of the Southern African Association of Research in Mathematics and Science Education, Capetown, South Africa.

Mathot, G.B. 1996. "Report on the Development of Maths/Science Teaching Force in Lesotho from 1985 to 1994." Internal publication, CDCS, Vrije Universiteit Amsterdam.

Nyagura, L.M. 1996. "Educating Science Teachers for Life-long Learning: Trends, Problems and Prospects in Southern Africa." In C. Stoll, L. de Feiter, H. Vonk, and J. van den Akker, eds., *Improving Science and Mathematics Teaching in Southern Africa: Effectiveness of Interventions*. Amsterdam: VU University Press.

Ottevanger, W., M. Benschop, and J. van den Akker. 1995. "Teacher Guides for Science Curriculum Implementation in Namibia." Paper presented at the AERA annual meeting, April, San Francisco.

Rogan, J.M., and M.A. Mcdonald. 1985. "The In-service Education Component of an Innovation: Case Study in an African Setting." *Journal of Curriculum Studies* 17 (1): 63–85.

Ross, A., and K. Lewin. 1992. *Science Kits in Developing Countries: an Appraisal of Potential*. Paris: UNESCO/IIEP.

Sharifah, Maimunah, and K. Lewin, eds. 1993. *Insights into Science Education: Planning and Policy Priorities in Malaysia*. Paris: UNESCO/IEEP.

Stoll, C., L. de Feiter, H. Vonk, and J. van den Akker, eds. 1996. *Improving Science and Mathematics Teaching in Southern Africa: Effectiveness of Interventions. Proceedings of a Regional Conference, December 11–14, Windhoek, Namibia*. Amsterdam: VU University Press.

Tabulawa, R. 1997. "Pedagogical Classroom Practice and the Social Context: The Case of Botswana." *International Journal of Educational Development* 17(2): 189–204.

Thompson, A.R. 1995. *The Utilization and Professional Development of Teachers: Issues and Strategies*. Paris: UNESCO/IIEP.

van den Akker, J. 1994. "Designing Innovations from an Implementation Perspective." In T. Husén and T.N. Postlethwaite, eds., *The International Encyclopedia of Education*. Oxford: Pergamon.

———. 1998. "The Science Curriculum between Ideals and Outcomes." In B.J. Fraser and K.G. Tobin, eds., *The International Handbook of Science Education*. Dordrecht: Kluwer.

van den Akker, J., W. Ottevanger, and T. Plomp. 1994. "Development Research: A Promising Approach for Educational Improvement in Developing Countries?" Paper presented at the AERA annual meeting, April, New Orleans.

van den Akker, J., and T. Plomp. 1993. "Development Research in Curriculum: Propositions and Experiences." Paper presented at the AERA annual meeting, Atlanta.

van den Akker, J., and S. McKenney. 1996. "Improving Science Curriculum Practice in Schools: Review of Strand Contributions." In C. Stoll, L. de Feiter, H. Vonk, and J. van den Akker eds., *Improving Science and Mathematics Teaching in Southern Africa: Effectiveness of interventions*. Amsterdam: VU University Press.

van den Akker, J., and L. de Feiter. 1997. "Perspectives on Science Curriculum Renewal and Science Teacher Education World Wide." Presentation at the Seminar on the University of Dar es Salaam Science Teacher Education Programs.

van den Berg, E. 1996. "Science Teacher Development in Developing Countries." *Science Education International* 7(3): 3–8.

van den Berg, E., and G. Giddings. 1992. *An Alternative View of Laboratory Teaching*. Perth, Australia: Curtin University of Technology.

van den Berg, E. , V.N. Lunetta, and M. Finegold. 1994. "Teacher Strand Report: The Teacher and Science Education in Developing Countries." Paper presented at the annual meeting of the National Association for Research in Science Teaching, Anaheim, Calif.

Verspoor, A.M., and J.L. Leno. 1986. *Improving Teaching: A Key to Successful Educational Change*. Education and Training Department, Report EDT50. Washington, D.C.: World Bank.

Verspoor, A., and K.B. Wu. 1990. *Textbooks and Educational Development*. PHREE background paper series PHREE/90/31, Education and Employment Division, Population and Human Resources Department, Washington, D.C.: World Bank.

Volmink, J. 1996. "A Systemic Approach to Sustainable Innovation in Science Education in South Africa." In C. Stoll, L. de Feiter, H. Vonk, and J. van den Akker, eds., *Improving Science and Mathematics Teaching in Southern Africa: Effectiveness of Interventions*. Amsterdam: VU University Press.

Vonk, H., and M. Kapteijn. 1996. "Educating Science Teachers for Life-long Learning: Review of Strand Contributions." In C. Stoll, L. de Feiter, H. Vonk, and J. van den Akker, eds., *Improving Science and Mathematics Teaching in Southern Africa: Effectiveness of Interventions*. Amsterdam: VU University Press.

Walberg, H.J. 1991. "Improving School Science in Advanced and Developing Countries." *Review of Educational Research* 61: 25–69.

Ware, Sylvia A. 1992. *Secondary School Science in Developing Countries*. PHREE background paper series PHREE/92/53. Education and Employment Division, Population and Human Resources Department. Washington, D.C.: World Bank.

Challenges to Reforming Science Education in South Africa: What Do the Third International Mathematics and Science Study Results Mean?

Sarah J. Howie

This paper discusses the participation of South Africa in the Third International Mathematics and Science Study (TIMSS). As this nation reforms its education system to better serve the needs of all its citizens, the reform of science, mathematics, and technology education has become a national priority. Monitoring the new government education program by way of involvement in international studies is one way of objectively assessing positive (or negative) trends in South African education. Furthermore, system-level monitoring of science education is vital as a baseline from which to monitor progress in implementing the reform agenda. The impact of the TIMSS results for South Africa has brought the national spotlight to bear on weaknesses in the system, and has added an impetus to the reform process. The field work component of the TIMSS presented a number of challenges to the project team, but the overall experience was successful and should contribute positively to the improvement of science and mathematics education at the secondary level in South Africa.

Introduction

One of the biggest challenges facing South Africa at present is the provision of high-quality education for all its children. Education—the key to a genuine participatory democracy— is also the foundation for the achievement of sustainable development in any country.

South Africa's 41.5 million people form a multicultural society and the population consists of four ethnic groups: Indian (1 million people), Colored (3.5 million), White (5.4 million), and Black (31.6 million) (Central Statistical Services 1995). There are 11 dominant languages spoken, all of which have been declared official languages of the country. In practice, English (spoken by 9.1 percent of the population as a home language) is the language of business and government (replacing Afrikaans). However, it is not the most widely spoken language at home (Central Statistical Services 1995).

South Africa is an economically and industrially developing country where first and third worlds meet. The majority of the population still reside in typical developing world impoverishment, while state-of-the-art technology in manufacturing and mining (in particular) is being developed and utilized by South Africa's scientists and engineers. Some of the significant challenges facing South Africa are discussed briefly below.

World Competitiveness in a Global Market

In 1995 South Africa was placed 42 out of 48 countries in the annual World Competitiveness report of the Economic Forum and the Harvard Institute for International Development. In particular, South Africa was placed 48/48 for the development of human resources for a

competitive economy. In 1997 South Africa was placed 44 out of 53 countries, below countries like Brazil and Colombia, and was again placed last with regard to the development of human resources. In the 1998 Africa Competitiveness report South Africa was placed seventh, behind Mauritius, Tunisia, Botswana, Namibia, Morocco, and Egypt.

Unemployment and Economic Growth in South Africa

More than nine million South African children live in poverty-stricken homes (HSRC 1998). The South African Institute of Race Relations survey of 1995/96 calculated an unemployment rate of 32.6 percent of the economically active population of 14.3 million South Africans, with 41.1 percent for the Black population. In some provinces, unemployment figures stand at more than 40 percent (Central Statistical Services 1995). It is estimated that in 2010 there may be eight million unemployed people and a shortage of 200,000 skilled workers. It has been further estimated that only 7 out of every 100 people who seek employment will find it (Gouws 1997). In order to attempt to rectify the situation outlined above, South Africa needs a real GDP growth of 6.1 percent by 2000, in contrast to the current rate of between 2.0 and 2.5 percent (Van Eldik 1998).

Education in South Africa

South Africa's political history is well known. Its impact on the education system and the youth who have passed through this system is especially devastating. The illiteracy rate of 55 percent among South Africa's disadvantaged communities illustrates this (Gouws 1997). South Africa is now divided into nine provinces incorporating former provinces and Black homelands. These new provinces have undergone the difficult task of merging several former departments. The present education system is an amalgamation of 17 different education departments that were merged in 1995 as a result of the change in government policies. Underresourced and often mismanaged, many of these departments provide insufficient and ineffective education to millions of young people, especially from the so-called Black, Colored, and Indian communities. The education system is still grappling with the inequalities of the previous system, while trying to maintain the standard of education received by the White students of previous years.

South Africa has two types of schools: government and private schools (which can be church-funded, commercially run, or run by nongovernmental organizations). In total, there are more than 32,000 schools, of which the majority are comprehensive in nature (that is, they offer general education). Students enter school in the year when they become seven years old. Schooling, at present, is divided into five phases: preprimary (grades 1–2), junior primary (grades 3–5), senior primary (grades 6–7), junior secondary (grades 8–9), and senior secondary (grades 10–12). Although schooling is compulsory up to the end of grade 9, absenteeism is rife and there is also a high drop-out rate throughout schooling.

Conditions in many South African schools are the same as in developing countries. In 24 percent of the country's schools there is no running water within walking distance. Sixty-seven percent of the schools have no electricity and, in most provinces, between 50 and 80 percent of the schools have no telecommunications; 13 percent of the schools have no toilets. Many schools

have a serious shortage of classrooms and, of these, many are in an uninhabitable condition. The student-to-teacher ratio is also very high; and in three provinces it was found to be more than 40 to 1. It is not uncommon to find classes of more than 100 students being taught by one teacher in classrooms designed for 30 students (HSRC 1997).

The present government has been working with these difficulties since the 1994 election. A number of government papers have emerged, including the White Paper on Education and Training, highlighting the government's awareness of their inheritance as well as intended policies to bring about change. These papers marked the beginning of a new era in education in South Africa. For instance, education and training are combined in all of the education department's documents, in recognition of the importance of training in schools, teacher training colleges, and other tertiary institutions. It is also seen as a move toward integrating the academic and practical, theory and practice, knowledge and skills, and the mind and the hand. This approach underpinned the launch of the new education system in 1995, and is found throughout the proposals for curriculum reform.

It is within this context that the challenges for science education in South Africa, with special reference to the TIMSS, will be discussed and presented.

Science Education in South Africa

Science and technology have proven to be two of the major factors driving development within countries. However, this is still underestimated as a factor by many decisionmakers and politicians looking for short-term success and benefits. The short-term perspective presents inherent problems for the basic sciences. In Africa most countries invested in curriculum development in school science, mathematics, and technology after independence. However, due to several socioeconomic factors, such as instability in government, growing populations, unemployment, and collapsed economies, these countries have been unable to achieve self-reliance with respect to scientific and technological workforce development. Two of the primary reasons for this failure have been a lack of emphasis in the policies on science, technology, and mathematics education as a route to science and technology manpower development and inadequate statistics on which to base their development plans. South Africa needs to be cognizant of the experience in other African countries and, in particular, recognize that the link between policies in science and technology and policies in science, technology and mathematics education must be clearly recognized.

Successful South African School-Leaving Students

The matriculation examination (the external final examinations taken at the end of grade 12) figures have often been used as an indicator of South African students' performance at the school level. At the end of 1997 the results were the lowest recorded since 1979. While the number of candidates sitting for these examinations increased by 7 percent from 1996, the percentage of failures increased by 23 percent (Shindler 1998). The inefficiency of the government school sector, in particular, results in resources being applied to students who do not pass through the system successfully. This is problematic, as most of these schools have very scarce resources. In

an historical overview of school enrollments and success rates at school, de Villiers (1997) quotes very disturbing figures. When analyzing students from different ethnic groups and their progress through the schooling system, he found the following:

- 69 out of every 100 grade 1 White students complete their matriculation examination within 12 years
- 62 out of every 100 grade 1 Indian students complete their matriculation examination within 12 years
- 19 out of every 100 grade 1 Colored students complete their matriculation examination within 12 years
- 8 out of every 100 grade 1 Black students complete their matriculation examination within 12 years.

One of the issues clearly emerging is that these high failure rates indicate that there is a problem in the junior phases of the education system. Certainly, pushing students up into a higher grade without them seemingly being able to cope with that year's work is resulting in high failure rates in the final year of schooling.

The South African White Paper on Education singles out mathematics and science as important school subjects and recognizes the importance of more students leaving school proficient in these subjects. In primary school and junior secondary school physical science is taught together with biology as general science. General science and mathematics are compulsory until the end of grade 9. After grade 10 general science is separated into physical science and biology and these subjects, together with mathematics, become optional.

The situation regarding the enrollments in mathematics and science and the matriculation exemption with these subjects also varies dramatically among ethnic groups. For instance, while only 1 in 312 Black students entering the school system leaves with physical science and mathematics as final-year subjects, 1 in 5.2 White students, 1 in 6.2 Indian students, and 1 in 45.9. Colored students obtain a matriculation exemption with physical science and mathematics (Blankley 1994). In 1993, while 49.6 percent of all White students took physical science in their final year, only 11.7 percent of all Black students took this subject for their school-leaving certificate. Of this number, 98 percent of White students compared to 50 percent of Black students passed their final-year examination. Of the total of 119,530 students who took the physical science examination in 1995 only 68,954 passed (54 percent) (Edusource 1997). In 1993 the figures show that only 26 percent of all Black students took mathematics compared with 37.5 percent of all White students. However, of those numbers, only 25 percent of Black students pass their final mathematics examination compared with 95 percent of White students (FRD 1996). On average, from 1991 to 1994, 45 percent of Black students passed their final physical science examination, and a mere 24 percent passed their final mathematics examination (FRD, 1996). The difference between the mathematics and physical science results may be attributed to the greater numbers taking mathematics, the fact that mathematics is a prerequisite for physical science, and only a select few even take physical science (13 percent of Black students in 1993).

Despite the increase in the debate around mathematics and science education and the need for more students to enter these classes, there is still inadequate funding of school mathematics, science, and technology-based subjects. Recent studies (FRD 1993 and Edusource 1997) show a real need for well-equipped laboratories, workshops, and libraries. Seventy-two percent of schools did not have libraries, and between 22 percent and 75 percent of schools (depending on the province) did not have physical science laboratories.

Third International Mathematics and Science Study in South Africa: The Challenges

It was in this context that the Human Sciences Research Council (HSRC) decided to participate in and conduct the TIMSS in South Africa. The challenges posed by undertaking a project of this nature and scale in South Africa were substantial. Being one of the very few developing countries in this international study meant that South Africa's participation was particularly significant.

Reasons for South Africa's participation in the Third International Mathematics and Science Study

The matriculation results of South African students in mathematics and science have suggested, for some time, the need for improved performance of South African students in these subjects and, in particular, an improvement in their understanding of basic science and mathematics. The primary reason for the HSRC undertaking TIMSS in South Africa was to use it as a longitudinal study to monitor the changes taking place in South Africa during and after the transition of the new government and introduction of the education reforms. These reforms include the new curriculum, Curriculum 2005, an outcomes-based model that is currently being implemented in its pilot phase. It was thought that TIMSS would be useful in monitoring trends in teaching and learning in mathematics and science on a national and provincial scale. Initially, it was felt that the curriculum-based research undertaken as part of the TIMSS project would be useful to compare the South African curricula to those of other countries.

Students who participated in the Third International Mathematics and Science Study in South Africa

TIMSS focused on 9-year-old students (grades 3 and 4), 13-year-old students (grades 7 and 8), and final-year secondary school students (grade 12), but South Africa participated in only the grades 7 and 8 and the grade 12 groups. Students in South African schools learn in their mother tongue or home language until grade 5, when the language of instruction becomes either English or Afrikaans.

Translating the test papers into another nine languages was not possible at the time of testing and testing these very young children in English or Afrikaans did not seem to be an option, given that they had received only two months of instruction. Thus the decision was made to exclude the first population group of 9-year-old students. A nationally representative sample yielded 300 schools for the 13-year-old age group. This included 150 primary schools and 150 secondary schools, as two grades containing the most 13-year-old students had to be tested and these two grades straddled the last year of primary school and the first year of secondary school.

The final-year students' (grade 12) sample was the same as the secondary schools that were used for the grade 8 students (150 secondary schools).

South Africa participated in the science and mathematics literacy test rather than the specialized mathematics and physics tests. The reason for this was that the mathematics and physical science curriculum followed by South African schools at the final-year level is not as specialized as in other countries. Therefore, it was felt that it would be inappropriate for South African students to take these specialized tests. Furthermore, it was also relevant for researchers to ascertain the mathematical and scientific literacy of the general population of students in their final year.

A national sample of schools, fully representative of provinces, race groups, and urban and rural communities, was randomly selected. This sample consisted of 14,020 students—5,532 from grade 7, 4,793 from grade 8, and 3,695 from grade 12. The volume of data retained after the data-cleaning process was such that the results presented in the national and international reports reflect the achievement of 12,437 South African students, of whom 5,267 were in grade 7 at 137 schools, 4,413 in grade 8 at 114 schools, and 2,757 in grade 12 at 90 schools (Howie 1997; Howie and Hughes 1998).

Third International Mathematics and Science Study Project Challenges

The challenges facing the TIMSS project team were many and varied. First, it was the first time that a survey of this size had been carried out in science and mathematics education in South Africa. Approval for the project was delayed, leading to a situation in which the researchers were under constant pressure for the remaining years of the project to catch up with the international deadlines. Training courses were conducted for the researchers working on the team to build the necessary capacity to undertake the project.

The field work in itself was the biggest challenge. A company specializing in data collection was contracted to collect the data and appoint external test administrators to collect data in each of the participating schools. The challenges in conducting the field work in South Africa arose from:

- A lack of information about the schools, due to incomplete lists of schools or departmental staff not cooperating
- Difficulty in communicating with the schools, due to no telephones or inefficiency within the schools
- The isolated situation of schools (including some schools that could only be reached on foot)
- The fact that, at the time of the data collection, the provincial boundaries were being modified
- The presence of schools in the sample that did not exist, a phenomenon in South Africa called "ghost" schools
- An inefficient postal service that resulted in a large number of lost letters and returned questionnaires
- The geographic size of the country

- Vehicle breakdowns, poor roads and lack of roads, accidents
- A general lack of cooperation on the part of some schools, with staff members being absent without reason.

Many of these challenges were addressed by the persistent field-workers and the national center project staff. For instance, some schools were visited up to four times in an effort to secure testing times and to test the students. Replacement schools were also used in cases where even this persistence was inadequate. The assistance of the provincial authorities was invaluable in locating schools and in giving the field-workers access to the schools. The experience of many of the field-workers (given these types of conditions) resulted in the relatively successful response rate of 91 percent for grade 7 classes sampled, 76 percent for grade 8 classes sampled, and 60 percent for grade 12 classes sampled (including replacement schools).

Third International Mathematics and Science Study Results and Their Impact in South Africa

The Results

The results for the South African students taking part in TIMSS, although not unexpected, were received with shock and dismay by the broader community. A summary of the findings mostly taken from the national reports (Howie 1997; Howie and Hughes 1998), with special reference to the South African students' performance in physical science, is presented below.

The overall results for grades 7 and 8 and grade 12 students were very low compared with other countries, and in fact were the lowest of all countries participating (table 1). This was also true for the results in mathematics and science, for both population groups. For grades 7 and 8 the overall mean was not calculated and is presented by subject only in table 1.

Table 1 Overview of Results for Performance of South Africa's Grades 7, 8, and 12 in Physical Science

Grade	Overall South African mean	International mean	Mathematics mean	International mathematics mean	Science Mean	International science Mean
Grade 7	–	–	348	484	317	479
Grade 8	–	–	354	513	326	516
Grade 12	352	500	356	500	349	500

The following findings were made from the achievement tests:

- The difference in the results for students in grades 7 and 8 was minimal and represented the lowest increase resulting from the lower grade to the upper grade of all the countries taking part.
- South African students in grades 7 and 8 and 12 did not excel in any individual science topic in the TIMSS test.
- In both grades 7 and 8 and 12, students struggled with the free-response questions and appeared unable to formulate their own answers.
- In grades 7 and 8 the performance of students on the science questions, based on the physical science curriculum, was the same as their performance in those questions that were not covered in the curriculum.
- There was evidence among students from all three grades of language difficulties and in both populations approximately 80 percent of the students took the tests in their second language. In grade 12 students with English or Afrikaans as their home language (the language of instruction and hence the language of the test) performed better than those speaking another language at home.
- South Africa was the only country with no significant difference between the performance of boys and girls in grade 12, and one of very few countries displaying no gender difference in grades 7 and 8.
- The performance of the final-year students varied considerably across different provinces in South Africa. Students from the two most economically impoverished provinces with the greatest number of underresourced schools performed worst in the grade 12 science literacy test and overall.
- The grade 12 students who did not take science at school did not score significantly less in the science literacy test than some groups of students (for instance those taking physical science standard grade with mathematics higher grade) taking mathematics and science at school. In fact, the highest scores from this "nonscience" group of students exceeded the national average and were comparable to the international average.

From the students' questionnaires, it was determined that:

- In grades 7, 8, and 12 students were older than their international counterparts in TIMSS, with one exception—the grade 12 students from Iceland were older.
- The amount of homework given to grade 7 and 8 students was much less than the international average for grades 7 and 8.
- South African grades 7 and 8 students spent less time learning in the classroom than students in the top-performing countries.
- The average number of books in the homes of students in all three grades was substantially less than the international average.
- Students in grades 7, 8, and 12 chose biology as their preferred science subject, with chemistry at the bottom of the list of choices.

The media attention given to the results of TIMSS generated much interest in education in political circles as well as among leaders in the scientific and technological fields. As a result, several initiatives have been undertaken in the field of science and mathematics education. The TIMSS results have been discussed at the cabinet level, where opposition party politicians have placed pressure on the education minister to follow up on the findings of TIMSS and to launch new initiatives. Most significantly, during a parliamentary debate, the education minister stated that

> "aspects that will receive particular attention are: addressing the mismatch between South Africa and international curricula . . . addressing the structure of text-books . . . [and] investigating the use of innovative methods and classroom approaches." Further aspects to be attended to are: "acquiring information on the syllabuses and methodologies on the seven best countries . . . comparing their education systems and curricula, and extracting the best to be implemented in South Africa . . . formulating a national mathematics, science, and technology vision . . . [and] promoting mathematics, science, and technology education among girls" (National Assembly 1997).

TIMSS has also added weight to the implementation of the Year of Science and Technology during 1998, where the Department of Arts, Culture, Science and Technology has been arranging, together with the science councils and the private sector, national initiatives at provincial and local levels to generate a public awareness and interest in scientific and technologically related fields. Finally, the Department of Education, disturbed by the mature age of the students highlighted by the TIMSS findings, has launched an enquiry into reasons for this.

Challenges to Reforming of Science Education in South Africa

While there has been a lot of talk in government circles about the importance of mathematics, science, and technology and about increasing the numbers of students taking on these subjects, there still appears to be inadequate funding of school science, technology, and mathematics subjects, as well as an inadequate provision of facilities and equipment at many schools. The African National Congress (ANC) policy framework document (1994) described the situation in science education as the following:

> "Science and mathematics education in Black schools in South Africa is characterised by a cycle of mediocrity. The infrastructure for the teaching of science and mathematics is poor, especially at senior secondary level. Materials are in short supply. Most schools lack laboratories. Teachers are under qualified. In Black colleges of education science and mathematics are low status subjects only taught at matriculation level to diploma students. Under qualified and poorly prepared teachers in turn produce weak and poorly prepared school students . . . The cycle of mediocrity is reinforced by the unsuitable nature of the science and mathematics curriculum in the schools. The curriculum is academic, outmoded, and overloaded. Applied science and technology as well as the social and ethical aspects of science are excluded. The consequences of a lack of a

suitable curriculum cut across racial divide. Only 12 percent of higher education students pursue degree and diploma programmes in engineering and the life, physical and mathematical sciences."

The cycle of mediocrity described above can also be compared to the "vicious circle" described by de Feiter, Vonk and Van den Akker (1995), concerning the BoLeSwa (Botswana, Lesotho, and Swaziland) countries and, in fact, does not appear to be unique to South Africa. From the TIMSS results and the current state of affairs in science education in South Africa, the following specific challenges are highlighted.

South Africa's Curricula

Over the years, concern about South Africa's curricula has led to the present government introducing Curriculum 2005 to "develop citizens who are active and creative inventors and problem-solvers, rather than dependent and unthinking followers, and also to inculcate an appreciation for diversity in the areas of race, culture and gender. " Curriculum 2005 is seen as the boldest attempt at curriculum renewal in South Africa' recent history. It aims to align the schools with the demands of the workplace and the social and political aspirations of South Africa's citizens. First, the contents of the curriculum are being rewritten in terms of clearly defined outcomes, and second, there is a planned shift in the focus of classroom activity to student activity and collaborative learning. While the intentions are noble, other concerns include the fact that this outcomes-based approach has been tried in other countries without success.

Science Educators in South Africa

There is serious concern among educators in South Africa that the underqualified or unqualified teachers will not be able to implement the new Curriculum 2005. The provision of well qualified and well-trained, competent teachers is surely the most essential component of any effective science and mathematics education program. However, South African teachers are suffering from low morale related to many factors, including the uncertainties associated with the changes and reform in education, low and delayed salaries, threats of retrenchment, re-deployment, lack of confidence, unmotivated and ill-disciplined students, no support staff, and a lack of teaching materials.

Currently, there is an insufficient supply of adequately trained mathematics and science teachers. In particular, if one looks at science, less than 50 percent of science teachers have accredited training in science. Approximately 42 percent of science teachers have only one year of training. There is also a lack of science-teaching experience in both general science and physical science. More than 45 percent of general science (taught in grades 9 and lower) teachers and nearly 40 percent of physical science (taught in grades 10–12) teachers have fewer than two years' teaching experience (Edusource 1997). Aggravating the situation, there is also a very high attrition rate, as about 2,100 science teachers leave the teaching profession each year.

South African Students Studying Science

South African students experience a number of problems with science, technology, and mathematics, some of which have been highlighted by TIMSS. They too battle with insufficient resources, the language (especially when science is being taught in a second or third language), and the usually poor infrastructure of the school in the most disadvantaged areas.

Where resources are insufficient, in less developed countries in particular, the use of a textbook has been shown to have a positive effect on students' learning. Thus students with no access to textbooks are at a disadvantage. Students often do not have the motivation to study, and absenteeism is rife among a large number of schools in certain communities, making teaching and learning almost impossible. Many girls are taken up with household chores that they are expected to complete in the absence of a parent and, therefore, they experience many problems completing the homework tasks assigned to them.

Culture and Attitudes in Education

With education having been at the forefront of the political struggle against the previous Apartheid government (for example, the Soweto schools uprising in 1976), a culture of resistance to teaching and learning crept in among teachers and students. This attitude still exists despite the political changes since 1994. This mode of resistance often manifests itself as apathy to learning and teaching in many of the formerly Black schools, obstructs many of the initiatives under way in education, and prevents students and teachers from settling into good classroom practices. One of the basic challenges is to reach the situation where teacher and students are in the classroom for the same length of time simultaneously, so that effective teaching and learning can take place.

Financial Concerns Related to Science Education

As mentioned previously, many schools lack the basic facilities, such as toilets, running water, electricity, and telecommunications. Furthermore, many schools are without textbooks, classrooms, libraries, and laboratories, making science teaching, in particular, very difficult. With up to approximately 90 percent of the education budget being spent on teachers' salaries (Bot 1998), large-scale retrenchments are currently under way in order to find money for equipment, textbooks, and facilities. The fact that expenditures on textbooks decreased by 41 percent between 1995 and 1996 is alarming, especially for physical science (Bot 1998). In areas where there are no facilities like libraries, both students and teachers rely heavily on the textbooks as their sole resource in this subject (and others). As a result of the cuts in the expenditures on textbooks, many students will go through school with no access to learning resources or materials. No change in this situation is foreseen in the short term.

The Way Forward

Since 1994 South Africa has developed policies in both education and science and technology. However, to date, there has been no close cooperation between the two departments producing these policies—the Department of Education and the Department of Arts, Culture, Science and

Technology. At present, innovation in South African education is heavily influenced by the experiences of the more-developed countries, especially the United Kingdom, the United States, Australia, and Canada. There are frequent visits to and from these countries by education specialists.

Bloom, in his discussion of ways to improve school instruction and curriculum, stated that the "most costly approach [to reform education] is to embark on a major reform of the curriculum. The success of this depends very much on the availability of highly trained curriculum specialists, who carefully weigh up the effectiveness of each new step as it is implemented. Success depends on the thorough retraining of existing teachers who are going to be involved in teaching according to the new curriculum" (Maphai, Wedepohl, and Howie 1996). Curriculum 2005 appears to be driven largely by a political agenda and, therefore, the time pressures are great on the implementers. As stated by van den Berg (Maphai, Wedepohl, and Howie 1996) "one cannot expect underqualified teachers to implement a new curriculum that incorporates the most modern teaching philosophies. Teacher development projects in all developing countries should not provide recipes for all schools and all teachers, but should choose different approaches depending on the school and teacher backgrounds."

Unfortunately, the above sentiments are seldom expressed and any concerns raised by those in education are seen as unpatriotic, instead of being considered as constructive criticism. A critical analysis as well as a monitoring system will have to be put in place to keep track of the development and implementation of Curriculum 2005, to ensure the most successful implementation possible. This is a role that the HSRC could play with projects such as TIMSS and the intended longitudinal project in mathematics and science.

Preparation of Science Educators

The preservice training of teachers is in a state of flux as the colleges of education are being reshaped, and the curricula in teacher education programs (at colleges of education, technikons and universities) nationally are being reviewed in preparation for the new school curricula. While many colleges are being transformed into agricultural, nursing, and community colleges, several have been merged with other colleges, closed, or affiliated with universities. However, since there is a question mark over the quality of teachers being produced by these colleges, careful attention will need to be paid to improving the quality of science and mathematics teachers emerging. A college specializing in the production of science and mathematics teachers has recently been established in an attempt by the government to address the question of the quality of science and mathematics educators graduating from these colleges.

Over the past two decades many initiatives have been launched in science and mathematics education by nongovernmental organizations. Many of these have focused on in-service training, but have been forced to close through the shortage of funding since the elections. The Department of Education will have to resume this part of the training on a larger scale to take the place of these organizations and to retrain teachers for the new curriculum, or else seek ways to delegate some of this responsibility to existing organizations and strive for closer collaborations in this area.

Contribution of Information and Communications Technology to Education

There are clear indications that a linear expansion of South Africa's current education and training systems is beyond the country's reach. An approach requiring transformation using interactive electronic technologies together with the most advanced telecommunications system and interactive multimedia courseware appears to be what is required. However, the challenge to South Africa is to seek and select appropriate combinations of electronic media, face-to-face delivery, and "learning at a distance" delivery approaches. Different technologies have different suitabilities and have to be assessed accordingly for their learning gains, appropriateness, quality, efficiency, and, ultimately, their cost-effectiveness. The challenge in the future will be to cater for both mass audience needs (especially in the informal and nonformal education sectors) and the more specialist needs-driven courses in the formal sector.

Government Policies and Interventions in Science Education

The White Paper on Science and Technology (1996), published by the Department of Arts, Culture, Science and Technology, emphasizes the importance of an awareness and understanding of science, engineering, and technology (SET). The importance of a national campaign to promote the public understanding of SET is seen to be an integral part of the government's plan to close the gap between the industrial and the developing segments of South Africa's population. The importance of SET awareness so explicitly stated in these papers emphasizes the need for the successful implementation of a National System of Innovation (NSI) in South Africa. The NSI is a system whereby knowledge, technologies, products, and processes must be converted into increased wealth and an improved quality of life for all South Africa's citizens. The aims within the White Paper are such that only with the close collaboration of the Department of Education can they be realized successfully.

Partnerships to Reform Science Education

Partnerships will play an important role in the future of science education in South Africa. These will be between the Department of Education; the Department of Trade and Industry; the Department of Labour; the Department of Arts, Culture, Science and Technology; industry and the private sector; and parents, schools, and their local business community. Local communities and local businesses must become more involved if the financial challenges facing education are to be met. Parents will have to pay school fees if their children are to benefit from education. Attitudes of entitlement (to free education) will have to be overcome, and the culture of teaching and learning restored, before education can make headway in these challenging times. Strict financial planning and management will need to be implemented in order to allocate the resources needed for textbooks, equipment, and facilities for underprivileged schools. With the devolution of power to the provinces as well as financial control over spending, provincial authorities will have the responsibility for planning and addressing their local needs.

The active promotion of science education for sustainable development by all must be undertaken by national and provincial government, commerce and industry, and communities, all working together. Collaboration between the four principal government departments mentioned

above is essential to ensure the formation of links between science and technology policies and science education policy, ultimately leading to the successful reform of science education in South Africa.

Producing a Winning Nation

If South Africa is going to compete effectively in world markets, a well-educated corps of people with knowledge and skills at all levels in mathematics, science, technology, economics, and communication will be needed. Government leadership will be crucial to drive this process forward publicly as it will have to demonstrate commitment and political will for the sake of long-term benefit to the whole country.

To produce this effective, well-educated workforce, well-qualified and motivated teachers of these subjects are needed. The prime reason often stated by students for going into careers in science and technology is the quality of their mathematics and science teachers at school. Only with competent, dedicated, inspiring teachers will science education reform be possible.

Monitoring government plans by way of involvement in international studies is one way of objectively assessing positive (or negative) trends in education. Furthermore, system-level monitoring of science education is vital to assess the impact of past policy; to identify interventions and their cost effectiveness, and to judge whether levels of student participation can or should be increased (Caillods, Göttelman-Duret, and Lewin 1997). The information gathered by TIMSS put the spotlight on mathematics and science education in South Africa and contributed to the introduction of various initiatives in mathematics and science education in this country. Comparing South Africa's students' performance in mathematics and science and its education system with other countries' education systems may result in many lessons being learned for the future and, thereby, many support the successful implementation of science education reform in South Africa.

Finally, cognizance must be taken of the fact that time is needed for the changes and reforms to be developed and implemented before their impact can be measured. The situation in science education cannot be rectified overnight, as it is the result of many complex factors impacting over a significant period of time. It is believed that only a comprehensive, strategic, and collaborative national effort can hope to meet the challenges that South Africa faces in the reformation of science education.

Acknowledgments

I would like to acknowledge the contributions of Professor Peter van Eldik and Professor Tjeerd Plomp. Their valuable comments contributed to the writing of this paper.

Dr. Sarah Howie is the Chief Researcher in the unit for Education and Training Systemic Studies at the Human Sciences Research Council in Pretoria, South Africa. She is the National Research Coordinator for TIMSS and TIMSS-Repeat for South Africa.

References

African National Congress. 1994. *A Policy Framework For Education and Training, Education Department.* Pretoria: African National Congress.

Blankley, W. 1994. "The Abyss in African School Education in South Africa." *South African Journal of Science* 90 (2): 54.

Bot, M. 1998. "Education Spending in the Provinces." *Edusource Data News* 20 (March).

Caillods, F., G. Göttelman-Duret, and K. Lewin. 1997. *Science Education and Development Planning and Policy Issues at the Secondary Level.* Paris: UNESCO and Pergamon Press.

Central Statistical Services. 1995. *South African Statistics 1995.* Pretoria.

de Feiter, L., H. Vonk, and J. Van den Akker. 1995. *Towards More Effective Science Teacher Development in Southern Africa.* Amsterdam: Vrije University Press.

de Villiers, A. P. 1997. "Inefficiency and Demographic Realities of the South African School System." *South African Journal of Education* 17 (2): 79–80.

Department of Education. 1997. *A Programme for the Transformation of Higher Education.* Education White Paper No. 3. Pretoria: Department of Education.

Edusource. 1997. *Mathematics and Science Teachers: Demand, Utilisation, Supply, and Training in South Africa.* Johannesburg.

FRD (Foundation for Research Development). 1993. *SA Science and Technology Indicators.* Pretoria.

———. 1996. *SA Science and Technology Indicators.* Pretoria.

Gouws, E. 1997. "Entrepeneurship Education: An Educational Perspective." *SA Journal of Education* 17 (3): 143.

Howie, S. J. 1997. *Mathematics and Science Performance in the Middle School Years in South Africa: A Summary Report on the Performance of the South Africa Students in the Third International Mathematics and Science Study.* Pretoria: Human Science Research Council.

Howie, S. J., and C. A. Hughes. 1998. *Mathematics and Science Literacy of Final-Year School Students in South Africa: Third International Mathematics and Science Study.* Pretoria: Human Sciences Research Council.

Howie, S., and P. Wedepohl. 1993. *Investigation of Science Teacher Education in Five Sub-Saharan Countries—A Comparative Overview.* Pretoria: Foundation for Research and Development.

HRSC (Human Sciences Research Council). 1997. *Schools Needs Based Survey Database.* Pretoria.

1997. *Interpellations, Questions and Replies of the National Assembly.* 1997. February 19, pp.111–114. Pretoria.

1997. *Interpellations, Questions and Replies of the National Assembly.* August 27, pp.2258-2261. Pretoria.

Jaff, R., M. C. Rice, and J. Hofmeyr. 1996. "The National Teacher Education Audit." *The Colleges of Education Report.* Johannesburg.

Lewin, K. 1995. "Development Policy and Science Education in South Africa: Reflections on Post-Fordism and Praxis." *Comparative Education* 31 (2).

Maphai, V., P. Wedepohl, and S. Howie, 1996. "The Importance of Mathematics and Science in South Africa." Human Sciences Research Council Internal Paper. Pretoria.

Shindler, J. 1998. "An Analysis of the 1997 Standard 10 Examination Results." *Edusource Data News* 20 (March).

van Eldik, P. 1998. "The Role of Higher Education in Technological Innovation in Economically Developing Countries." Paper Presented at the 38th Annual Forum of the Association for Institutional Research, May 17–20, Minneapolis, Minn.

Department of Arts, Culture, Science and Technology. 1996. *Preparing for the 21st Century.* White Paper on Science and Technology. Pretoria.

Department of Education. "White Paper on Education 1995." Pretoria.

Woolnough, B. E. 1994. *Effective Science Teaching.* Buckingham: Open University Press.

The Internet in Our Classrooms: Teaching Tomorrow's Skills For Tomorrow's World

Boris Berenfeld

In addition to industrial countries, an increasing number of developing countries are investing enormous resources to ensure students' access to the Internet. However, the question remains, "Why connect?" What is the rationale for linking classes to the world of telecommunications? This paper defines six major educational functions of the Internet and discusses their role in preparing students to live and thrive in the "Third Wave" postindustrial society. Specific emphasis is placed on the role of computer-mediated communications to support international student communities of practice. Based on a number of pioneering projects that involved students from both industrial and developing countries, this paper describes how, united by common goals and mutual activities, student networked communities of practice provide unique educational opportunities, increase motivation, and place learning in rich, cross-cultural contexts.

Introduction: The World of Two Nationalities

In the last decade the information revolution spilled into the mainstream culture of industrial nations, where computer-mediated communications have become a fact of everyday life. In these countries information and communication technologies have changed how people live, work, and play. From using the Internet to access resources in the workplace to browsing the World Wide Web for shopping and hobbies, the lives of citizens of industrial societies are increasingly wired and, as a result, these societies are becoming increasingly wired to each other.

This fundamental change in human culture is often described as the third fundamental revolution, or "Third Wave" (Toffler 1981). "We find ourselves in the midst of a revolution, whether we wish to be or not," anthropologist Robert Textor of Stanford University noted more than 15 years ago (Textor 1984). The pace of revolution is accelerating. Textor compares the information revolution with the first two revolutions—agricultural and industrial. The agricultural revolution took several thousand years to achieve its global impact, and the industrial revolution took more than two centuries. The information revolution is less than two generations old, but its global impact is already profound.

Lawless and Passman (1985) in their report to the U.S. Agency for International Development stated that the information revolution represents the first significant technological advance that developing countries can assimilate and exploit, with relatively low capital investment and without extensive prior knowledge or involvement in prior technologies. Unfortunately, as one of the authors of the report noted later (Lowless 1996), "This new technology represents not only an opportunity, if properly exploited, but a threat, if ignored." If a developing country fails to take advantage of the opportunities that these computer technologies represent, its level of development in relation to developed countries will be significantly lowered."

In 1966 the United Nations launched an interagency project on universal access to basic communication and information services—"the Right to Communicate." Dr. Tarjanne, Secretary-General of the International Telecommunication Union and initiator of the project, warned that without action on the part of the world community, there would be a very real danger that the global information society would be global in name only. He added that the gap between industrial and developing countries would then widen into an unbridgeable chasm. "There are only two world's nationalities," remarked President Figueros of Costa Rico. "those who are connected to the Internet and those who are not."

Access to the World of Information and School Change

Teaching Yesterday's Skills for Tomorrow's World

Many experts share the view that the current education system does not prepare students for the Information Age. A recent report from the U.S. Office of Technology Assessment (OTA 1996) maintains that our schools, with their factory-like organization, are a remnant of the Second Wave industrial society and are quickly becoming outdated in the Third Wave technological world. Without major educational reform, the authors maintain, schools will not be ready to assimilate the spirit and ideas of the information revolution and, instead, will continue to prepare students for a world that no longer exists, developing "yesterday's skills for tomorrow's world." Corporate leaders such as Bob Hughes, Boeing's Director of Education Relations, views the traditional classroom as "singularly ill suited to produce lifelong learners." He remarked, "Right now, you have got 30 little workers who come into a room, sit in rows, follow instructions from the boss, and can't talk to one another. School is the last time they'll ever see that model" (Corcoran 1993).

One of the driving forces in the current wave of educational reforms now under way in many industrial and developing countries (Ware 1992) is the need for the education system to keep up with a changing world economy that is increasingly based on information rather than industrial production. There is widespread belief that integrating information technologies with student-centered inquiry learning in an education system can mutually reinforce both, and can eventually help nations meet the needs of the information society for creative thinkers and lifelong learners.

This need to prepare societies politically and culturally for the Information Age is especially urgent in developing countries, where the younger generation has extremely limited access to information technologies. There is a widespread belief that the nation's wealth defines its access to information and communication technology. As digital guru Don Tapscott (1998) recently noted, perhaps provocatively, whether a nation remains a technology "have not" depends on its mindset, not its bank balance. He theorizes, ". . . countries that have a culture that impedes innovation . . . cannot find the national will to go forward with technology." Where computers and networking are scarce, there is often a tendency by governments to supply "adults" with these new tools. Arguably, when they are scarce, technologies may not make a

huge difference in productivity in the workplace. Yet, making them available to education may be the most promising use of limited resources.

Access to the World of Information

Recently published by UNESCO (1998), the World Education report, *Teachers and Teaching in a Changing World,* states that the new technologies, particularly those providing access to the Internet and the World Wide Web, will inevitably transform traditional schooling, the nature and type of learning materials available to students, and teaching methods and approaches. The report emphasizes the danger of a widening gulf in availability of computers and access to the Internet between "information rich" and "information poor" countries. Indeed, while in the United States the estimated number of web users reached 57 million, and nearly 70 percent of all public schools have access to the Internet, in India, with its almost one billion population, the total number of Internet users is only approximately 80,000 (Wired News 1998).

In recent years many developing nations such as Brazil, China, Pakistan, and Singapore have invested significant resources linking schools and libraries to the Internet. Perhaps the most impressive development is in Singapore, where the government announced plans in the next few years to link every household, school, and office in the city-state to the "Singapore One," high bandwidth network making Singapore a "wired nation." (http://chicagotribune.com/textversion/article/0,1492,SAV-9809280063,00.html).

Implementation of the Internet in developing countries starts with the development of the basic infrastructure and training of those who can maintain and develop the new connectivity. Regional planning has been helpful. African countries, for example, are at work on plans that will allow them to jump into the twenty-first century. "Africa's Information Society Initiative (AISI): An Action Framework to Build Africa's Information and Communication Infrastructure" was adopted in 1996 at the ECE Conference of Ministers and calls for coordinated planning for the information age .

Many nations have set up national educational networking centers to build infrastructure and to link educators, and sometimes even students, into meaningful resource groups. In 1993 China established CERNET (http://www.net.edu.cn/cernet/index.html) to interconnect regional networks and link them to the Internet. Managed by the Chinese State Education Commission, it will connect more than 100 universities and institutes and, by 2000, all school and other educational institutions. Its regional networks are managed from centers located at major universities.

After regions of a country are connected, they are in a position to provide basic services for education. EDUNET of Pakistan, for example, has recently received a PULSE grant from the United Nations Development Programme (UNDP) to develop an extended educational database. In addition to the database, it will offer conferences, free software, electronic mail and mailing lists, and access to the Web (http://isb.sdnp.org.pk/edunet.html).

Software and services can be tailored to fit regional and local educational needs. Project Enlances in Chile (http://www.enlaces.cl/), for example, began in the early 1990s by offering equipment, software ("La Plaza"), and training to primary and secondary schools. It now offers programs to specific regions, professional communities (for example, biomedical), and keeps a calendar of educational conferences and other events. Networking has been facilitated by Educational Networking Centers set up at participating colleges and universities. Enlances is part of the Program for the Modernization of Secondary Education (Programa de Modernización de la Educación Media, MECE) under the Ministry of Education. By 1998 the system was reaching thousands of elementary schools, almost 1,000 secondary schools, and millions of students. Vice-coordinator of Project Enlaces Ignacio Jara summarized:

> "Las escuelas se integran a una comunidad escolar nacional, independientemente del lugar geográfico, en donde se encuentran y de las características socio-culturales de su comunidad." (The students are integrated into a national learning community, independent of geography of place, in which they meet [and learn about] each other and are introduced to sociocultural aspects of the community.)

Equity of Access and Usage

In the early implementation stages of communication technologies access to the Internet by students often is used as a measure of equity. To confront potential inequality in the meaningful use of technologies, educators should not only ensure equitable access to advanced telecommunications, but also develop challenging, technology-based projects for all students.

The way technologies are used by different socioeconomic groups is an important aspect of equity. Charles Piller, in a 1992 *MacWorld* report (Piller 1992) detailed sharp differences in approaches to teaching with the use of computers. "Those who cannot claim computers as their own tool for exploring the world never grasp the power of technology," he stated. "Such students become passive consumers of electronic information—usually in front of the television. Once out of school, they are relegated to low-wage jobs where they may operate electronic cash registers or bar-code readers. They may catch on as data-entry clerks, typing page after page in deadly monotony. They are controlled by technology as adults—just as drill-and-practice routines controlled them as students."

Even when access to advanced telecommunications functionalities is equivalent among groups, there may be important differences in the way computers are used. Academically more able students tend to use computers more than less-able students (Becker 1993; DeVillar and Faltis 1991). They noted that students in low-ability classes tend to use computers for drill and practice, while higher-ability students tend to use them more broadly—in ways that are more congruent with education reform goals. Of course, families with computers are able to introduce children to educational skills that allow the children to be assessed as "high ability!"

Why Connect Classrooms to the Internet?

A common rationale for connecting classrooms to the Internet is the need to prepare students for future work. Indeed, we see on a worldwide basis an increased demand for "knowledge workers" versed in telecommunications and able to work in collaborating, communicating teams. Information technologies have radically changed the workplace and enhanced our ability to search, access, analyze, process, and exchange information. It is estimated that by 2010, 60 percent of the new job opportunities in the United States will require skills that only 22 percent of workers have today (U.S. Department of Commerce 1995). This trend can be observed not only in industrial countries, but across the developing world, where computers and communication technologies are increasingly used in transportation, banking, management, and planning.

With the fast pace of technological advances and significant financial investments in bringing computers and networking into schools, more and more schools are rapidly joining the Information Revolution. The following are among the most frequently cited reasons for connecting schools to the Internet:

- *Bringing real-world relevance into the classroom.* Electronic networking expands the learning context by bringing the real world into the classroom. Students and teachers can establish interactive connections with anybody or any source. They have a tool to make learning more relevant to their lives—to their own interests and concerns. Students in rural areas, especially in developing countries, are extremely isolated from each other and the world at large. Electronic networks can bring them into the midst of the world's most important events.
- *Helping students perceive knowledge as constructed.* Traditional sources of knowledge—teachers and textbooks—can be significantly enhanced when students participate in collaborative projects that involve communities of students sharing data and observations that together may constitute new knowledge. Active participation in knowledge construction is critical for students' understanding of the open-ended, collaborative nature of knowledge and helps students from different countries and regions to place their findings into rich, cross-cultural contexts.
- *Providing students with an effective model of life-long learning.* When students research vast arrays of multimedia information and learn how to apply credibility tests to assess what they find critically, and when they learn information management techniques such as Web-searching and Web-publishing, they develop skills they can rely on for the rest of their lives. The use of communication technologies to access various sources of information is especially valuable to students in rural areas of many developing countries, where students access to libraries, museums, galleries, and other repositories of cultural artifacts are very limited.
- *Bolstering social, communication, and critical-thinking skills.* Students can enhance their communication, social, and collaborative skills as they interact and learn with other classrooms or on-line mentors. They also will learn to apply their critical-thinking skills when they are called upon to solve problems collaboratively and perform analyses with peers from a remote location.

- *Increasing the authenticity of learning environments.* By directing students to access such resources as rare historical archives, unique science apparatus, eyewitness reports, or on-line museums, teachers increase the authenticity of the learning environment. Advanced telecommunications create enhanced pedagogical settings in which students can communicate, cooperate, conduct distributed experiments, and build upon each other's knowledge. In this context, students are learning in the real world like adults.
- *Finding role models for students.* By electronically bringing professionals, scholars, explorers, educators, writers, poets, and scientists into classrooms, teachers expose students to positive role models. On-line resources can put a human face on many aspects of learning, whether it be communicating with other classrooms or with experts and scholars who serve as mentors. This can be especially valuable in a developing country where few students have access to professional scientists, scholars, astronauts, or other representatives of cutting-edge research and engineering.
- *Assuring equity.* Advanced telecommunications offer a vast palette of learning resources that would be beyond the means of even the wealthiest schools to obtain any other way. When online, all schools are on an equal footing in their ability to access the same resources. Students from the most rural location can take a virtual trip to a famous museum or art gallery and download the contents of a rare book or article—regardless of how far they are from the place where the paintings, books, or articles are stored.

The Functional Capabilities of Classroom Telecommunications

To achieve the anticipated impact of the information and communication technologies on student learning, educators should fully exploit the relevant educational functionalities of immerging technologies. Examination of available on-line resources and potential classroom usage of the Internet reveals six general educational functionalities of this new electronic medium (Berenfeld 1996).

Tele-access

Tele-access is the use of on-line resources in learning, including on-line libraries, databases, museums, satellite data, and other classrooms, often in different countries. The latest space shuttle photos (shuttle.nasa.gov) or resources for 40 languages (www.cc.utah.edu) are available to students via the Internet. When students conduct on-line searches, they are tapping into information that is real-world oriented and nearly unlimited. As of April 1998 the number of pages on the World Wide Web reached 330,000,000. They contain artifacts from the world's finest museums, pictures from the best art galleries, books, magazines, thousands of newspapers from all over the world, archive documents, lessons offered by the best scholars, lesson plans, maps of all kinds, scientific data, and much more. This access to the vast sea of information resources could be especially valuable in developing countries, where students often lack textbooks and visual aids or use outdated learning materials.

Internet tools facilitate easy access to information by offering simple-to-use search engines that enable users to find references based on a selection of key words. In addition, all on-line resources can be updated quickly; any word or picture within them can be linked to any

other source. These capabilities are the basis for the World Wide Web, the part of the Internet that is structured both graphically and with text "hot-links" to related material and resources.

Virtual Publishing

For the first time in history the ability to publish no longer depends upon owning a printing press and a means of distribution. Once the province of scholars and large companies, publishing is now an option for classrooms by means of virtual publishing on the World Wide Web. Indeed, the term "desktop publishing" arguably is a misnomer. Although computers and printers enabled users to design and print materials, it was only with the advent of the World Wide Web that users could truly distribute materials to whoever wants them.

Virtual publishing can authenticate learning by setting students' scholarship in the real world. Students derive a sense of self-worth when they can claim ownership of work that reaches an audience beyond the classroom. They also tend to invest more effort in work that is to be widely distributed. For example, in the Writers in Electronic Residence project, students in Toronto publish their poetry for feedback from their peers throughout the country. On the networks supported by Global Schoolhouse (gsn.org) and International Education and Resource Network, I*EARN (www.iern.org/iearn), students published a newsmagazine, an award-winning literary journal, an environmental newsletter, and a human rights newsletter.

Virtual publishing is hardly limited to text documents. Students can include graphics, video, sound, and animation in their publications, as well as the hypertext links of digital books. Unlike conventional publishing methods, virtual publishing is constrained, not by the media, but by students' imaginations. With the right equipment and connections, students can even tele-broadcast live sounds, film, and video to each other.

Tele-presence

Tele-presence enables students to experience, directly or indirectly, events at remote sites. Students near an ecological disaster or in the path of a hurricane can serve as eyewitnesses for their peers by issuing firsthand accounts. Using the Internet, students can collect data from remote probes installed in Antarctica or on the moon.

In NASA's Passport to Knowledge project classes can travel on field trips to the Brazilian rainforest, participate in space experiments, and, in effect, "look over the shoulders" of working scientists and astronauts (http: nasa.gov). Students in the Jason project remotely explored the ocean floor from their classrooms through a robot operated by the Woods Hole Oceanographic Institute (seawifs.gsfc.nasa/JASON/HTML/JASON.html). In the "Live from Antarctica" project (quest.arc.nasa.gov/livefrom/livefr) students accessed scientific diaries and field journals to learn how scentists "lived, worked and played" at the South Pole.

Tele-mentoring

With telecommunications mentoring becomes a rich and viable teaching option. Many sites on the Internet, such as professional groups and bulletin boards, are responsive to student inquiries.

By serving as mentors, scientists and scholars can answer questions and provide classrooms with resources beyond textbooks and the individual teacher's expertise. A retired engineer or a graduate student in mathematics, for example, could mentor students at a remote high school. One example of tele-mentoring is the on-line program, *Ask-A-Geologist*, sponsored by the U.S. Department of the Interior (walrus.wr.usgs.gov) in which students ask questions of professional geologists.

Tele-mentoring appears to validate classroom activities for students. Through exposure with experts, scholars, and other achievers, tele-mentoring can provide students with positive role models, particularly important to those students who have none. Such relationships can reward the students and the role models themselves.

Though often associated with teacher development and adult education, net courses are a combination of tele-mentoring with other educational functionalities of the networking, such as tele-access, tele-presence, and on-line collaboration. Net courses significantly expand schools' educational opportunities and are a potentially powerful strategy for advanced, remedial, and home instruction. See, for example, the Virtual High School Web site at (www.concord.org).

Tele-sharing

Computer-mediated communication enables various forms of sharing of information in a digital form via electronic networks. In this definition, tele-sharing incorporates all forms of exchanges of digital information among participants over the electronic network. It begins with a simple "one-to-one" e-mail exchange between so-called "keypals," followed by "one-to-many" and "many-to- many" communications in on-line discussion groups, and eventually advances to the sharing of resources, ideas, experiences, and data when participants cooperate on specific shared tasks. In certain projects and activities tele-sharing provides true collaboration in a distributed electronic community of peers. These communities can offer students relevancy and engage them in comparative cross-cultural analyses and deep social interactions.

Presently, one of the most ambitious tele-cooperative programs is Global Learning and Observations to Benefit the Environment (GLOBE). This project was initiated by the Vice President of the United States Al Gore in collaboration with governments and environmental organizations of 70 industrial and developing countries. The program forges a partnership between students worldwide and leading scientists to monitor key environmental parameters. Currently, students from more than 40 nations transmit their findings to a GLOBE database that has become a rich resource for students and environmental scientists (http://www.globe.gov).

Tele-collaboration

Tele-collaboration is one of the most sophisticated deployments of classroom telecommunications. It advances on-line cooperation to distributed problem solving, collaborative design, and cross-classroom collaborative inquiry. Though tele-collaboration is a relatively new implementation of classroom telecommunications, teachers in many countries have initiated an increasing number of interesting on-line projects. These teachers developed

promising ideas, posted them on networks to recruit collaborators, and eventually implemented the projects.

One example of tele-collaborations is the Global Laboratory Curriculum, an international, telecommunication-based project developed by TERC, a science and math education research firm in Cambridge, Massachusetts, United States, with support from the National Science Foundation (http://globallab.terc.edu/). (See the case study that concludes this paper.)

Though tele-collaborative projects require careful preparations in order to standardize and synchronize activities among participating classrooms, they increase the authenticity and relevancy of learning environments and offer important benefits for all disciplines. They enable classes to conduct distributed research and experiments, thus replicating the processes of scientists and scholars. Participating students must follow uniform procedures, yet the diversity of the data enables them to place their findings into regional, national, and global contexts (Berenfeld 1994)

Classroom Implementations of Advanced Internet Functionalities

How do these advanced educational functionalities of computer-mediated communication find their way into classrooms? An accurate picture is difficult to come by because the most advanced functionalities require high-quality connectivity, which is in short supply among many schools. Whereas some schools enjoy powerful computers and high-bandwidth links to the Internet in every classroom, many have obsolete computers relegated to computer labs. In addition, there are great discrepancies in teachers' expertise and experiences; some teachers navigate the Internet effortlessly, while others struggle to get online during lunch. Although presently there is only limited research into how advanced on-line functionalities are adapted into classrooms, the following patterns have become discernible (Tinker and Berenfeld 1994).

Beginner Pattern: From Extracurricular Use to Curricular Augmentation

The easiest way to introduce telecommunications into formal courses is through a practice called telecommunication-augmented curricula, in which teachers supplement their existing curricula with on-line activities. A science class could augment its astronomy curriculum by downloading the latest images from the Hubble telescope, or a sociology class could supplement its studies by accessing population figures from a census bureau. A literature class could discuss a book with its author or virtually publish its poetry. Teachers need not revamp their curricula nor their teaching practices to augment courses with telecommunications. Although the overall teaching strategy remains conventional—teacher- and textbook-centered—students now have routine access to online resources and are exposed to an array of information sources and opinions that demand their critical thinking.

Intermediate Pattern: From Augmentation to Added-On Curricular Inserts

Teachers who have successfully augmented their curricula with various on-line functionalities take the next step by inserting specially designed telecommunication-based curriculum modules into traditional courses. Middle and high school teachers involved in the Global Lab Curriculum,

for example, use specially designed tele-collaborative curriculum units as inserts into regular earth science, biology, physics, chemistry, and environmental science courses (Tinker and Berenfeld 1994).

There are diverse reasons for this transitional implementation pattern. Insufficient or inadequate access to the Internet may limit the level of connectivity some teachers can offer. Also, there is a dearth of full-course curricula designed to fully implement advanced telecommunications features. In addition, many teachers lack the training, experience, or confidence to abandon conventional teaching practices in favor of new and unfamiliar ones.

Advanced Pattern: Networking Is Fully Integrated into Curricula

In telecommunications-integrated curricula the use of the Internet becomes integral to classroom instruction. The curricula are designed to exploit fully its advanced functionalities and information flows both to and from students. Learning becomes less dependent on the centrality of teachers, and the teacher's role transforms from "sage on the stage" to "guide on the side."

Integrating telecommunications fully into daily instructions is more challenging than merely downloading some files or sending an e-mail. Full integration requires that schools, in addition to providing students with sufficient telecommunication access, must redefine their learning objectives, restructure curricular offerings, and provide teachers with training and support materials. Often teacher-inspired grassroots efforts lack the resources to provide the support and curricular framework that telecommunication-based curricula demand.

Student Communities of Practice

The most powerful and pedagogically advanced, yet challenging application of advanced Internet functionalities in education is their ability to support geographically dispersed learning communities of practice. The rise of such communities could herald a renaissance of pedagogical practices. Empowered by technological advances, these communities will enable educators to reshape the goals and techniques of teaching and make learning a life-long, real-world experience for all.

Virtual Communities

A community is generally defined as a group of persons living in the same locality who share common interests, common values, and a common social order. Second perhaps only to the family, the community has been a basic form of social organization since the earliest tribes and clans were formed for self-protection and kinship.

When members of a community are united by common purposes and engaged in mutual activities, they become a community of practice. Communities of practice can range from a group of stamp collectors to an international team of scientists planning a Mars expedition, from a group of students publishing a newspaper to members of a retirement community putting on a Shakespeare play for their peers. In the last example, the retired people already live in a genuine

community setting, but they became a community of practice when they embarked on a common enterprise.

Communication is an essential component of any community because members must mediate common values, interests, and goals. A group of people who live in the same geographical area but do not communicate would hardly constitute a community. Technologies have greatly augmented communities of practice. The printing press and journals, the telegraph and telephone, and advances in transportation have enabled many communities of practice to expand their membership, enhance the sense of belonging among members, and improve the accumulation and dissemination of knowledge.

It is no wonder that computer-mediated communication, being an amalgam of all communication technologies, has spawned what are called virtual communities. These have the general characteristics of traditional communities with one difference—the locality their members share is cyberspace. Virtual communities emerged from a surprising intersection of humanity and technology. When the ubiquity of the world telecommunications network is combined with the information-structuring and storing capabilities of computers, a new communication medium becomes possible.

Learning in a Community of Practice

From medieval merchant and trade guilds to today's professional associations, learning, in its broadest sense, is a principal function in communities of practice. Community-specific knowledge affords each group and its members a common identity and access to joint resources and methodologies. Members establish standards and norms for professional behavior, methods for self-improvement, and opportunities for advancing common interests and goals.

Communities of practice are engines for engaging members in collective knowledge construction. They have established means for encouraging members to contribute to the knowledge base, such as publication in journals, and they certify what is accepted as new knowledge through peer review or general consensus. Communities reward their members, acknowledge their accomplishments and altruistic behavior, and provide them with self-identification and common ethics. In addition, each community of practice is responsible for the storage and accessibility of its accumulated knowledge.

It is ironic that although communities of practice have, for centuries, been key arenas for learning in the adult world, students who are dedicated learners do not have established communities of practice beyond their classrooms. This is all the more remarkable in that, for most of human history, children have learned in community settings by watching adults and practicing with their peers. The relatively recent classroom model of pedagogy isolated students from larger communities and rendered learning a largely passive activity.

Leading educators have long appreciated the social aspects of learning. Their work has inspired efforts to reorganize classes into learning communities through project-based teaching and learning—student apprenticeship to professionals. However, schools have lacked the

resources, means, and incentives to build enduring communities of practice for students similar to professional associations and groups.

Building a Student Virtual Community

Since the mid-1980s there have been many efforts to use electronic networks to foster student-based geographically distributed communities. Although it is difficult to identify the very first school that hooked up a modem to a computer and began looking for "key-pals," most initial efforts were grassroots in that they originated from the classroom. For more than a decade the Global School Net Foundation played a very important role in engaging hundreds of schools from many countries in meaningful projects. Built around "franchised" nodes run by volunteers, this international network devoted to K–12 education developed support materials to guide teachers through successful on-line learning experiences with their students. Another example mentioned previously is I*EARN, which engages teachers and students in international projects in science, literature, social studies, and economics. Activities have included the publication of student-developed journals and newsletters, the bilingual study of cultural heroes, and studies of rainforests.

In 1986 TERC, working with the U.S. National Geographic Society (NGS), developed NGS Kids Network, a first worldwide community of elementary students engaged in environmental investigations. Students use special curriculum and software to participate in large-scale, cooperative experiments, share their data on a computer network, and consult with scientists. The success of NGS Kids Network created a growing number of diverse telecommunication -based projects that range in size from several schools to several hundred sprouting up in Europe, Asia, Africa, and Australia.

Educators have learned that to build effective student communities of practice classes require routine access to telecommunications and the following design components:

- A telecommunications structure that meets the communications and data-exchange needs of the community yet is easy for all members to use.
- Common goals and education objectives that include shared content and process skills.
- A tangible end-product(s). A community as a whole can work toward designing a shared product or set of products such as a sociological survey, a research report, a joint projectwide database, or even a poem.
- A common time line and tools.
- Common objects or topics of study.
- A shared curriculum. Educators only recently have begun to design new types of learning materials around computer-mediated communication, rather then working computers and communication technologies into existing curricula.

Pedagogical Benefits of Virtual Communities of Practice

New Learning Opportunities

Ensuring student access to the Internet, integrating the networking into the school culture, and fostering the creation of student communities of practice can be costly and time consuming. Are these efforts worth it? Teachers and educators involved in pioneering telecommunication-based collaborative projects reported that, when properly implemented, computer-mediated communication can do the following (Harasim 1990; Riel and Levin 1990; Goldman and Newman 1992; Weir 1992; Riel 1993; Roupp and others 1993; Berenfeld 1994; Harris 1994; Julian and Wiske 1994):

- Increase the authenticity and bring out a rich, cross-cultural context.
- Emphasize the social aspects of learning and foster social interaction among participants.
- Enhance communication and social skills, including writing, reading, and listening.
- Enhance interdisciplinary opportunities.
- Provide greater resources. Learning expands from the internal resources of teachers and books to a greatly expanded pool of resources and cultures.
- Broaden students' audience, giving them a sense of the importance of their work. Usually, the teacher is the sole audience.
- Give students a sense of being needed and valued by their communities.
- Find role models for students. Effective student communities can attract the support of esteemed professionals.
- Encourage communication among students of all socioeconomic classes and diverse cultures. Build a bridge to bring students from industrial and developing nations together.
- Prepare students for future work.

Documenting the Impact of Networking

One of the first large-scale studies that documented the impact of connectivity on student performance was published recently in the United States—*The Role of Online Communications in Schools: A National Study* (http://www.cast.org/publications/stsstudy/ststab2.html). Conducted by the Center for Applied Special Technology and sponsored by Scholastic Network and the Council of Great City Schools, this study demonstrated that students with on-line access perform better on key information management, communication, and presentation skills (table 1). The authors designed a controlled experiment to isolate the impact of the use of online access and measure its impact on student learning in the classroom (Follansbee and others 1997).

Table 1. Impact of On-line Access on Student Learning

Student project learning criteria (Scale—0 to 3)	Classes with on-line access	Classes without online access	Percentage difference
Effectiveness of synthesizing different points of view	0.57	0.29	97*
Presentation of a full picture (who, what, when, where, why, how)	1.31	0.87	51*
Effectiveness of presenting ideas and information	1.42	1.11	28*
Effectiveness of stating an issue	1.31	0.87	26*
Completeness of assignment	1.41	1.18	19*
Demonstration of insight into the topic	0.82	0.74	11
Accuracy of information	1.70	1.61	6
Taking initiative to demonstrate "best work"	1.95	1.87	4
Organization of ideas and information	1.27	1.26	1
Aggregate of scores	11.73	9.92	18

The study compared the work of 500 students in grades 4 and 6 in seven urban school districts in the United States (Chicago, Dayton, Detroit, Memphis, Miami, Oakland, and Washington, D.C.). Half of the districts had on-line access to the Internet and Scholastic Network and half did not. The two groups of students did collaborative projects on the issues of civil rights, both groups discussing, then researching and presenting portfolio projects. Trained internal and external evaluators scored the projects along nine learning dimensions. The study found that students with access to the electronic network and the Internet excelled in finding, comprehending, and evaluating information, and in presenting information and ideas effectively. Students with access scored better in all learning categories at a statistically significant level in more than half of the categories (see table 1).

Doing More with Less

Electronic networking offers ways for a classroom to embark on sophisticated explorations without significant investment in equipment. For example, the average class often lacks the tools to offer students authentic learning experiences in physical sciences or Earth explorations. A lone science class will never have the resources to acquire costly instruments, such as an electron microscope or a radiation meter, or to perform extended sociological surveys. Electronic communities help overcome many of these shortcomings by allowing access to science data online, or combining many data collected worldwide with inexpensive tools and the power of class connectivity.

For example, in the Global Laboratory Curriculum students were able to observe global trends in air quality when they used a simple Haze monitoring device and dust collectors based on adhesive tape and graph paper. When done by a single classroom, such an activity delivers only a limited experience. When it is performed simultaneously by a 100-member network of schools, the activity creates a rich set of data that can be the source of many interesting discoveries and conclusions. For a tiny expenditure per class, students in networked classrooms

can do local studies, conduct longitudinal analysis, and make interesting comparisons with data from different regions of the world. This approach is particularly useful in developing countries that often have access only to the simplest science tools and instruments.

Case Study: the Global Lab Curriculum

In 1990, with support from the National Science Foundation, TERC launched the Global Laboratory to experiment with the use of electronic networking in science classes. Since 1990 Global Lab has linked thousands of teachers, high school students, and scientists in an international community united by common goals, curriculum, and technologies and engaged in real-world, open-ended investigations. The goal of Global Lab was to help students learn science by practicing science together with their peers from all over the world.

Technology of Freedom and the Freedom to Choose

Telecommunication technologies are often called the "technology of freedom" for the ability to support unrestricted communications and access to information resources. As developers of an Internet-based curriculum, we tried to design an instructional environment that matches the "technology of freedom." The first step was to engage students themselves to choose the object of their year-long study, the Global Lab study site. (Usually, students do not have an impact on what they will study; the textbook is preselected by a teacher and the content by the writer.) Global Lab class participants were asked at the beginning of the school year to choose a part of their locale that sparked their interest or concern—usually a plot of land or a body of water. Students knew that over the course of the school year they would be exploring the study site in detail and presenting their findings to the entire world via telecommunications media.

Selection of the study site was an important event for each school; sometimes the deliberation took more than a month. During this period, classes explored their locale, learned about their community, and compared different terrains. They had to consider the features and accessibility of sites during limited class periods. Over the course of the year students conducted environmental investigations, shared their data via the Internet, and placed their local findings into a global context. The community focused on environmental studies due to the interdisciplinary nature of the field, the ubiquity of objects to study, and their relevance to students. Since 1990 more than 400 schools from about 30 industrial and developing countries joined Global Lab. Participants included Argentina, Australia, Canada, China, the Czech Republic, Denmark, Germany, Hungary, Indonesia, Italy, Japan, , Mexico, New Zealand, Nigeria, the Netherlands, Poland, Qatar, Russia, Saudi Arabia, South Africa, the Philippines, the United States, and Zimbabwe.

Global Lab's Telecommunication Infrastructure

To support the Global Lab Curriculum we created a telecommunications structure that reflected a real-world setting. Structurally and metaphorically the Global Lab was organized as an international networked science laboratory. Every participating class had its own presence on the World Wide Web, all interactions between schools were computer-based, and each participating school was a fully functional node on the network. The community was supported by a virtual

library where project data and background resources were kept— a projectwide electronic bulletin board for announcements, on-line discussion groups for students, and a separate one for teachers. Student tele-forums, such as Global Lab Mysteries and an idea-bank, allowed classes to post their findings, ideas for further investigations, and research plans. In their own on-line discussions groups teachers reflected upon their practices and shared tips and advice.

Using easy-to-use software placed on the central server, all global classes developed their own web pages stored in the project's database; a number of classes placed photographs of themselves and their study sites on the Web. In addition, they sent photographs and audio recordings to TERC, where they were digitized and placed onto a CD-ROM, a copy of which was sent to participating classes. In the future, improved connectivity will enable these pictures, sounds, and video material to be exchanged via the Internet.

Three Phases of the Global Lab Year

The Global Lab year consisted of three distinct yet progressively sequential phases. Each phase had its own objectives and goals. The first phase focused on helping students to establish social interactions with their peers from different countries, build a functional international community of schools, and develop local, regional, and global perspectives. By doing so, we gradually developed in students the ability to compare and contrast their findings and place them into regional and global perspective.

The second ("guided discoveries") phase prepared students to conduct investigations by carefully scaffolding the process of acquiring the basic investigative skills. Students usually begin their investigations by making drawings, mapping, and conducting qualitative observations of their study sites. Then, with guidance from the instructional materials provided, students worldwide used similar tools and instruments and conducted the same measurements, following the same schedule and protocols. Within a few months, every class collected a rich set of data on the soil, water, and air of their study site. Using the Internet, students sent their findings to the Global Lab database for comparison and analysis. As the result of this phase of Global Lab, every class could compare its findings with those done by their peers worldwide and identify classes that looked like interesting potential collaborators for the third phase of the Global Lab year.

Joining the Global Lab Community. One unique feature of the project was its initial phase, "Joining the Global Lab Community." This phase was a concerted effort to instill in students a sense of community, and to build the skills, familiarity, and trust they would need for collaborative studies later in the year. The project began to develop a group identity through the use of visual cues, such as logos, and a standardized look that included common colors and graphical designs. Moreover, a world map was sent to each classroom with colored adhesive dots so students could mark the locations of their schools, and all others within the community. Classrooms also received a certificate verifying that students were members of a global community of peers.

The project's first activity called upon each class to send a "hello" message over the network to all participants. Students introduced themselves and described their schools, their communities, and their study sites. The hello messages communicated the community's overall size, shape, and composition. They enabled students to communicate with, and feel accepted by, peers in distant classrooms. The messages also began to instill in students the community's etiquette, standards, and ethics. In schools from Boston to Moscow, from the deserts of Saudi Arabia to the Arctic Circle, students learned that they belong to a global village populated by teenagers like themselves.

Building investigative skills. After community-building activities, the project launched its second phase, Building Investigative Skills (BIS), which lasted approximately three months. The pedagogical premise of BIS is that students require some training and preparation before they can conduct open-ended, real-world collaborative investigations. Each class was provided with a set of low-cost yet high-tech tools, supplied by TERC, with which to make environmental measurements of their study sites. Then they reported their findings via the Internet to a communitywide database. Students adhered to the same standards of rigor as scientists and scholars, carefully following common protocols and standards.

After a series of introductory data-gathering activities, the community participated in a series of synchronized skill-building procedures called Global Lab Snapshots. At the same hour, on prearranged days, all schools made identical measurements on their study sites. These and other directed research procedures prepared students with invaluable skills in collaborative techniques and data-collecting and added to the increasing functionality of the community.

The nature of students' communications evolved from subjective observations to student-generated data and discussions about various protocols. Each class cooperated to create a global view of the entire virtual community, enabling students to place their local environments into a global context. The level of network discussion became elevated as students examined the similarities and dissimilarities of their locales.

Extended investigations. The third and final phase of Global Lab introduced students to an extended inquiry by engaging them in open-ended, collaborative investigations of their own design. Following curriculum guidelines, every class described its research question related to their study site and based on preliminary findings. They placed this description on the class Web site. In the next few weeks every class read and discussed research questions posted by the community and decided who would be the right collaborator(s). Classes exchanged letters of invitation explaining the needs of the collaboration using the Internet.

The project's final phase, Extended Investigations, engaged students in open-ended investigations. The curriculum supported fields of study that were drawn from students' own observations of environmental phenomenon on their study sites. Each class was asked to select one of these fields in which to perform an investigation. The community reconfigured itself from one that was curriculum-directed to one that was student-directed. Research topics included air and water quality, tracking pesticides, nitrate studies, butterfly migrations, lichens and other bioindicator plants, and UV and stratospheric ozone.

Calling upon the skills and strategies to which they were introduced during BIS, classes collaborated on their open-ended investigations. They were called upon to pose a research question, identify the data they would need to answer it, develop a research strategy with which to acquire this data, and then perform investigations collaboratively. Classes were asked to peer review each other's work for accuracy throughout the process.

The Global Lab as a Community of Practice

The Global Lab began each school year as a mere group of schools that had little if any contact with each other. The overall curriculum design aimed to transform this group into a fully-functional student community of practice by offering all participants the following shared components:

- Time line and project calendar
- Methodology, experimental techniques, and protocols
- Instruments and shared calibration procedures
- A telecommunication network, central Web server, and shared networking software
- A common standard (the metric system) and language (English)
- On-line resources
- On-line scientists
- Similar learning opportunities for each student.

This uniformity enabled students to study their local environments in precisely the same way, thus allowing for comparisons and analyses. While sharing the same methodologies, the Global Lab community was geographically, ecologically, and culturally diverse and represented many unique social and historical perspectives. This interplay of uniformity and diversity produced a dynamic and stimulating learning environment.

As the Global Lab experience demonstrates, advances in information and communication technologies have made feasible the building of student communities comprising geographically dispersed classes from different regions of the world. Analysis of learning in the network led to a growing awareness that the success of these communities requires specially designed curricula; shared tools, techniques, and methodologies; and access to advanced telecommunications capabilities. The Global Lab project was one of the first such classroom communities of practice to employ a curricular structure and community-building techniques. Students communicated with their peers worldwide, engaged in building their own community, and learned both skills and content through participation in the life and work of a community of practice. In doing so, they delivered the promise of Internet connectivity to enhance education and justify the enormous costs of wiring classrooms to each other and to the world.

Russian Educator and Biophysicist Dr. Boris Berenfeld is a renowned authority in educational technologies. He was Cofounder and Principal Investigator of the Global Laboratory Project, and served as Co-principal Investigator of the GLOBE program. Currently, he serves as Director for the International Center of the Concord Consortium, a recently

founded educational research and development firm focusing on the use of electronic networking in education.

References

Becker, H. 1993. "A Truly Empowering Technology-rich Education—How Much Will It Cost?" *Educational IRM Quarterly* 3 (1): 31–35.

Berenfeld, B. 1994. "Technology and the New Model of Science Education." *Machine-Mediated Learning* 1 (4 and 5): 121–38.

———. 1996. "Linking Students to the Infosphere." *Technology Horizon in Education* 23 (9): 76–84.

Corcoran, E. 1993. "Why Kids Like Computers Net." *Fortune* 128 (6): 103–112.

DeVillar, R.A., and C.J. Faltis. 1991. "New Policies for an Evolving Future." *Educom Review* 28 (3): 28–30.

Follansbee, S., R. Hughes, B. Pisha, and S. Stahl. 1997. "Can Online Communications Improve Student Performance? Results of a Controlled Study." *ERS Spectrum* 15 (1): 15–26.

Goldman S., and D. Newman. 1992. "Electronic Interactions: How Schooling is Organized over the Wires." *Interactive Learning Environment* 2 (1): 31–44.

Harasim, L. 1990. "Online Education: An Environment for Collaboration and Intellectual Amplification." In L. Harasim, ed., *Online Education. Perspectives on a New Environment.* New York: Praeger.

Harris, J. 1994. *Way of the Ferret: Finding Educational Research on the Internet.* Eugene, Ore.: International Society for Technology in Education.

Julian, K., and S. Wiske. 1994. *Learning along the Electronic Path: Journey with the NGS Kids Network.* Cambridge, Mass.: TERC.

Lawless, W., and S. Passman. 1985. *Informatics and Tunisian Development.* Washington, D.C.: U.S. Agency for International Development.

Lowless, W. 1996. *Microcomputers and their Applications for Developing Countries.* Report of an ad hoc panel on the use of microcomputers for developing countries. Boulder and London: Westview Press/National Research Council.

Means, B., and K. Olsen. 1995. *Technology's Role in Educational Reform, Findings from a National Study of Innovating Schools.* Menlo Park, Calif.: SRI International.

OTA (Office of Technology Assessment, U.S. Congress). 1995. *Teachers and Technology. Making the Connection*. Washington, D.C.: U.S. Government Printing.

———. 1996. *Education and Technology: Future Visions. Learning from the Past, Moving Toward the Future*. Washington, D.C.: U.S. Government Printing Office.

Piller, C. 1992. "Separate Realities." *MacWorld* 9 (9): 218–230.

Riel, M. 1993. "Cross Classroom Collaboration in Global Learning Circles." Paper presented at the annual meeting of the American Educational Research Association, Atlanta, Ga.

Riel, M., and J. Levin. 1990. "Billing Electronic Communities: Success and Failure in Computer Networking." *Instructional Science* 19: 145–69.

Roupp, R., S. Gal, B. Dryton, and M. Pfister. 1993. *LabNet: Toward a Community of Practice.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Tapscott, D. 1998 "Upside." *Educom Review* 33 (3): 6.

Textor, R. 1984. "Shaping the Microelectronics Revolution to Serve True Development." Paper presented at a symposium on microcomputers. In *Microcomputers and their Applications for Developing Countries. Report of an Ad Hoc Panel on the Use of Microcomputers for Developing Countries.* Boulder and London: Westview Press/National Research Council.

Tinker B., and B. Berenfeld. 1994. "Patterns of Use: Global Lab Adaptations." *Hands-On* 17(2).

Toffler, A. 1981. "School in the Third Wave." *School Administrator* 38 (4): 1, 28–30.

UNESCO. 1998. *World Education Report. Teachers and Teaching in a Changing World.* Paris.

U.S. Department of Commerce. 1995. *Connecting the Nation: Classrooms, Libraries and Health Care Organizations in the Information Age*. A report from NTIA. Washington, D.C.: Government Printing Office.

Ware, S. 1992. *Secondary School Science in Developing Countries*. PHREE background paper series PHREE/92/53. World Bank, Education and Employment Division, Population and Human Resources Department. Washington, D.C.

Weir, S. 1992. *Electronic Community of Learners: Fact or Fiction?* Cambridge, Mass.: TERC.

Wired News 1998.

Environmental Education: The Millennium Challenge

Jacob Bregman, Sr. and Morten Fisker

New forms of information access, communication, and learning made possible by the information and communication technology (ICT) revolution have provided new opportunities to revitalize environmental education in primary and secondary schools. Changes in teaching and learning methodologies are being implemented, especially in countries where access to the Internet is becoming more widespread. However, even in highly industrial countries, there are perceived cost barriers to the widespread implementation of ICT. Yet, developing countries cannot be left behind. They need to find cost-effective ways of implementing ICT. Adequate investments, required for relevant and effective science and environmental education, will always be a substantial part of any national education budget. In view of the faster reforms in science and environmental education and their increasing costs it is important for the World Bank to encourage and assist the worldwide debate on these issues and to give sound advice to its client countries.

The Environmental Challenge

As we approach the millennium environmental issues are gaining importance by default. One billion people—mostly in developing countries—do not have access to clean water, while 1.7 billion people do not have access to sanitation. Consequently, two to three million children die annually because of diseases associated with this lack of water and sanitation. Meanwhile, the global population is still increasing by 90 million people each year, primarily in developing nations. This raises huge challenges for policymakers as they seek to reconcile the needs and aspirations of growing populations with the limitations of the natural world (Serageldin and Steer 1998).

Many countries have become newly aware of the importance of developing national environmental strategies. This is partly due to the 1992 Rio Earth Summit and Agenda 21, but also results from an increased global awareness among planners, decisionmakers, and voters of the negative financial impact of disregarding environmental sustainability. The lessons are dire. For example, for many African countries the lost productivity of soil (some of which is irreversible) has been estimated to cost 3 to 5 percent of their GDP. In Hungary air pollution and acid rain is estimated to result in agricultural losses of US$100 million yearly and another US$50 million in damage to forests. Individuals are also affected by air pollution and degraded landscapes. A recent World Bank study reported that the annual health-related costs of air pollution in Mexico City could be in the order of US$1 billion.

In acknowledging the extent of global environmental problems, many countries have recognized that sound environmental planning and regulations are necessary components of a national environmental strategy. Equally important is ensuring a positive change in consumer

behavior. Government policies and citizen awareness must go hand in hand to make effective progress towards environmental sustainability.

Environmental Education

The education system can be an effective partner in promoting environmental awareness. School systems can teach students about the interactions between society and the environment, fostering an understanding of our dependence on the natural world for raw materials, and our role in producing waste materials, which are returned to the environment. The schools can help produce students with a sense of responsibility toward protecting the environment, and they can encourage practices and actions that benefit the environment.

In the 1960s and 1970s, when the environmental movement in Europe became involved in political processes at national and local levels, one major concern was the lack of environmental information resources for use in the classroom. Over time, such resources were developed in many European countries, where they were used to enrich the curriculum. However, it became clear that introducing environmental education into the schools was a complex undertaking, involving instruction across a range of disciplines, including science, geography, economics, and social studies. In Europe environmental education was taught mainly by science teachers. At the upper secondary level it was taught by biology, chemistry, and physics teachers, who introduced environmental topics from the perspective of their own discipline. By the 1980s education systems were struggling to find effective ways to integrate environmental education as a multifaceted subject into existing curricula, while at the same time dealing with its political, scientific, and management dimensions.

In the 1990s many of these problems have been resolved, and environmental education is becoming much more fully integrated into the curriculum. In the past few years Internet sites that provide environmental data and discuss global and regional environmental issues have grown significantly, primarily in Europe and the United States. For the first time both governments and the private sector are making environmental data instantly accessible to a large audience. Students can exchange data across schools and even countries, and students can take part in multinationals, environmental data-gathering efforts. The use of the Internet to teach environmental education is an exciting development that has yet to be fully exploited.

However, some lessons need to be remembered, and questions asked. Other technologies have been hailed as revolutionizing instruction, for example, radio, television, and video. The promise of these technologies has, perhaps, been oversold or is yet to be fully realized. Furthermore, initial investment in ICT is expensive and requires sound and sustainable strategies for ongoing resource management. Proposals to provide a computer for every student in every classroom, while more feasible for industrial countries, are not realistic for developing countries. Yet, as some developing countries are already showing, appropriate cost-efficient ICT strategies can be developed. (The experiences of several Latin American countries are described later in this report.)

The challenge is to find cost-efficient ways of adapting teaching and delivery strategies to the new media so that teachers can integrate the wealth of environmental information on the Internet into the classroom. In industrial countries the process of adaptation has begun and is making an impact on all classroom subjects and on the ways in which teachers are being educated. A number of European countries have been exploring ways of combining ICT with environmental knowledge collection, transfer, and analysis. Their experiences provide a valuable set of "do's and don'ts" for others interested in using the Internet in the classroom.

How Is Environmental Education Taught in Formal School Systems?

In principle, there are two ways to deliver environmental education. Either it can be taught as a separate subject with "blocked" instruction time, or it can be "infused" into other subjects in the curriculum. In reality, the blocked approach is rarely used, primarily because of the difficulties (including costs) inherent in adding one more subject to an already crowded curriculum.

The solution has been to infuse environmental topics into a number of existing subjects, such as biology, physics, chemistry, and social studies. Thus environmental education has been launched as an all-embracing, cross-curricular theme. The infused approach, which often involves students in project work, works well in the student-centered classroom, where the teacher serves as a facilitator of student learning, but less well in the teacher-centered, traditional classroom.

Osin (1998), among others, has pointed out that we all learn best by "doing" and thus schools should devote much more of a student's time to project activities related to real-world issues, including environmental issues. Several examples of countries that have integrated environmental education across the curriculum are described throughout this paper.

The Scottish Approach to Environmental Education

In Scotland environmental education is introduced at both the primary and secondary levels. It is taught as a cross-curricular theme, and teacher colleges offer an environmental education module to all student teachers. Private sector institutions and Internet-based networks are playing increasingly important roles as partners in the infusion of environmental education across the curriculum. The national guidelines for infusion of environmental education into the Scottish curriculum are given in table 1 (Scottish Consultative Council on the Curriculum 1995).

Table 1 Scottish Guidelines for Environmental Education

Science

Stage P1 to P3	Stage P4 to P6	Stage P7 to S2
Animals and plants in a variety of habitats to demonstrate variety and show how living things depend on each other	The interactions between humans and their environment in relation to aspects such as farming, fishing, and other local industries	The various ways in which humans can act on the environment, whether to its benefit or detriment (for example, forestation, dealing with pollutants, farming methods, chemical processing plants).

Social subjects

Stage P1 to P3	Stage P4 to P6	Stage P7 to S2
The uses of buildings and land in the local area, ways of maintaining a clean environment	Ways in which people can affect and change places through their work and leisure activities	The background to large-scale (continental or global) environmental or development issues

Technology

Stage P1 to P3	Stage P4 to P6	Stage P7 to S2
Technology and demand for resources	Technology as it affects lifestyles	Technology to control the environment
Some simple advantages and disadvantages to individuals and the community of having and using everyday products (for example, food packaging, video cassettes, refrigerators)	Simple relationships between the ways in which people live and the technologies they use in different communities and environments (for example, how water is used for domestic purposes, for irrigation, to generate power; how food is preserved and distributed; how houses are heated and insulated; how news is broadcast	Ways in which energy is converted and materials can change state (for example, burning fossil fuels to create electricity). Control of the environment (for example, the monitoring and control of flue gas emissions).

Note: P is primary, *S* is secondary.

There is always the issue of whether or not national guidelines transform into classroom action. Colin McAndrew, senior educator at the Scottish Consultative Council for the Curriculum (SCCC), draws the following picture of environmental education in Scotland (McAndrew 1996). He indicates that most primary schools in Scotland have done well in teaching the "traditional" aspects of environmental studies—the ecological and natural heritage areas. Most Scottish primary school students also study different forms of pollution, energy use, and conservation. They take part in small-scale practical projects such as developing the school grounds for wildlife, planting trees, and the like. They are also taught about global issues such as depletion of the rain forest and the ozone hole. However, according to McAndrew, "There is far from a critical mass of schools where a truly holistic approach to environmental education is to be found. Most primary schools rely on the leadership shown by the single enthusiastic teacher. Few have developed environmental policies and long term development plans."

McAndrew (1996) also reports that the situation in the secondary schools is even more challenging. First, the power base of the individual subject department remains, and the teachers'

principal concern is student achievement on public examinations. Second, teachers are under pressure to demonstrate that the schools are addressing wider social problems such as drugs, AIDS, and students' underachievement. Third, the decentralization of school management, which includes local financial management, means that school principals and senior managers need to be persuaded that environmental education should be a priority.

Bringing in the Networks

The use of computer networks in primary and secondary education, as well as higher and adult education, introduces new options to transform the way teaching and learning takes place in schools. The use of these networks is generating enthusiasm among educators and students, who find that networking technologies open new opportunities for communication, collaboration, and knowledge building and improve traditional ways of teaching and learning. As school systems seek ways to move away from frontal, expository, didactic presentations to classrooms, where learners are active discoverers and builders of knowledge, the computer is a tool with promising potential. ICT-based environmental education is opening up a world of new opportunities and potentially ending the confinement of the traditional curriculum for the advanced learner.

However, these changes will not come automatically by installing computers. First, the shortcomings of traditional class-based, frontal teaching should be addressed. One issue is whether or not the teacher, as facilitator of ICT-based learning, will be enabled to spend more time with the slower learners without shortchanging the advanced students.

Networks of Knowledge—New partners in learning

ICT-based environmental education ranges from presentations of environmental issues, such as the composition and fragility of the atmosphere, to concrete instruction on how students can take affirmative action to improve their environment, such as recycling or monitoring the energy consumption at their schools. Most of the new Web sites offer easy communication among schools and among countries. In a program such as the Costa Rica-Netherlands cooperation, Dutch students discuss significant local environmental issues with Costa Rican students and develop common research questions by exchanging proposals and experiences. We will elaborate on this program later (see "ICT-based environmental education in Latin America and the Caribbean" below).

In Great Britain the Eco-Schools project, which is promoted and supported by the Going for Green campaign managed by the Tidy Britain Group, gives teachers and students at the participating schools an opportunity to apply concepts and ideas from environmental education to the everyday life of their school. Because Eco-Schools applies knowledge and skills to real life issues, it enables students to see the relevance of what they learn in the classroom.

In Portugal "Vamos falar de Ambiente" (Let's talk about the environment), a similar project, aims to motivate students and their teachers to learn about the main problems of protecting and managing the environment in a global and local context. Each participating school does research work with the support of environmental protection nongovernmental organizations

(NGOs) and by consulting public documents and thematic information sources. The project is open to students from primary and secondary schools. Each school has one or several groups participating, each made up of five or six students. The projects last two years, but schools can take part over shorter periods. Computer equipment is available as well as several user and research guides on "Environmental Research" and "Environmental Routes." Communication is by e-mail, telephone, mail, the World Wide Web, and, if necessary, by group meetings. At the start of the project, schools have to answer the question "What is the condition of my environment?," by using the "Environmental Routes Guide" and then repeating this work after one year. A "Guide on Small Things that Can Be Done for the Environment" is written as part of this project. It is based on all the activities offered by the schools in response to their local environmental problems.

Whereas most of the new networks feature material for self-study for teachers and teaching guides as one of many different services, the American network, the Environmental Education and Training Partnership, focuses exclusively on educating professionals in environmental education.

In 1995 The North American Association for Environmental Education (NAAEE) and the U.S. Environmental Protection Agency (EPA) signed a cooperative agreement to undertake a multiyear national project to deliver environmental education training and related support services to education professionals. As a first step, NAAEE formed the Environmental Education and Training Partnership (EETAP). EETAP is a consortium of organizations working together in a coordinated manner to implement the project's environmental education and training objectives. EETAP is designed to increase the number of education professionals trained in environmental education. Over the five-year life of the project, EETAP will train 75,000 professional educators. To date, more than 45,000 have received training through the Partnership. The professional educators trained come from all 50 states, the District of Columbia, Puerto Rico, and Guam.

Educators need access to quality environmental education resources, information, and support at the local level. To address these needs EETAP is taking a comprehensive approach to training by assisting with related support services that educators require to successfully incorporate environmental education into their work.

How Widely Used Are the Networks?

All of the projects and networks mentioned above are cutting-edge programs. Yet, how widespread is their use? How widespread is the use of ICT-based teaching and learning in the schools? Five European associations (Ecole et Nature, Réseau Idée, IEP, Nature et Loisirs, ASPEA) have recently conducted a survey on the use of Internet-based teaching in European school systems (Eurosymbioses Survey 1996) The survey was sent to all 15 countries in the European Union, and the research was coordinated by Réseau Idée. As a result of specific contacts, those countries closest to the associations conducting the study received more coverage than other countries. The survey reported an 11 percent response rate. Some 34 percent of the respondents use the Internet as part of their teaching activities; an additional 10 percent use the

Internet for other matters and have e-mail addresses. The nonusers do not—as could have been expected—reject the Internet as a tool. Rather, they point to the financial constraints of accessing this technology. Institutional constraints were also identified, indicating that the working environment may also be a source of problems.

The survey asked the teachers what they expected of a communications network like the Internet in the context of their teaching activities (table 2)? The survey also asked the Internet users how they use the Internet for a teaching project. Only a few respondents mentioned specific experiences, and few of the responses indicated any real pedagogical enthusiasm for the new tool.

Table 2 Teacher Expectations of Information and Communication Technology

Contact/exchange	Circulation of information	Training
• Contact between people • Exchanges of information on teaching tools • Creation of a network • Exchange of ideas • Exchange of knowledge • Quick international contacts • Search for a genuine exchange of information and experience • Developing the same project	• General information on the environment • Information about environmental projects • Databases of experience and exchanges • Improving abilities through self-training • Accessing recent information • Increasing the speed at which information circulates • Telling others about experiences • Making people aware of environmental problems	• Learning about the Internet • Developing personal ability to use and communicate with it • Developing educational projects • Technical help

Why is the response of school systems so indifferent when the potential of ICT is apparently so great? Though the findings from the European survey indicate that teachers do not reject the new technology, only one-third of the respondents actually use the Internet in their teaching. The teachers point to financial and institutional constraints. Many affluent, industrial countries have not yet made the investments necessary to introduce ICT-based teaching and learning. It appears that many institutions are hesitating to implement this type of instruction because they fear the initial investment necessary and are not able to assess the ongoing costs of ICT over the long term.

Another issue is that ICT-based education is associated with the student-centered classroom. Thus teachers using ICT are also being challenged to move from their traditional teaching practices to become "facilitators" or "consultants" to the students. One serious problem that impedes acceptance of the student-centered classroom relates to experience from diversified, facilitator-based teaching and learning in the schools. There is evidence that the approach tends to exacerbate differences in achievement among students. Teachers have difficulty meeting the needs of the poorest achieving students in a student-centered classroom. This problem may be intensified when the teacher introduces ICT into the classroom.

Though reforms of education systems in several countries require teachers to adopt a student-centered pedagogy, the distance from national guidelines to classroom reality can be long. It appears that the road that must be traveled before ICT becomes an integral classroom resource is even longer. While most students in the industrial world have grown up with the telecommunications revolution and have integrated the new resources into their lives, this does not necessarily apply to their teachers. Many teachers, particularly the older generation, are reluctant to place themselves in a situation where they (compared to their students) are computer illiterate. Even for the teacher who does surf the Internet, there may be a problem in adjusting the pace of the class to allow for downtime and searching the Internet (table 3).

Table 3 Feedback from Post-secondary Teachers Using the Internet in Their Teaching

"When we surf the network with a group of students, we have to organize our equipment very carefully. Access times vary tremendously, according to the time of day. When surfing alone, the connection often goes down." (Susan Barker, Institute of Education, United Kingdom)
"The main problem is finding the time to do everything by oneself and successfully completing the project. We also do not have sufficient funds in our school to use the Internet properly. We only have access via one computer. It is very hard to draw any positive conclusions. There have been a few—but not many—useful contacts with colleagues in other schools, including some abroad." (Onno Kalverda, Cals College, the Netherlands)
"There is a huge quantity of information available on a vast range of subjects...The problem is that you can waste a lot of time if you do not know how to find the information you need." (Ismo Sarajarvi, Forestry College, Finland)
Source: Eurosymbioses Survey 1996.

Environmental Challenges in Latin America and the Caribbean

As summarized in the World Bank publication *Environment Matters, Annual Review '97* the Latin American and Caribbean region "faces a daunting array of environmental challenges, from conserving the biodiversity to cleaning up its polluted air and water." Latin American cities are growing faster than those in any other region in the world; three-fourths of the population presently live in cities, 43 of which have populations of more than a million. Severe pollution problems are causing a heightened incidence of pollution-related illness, particularly among the poor (Mahar and Partridge 1997). To meet the challenge, sound environmental planning and regulations are necessary, but it is equally important to improve environmental literacy and thus provide long-term support for sustainable, environmentally balanced development. Environmental education is yet to find its way into the curricula of school systems in the Latin American and the Caribbean region, but there might be an opening as the countries in this region have made good progress toward achieving universal primary education. This should open up opportunities for environmental education because educators in the region seem to be more comfortable with including environmental education at the secondary level, as the basic skills learning must take priority at the primary level. (Lakshmanan, Abedin, and Chee 1998)

Information and Communication Technology–based Environmental Education in Latin America and the Caribbean

Many Latin American and Caribbean countries already use distance education (teacher and student) cost-effectively. Three such countries are Brazil, Chile, and Costa Rica. The Enlaces project in Chile is a program that aims to introduce ICT-based education into the Chilean schools. In Brazil GRUDE (an conservationist NGO) has developed an impressive environmental education network that links some 68 schools with 5,600 students. In 1994 Costa Rica and the Netherlands signed a bilateral convention on sustainable development. This has led to exciting cooperative activities between Costa Rican and Dutch school networks. The Costa Rican Ministry of Education provides support to its participating schools, and the Dutch "EducaPlan," an affiliate of the Dutch National Curriculum Institute, supports the Dutch schools.

Enlaces, Chile

Established in 1993 as a pilot demonstration project in the southern part of Chile, the Enlaces project has built a remarkable computer network among some 180 primary and 62 secondary schools; trained hundreds of teachers in its use; and is supplying, and sometimes developing, educational software. Most significantly, a majority of the schools in the pilot program are located among the country's poorest, primarily indigenous, communities, which are those most lacking educational resources. Significantly, there is growing evidence that the computing and communications technology provided by Enlaces is contributing positively to the many exciting changes now taking place in Chile's schools.

Having proven so successful in its pilot phase, Enlaces was recently been converted to a national program by the Ministry of Education. By 2000, with strong political and financial support, the program will be incorporated into all secondary schools and into half of the primary schools in Chile. The major challenge now facing Enlaces in achieving this ambitious goal is to provide schools with the teacher training and technical support required to use the technology successfully. In this new national phase Enlaces will also be challenged in having to work through and with some new partners—the universities and IBM. The nation's universities now form part of a technical assistance network established by the Ministry of Education to assist Enlaces in providing network schools with necessary training and technical support. IBM, having won a major bid to supply hardware and software to the network, joins the Apple Computer Corporation, which has provided most of the existing hardware and considerable technical assistance, in helping Enlaces expand its network in the years ahead.

Groupo de Defesa Ecologica, Brazil

Since it was founded in 1996, environmental education has been GRUDE's main activity. Since 1991 GRUDE (http://www.grude.org.br/histo_i.htm) has offered the community a wide range of services including:

- A library
- A video library

- An advisory service on environmental subjects
- Courses on environmental education, social ecology, recycling, and craftsmanship
- Seminars, encounters, and professional education for young people
- Technical advice to community associations, teachers, students, businesses, other NGOs, and churches.

In 1995 GRUDE developed the project "Environment as a Whole." Its purpose was to present nonformal environmental education courses aimed at developing ecological projects in communities and schools. The methodology used in the Environment as a Whole project was also used in an environmental education project about an expressway linking the northern and southern regions of the city of São Paulo. This involved 112 teachers, 68 schools, and 5,600 students in 19 communities.

GRUDE's Agenda 21 schools project, developed in 1996, has the following objectives: identifying problems affecting the quality of life in schools and school communities, stimulating critical analyses and active problem solving, and disseminating knowledge developed by the school community. Under Agenda 21 GRUDE has, in partnership with 12 schools in different cities, coordinated activities related to urban waste, involving some 16 teachers, 480 students, and 25 communities.

The Costa Rica-Netherlands Cooperation

In March 1994 the governments of Costa Rica and the Netherlands signed a bilateral convention on sustainable development, as a result of which a consultation took place in 1996 aimed at establishing cooperative activities between Costa Rican and Dutch school computer networks. The project has developed new and student-driven environmental education materials. The project deals with issues of global sustainability in local educational contexts. It involves teachers, students, and curriculum specialists from both countries working together to develop new educational approaches in environmental education. The schools involved were equipped with computers and got access to the Internet. Technical maintenance support is also provided. In all schools in both countries initial training was given to the teachers and discussions took place to set the project in motion. The project's methodology took the form of "action research" at two levels:

- Students in both countries are investigating actual (local and international) environmental issues in several cycles of action and reflection. Common research questions are developed by exchanging proposals and experiences. This leads to question exchanges among students from both countries.
- Teachers and planners with curriculum development responsibilities use the students' activities as sources of knowledge on the required curriculum framework. Evaluation activities include observations and interviews on the experiences resulting from the Internet interactions.

Initially, 10 secondary schools from each country are participating in the project, with the involvement of one or two teachers per school. The students involved are between 14 and 18

years old. The schools were recruited and selected during the project preparation phase and were actively involved in planning the project. There are plans for expanding this project and involving more schools, after an evaluation of the first phase.

The World Bank and Environmental Capacity Building

The lack of institutional capacity in developing countries, including those in the Latin American and the Caribbean region, has long been a constraint to implementing environmental policies and programs. To address this problem the World Bank is presently engaged in 26 environmental institutional development projects in all regions, with an average cost of US$55 million per project. This effort is part of a large environmental portfolio consisting of 163 projects costing nearly US$11 billion in Bank loans in areas such as biodiversity protection, pollution control, and water supply and sanitation.

The Bank also continues to support National Environmental Action Plans (NEAPs) (as it has done since the mid-80's) to help countries establish a framework for environmental management. By the end of 1997, 57 countries, members of International Development Association (IDA) and the World Bank, completed NEAPs and 24 more were preparing them. In the education sector World Bank financing included science and environmental education activities in many countries, often as part of curricular reform and infrastructure (laboratory construction and equipping) improvements. However, a comprehensive strategy for environmental education lending by the World Bank has yet to be developed. Systemwide investments required for relevant and effective science and environmental education and the new subjects linked to ICT learning are substantial, as proven by industrial countries. This includes investment and recurrent costs for school laboratories, equipment, teacher employment, and teacher and staff training as a major part of countries' national education budgets. However, the pay-off in terms of economic development are significant, as proven by industrial countries.

In the United States and Europe there is renewed interest in innovative solutions for science and environmental education. New ICT, in spite if their cognitive risks and pitfalls, open promising new ways of making knowledge more easily accessible at a much lower cost. However, there is still much debate on the content, quality, and the way in which environmental education fits into the curriculum at the secondary school level. At the tertiary level its case is overwhelmingly positive and many new environmental education-related disciplines have gained ground in the 1990s. At the primary school level the general consensus is that all students must have at least some basic knowledge of science and the environment. But at the secondary school level the picture is more varied and many questions (on content, investment, teacher training, equipment, and methods of teaching) remain under debate (McAndrew 1996; SCCC 1995). The new ICT developments will add unexpected solutions and, at the same time, pose new challenges. In view of the faster reforms in science and environmental education and their increasing costs it is important for the World Bank to encourage and assist the worldwide debate on these issues.

Jacob Bregman taught chemistry at secondary schools in the Netherlands. From 1978 to 1987 he and his family worked and lived in various African countries. During this time he was a

university chemistry and science education professor, financed by the Dutch bilateral University Cooperation for Development. In 1989 he joined the World Bank and worked in the Middle East and North Africa (MENA) and South Asia (SASED) Regions. Currently, he is Senior Education specialist working in the World Bank's Latin America and the Caribbean (LAC) Region.

Morten Fisker holds a Master's in Social Anthropology from the University of Copenhagen. Currently he has a long-term contract with the World Bank's LAC Region to study the recent reforms in environmental and science education in primary and secondary school curricula, with particular emphasis on the LAC countries.

References

Brown, L. 1998. *The State of the World 98*. Washington, D.C.: World Watch Institute.

Calderoni, J. 1998. *Telesecundaria: Using TV to Bring Education to Rural Mexico*. World Bank Education and Technology Series. Washington, D.C.

Chee, N. 1998. *Environmental Education in Sub-Saharan Africa—Past Lessons and Future Directions*. Washington, D.C.: World Bank.

Alvarez, M.I., and others. 1995. *Computers in Schools: A Qualitative Study of Chile and Costa Rica.* World Bank Education and Technology Series. Washington, D.C.

Danish Ministry of Education. 1998. *A Green Approach to Education and Training—A Summary of Five Years Practice with a Green Approach.* Copenhagen, Denmark: Ministry of Education.

Eco-schools. http://www.gfg.iclnet.co.uk/eco_schools/page.htm

Ecole et Nature. http://www.educ-envir.com/ecole_et_nature/

Environment and Youth. http://www.igc.org/igc/issues/educat/index.html

European Environmental Education Newsletter. http://www.crossroad.de/realworld/eeen/index.html

EuroSymbioses. 1996. "1996 Survey: Internet and Environmental Education." http://www.ful.ac.be/Eurosymbioses/Eurosymbioses-1/Survey

GRUDE (Groupo de defesa ecologica). http://www.grude.org.br/histo_i.htm

Lakshmanan, D.A., E. Abedin, and N. Chee,.1998. *Environmental Education: Building Constituencies.* Washington, D.C.: World Bank.

Lakshmanan, D.A. 1998. *The Role of Civil Society in Monitoring the Environment—A Case for Public Awareness and Functional Literacy*. Washington, D.C.: World Bank.

McAndrew, C. 1996. *Science and Environment in the Scottish Curriculum.* Dundee, Scotland: Scottish Consultative Council for the Curriculum.

Midgley, C., ed. 1995. *The Annual Review of Environmental Education 1995, No. 7.* Reading, England: Council for Environmental Education.

Ministère de L'Education, National Direction des Ecoles. 1996. *Programmes de l'Ecole Primaire Française*. Paris.

National Institute for Curriculum Development. 1990. *The Curriculum Journal* 1 (3) December.

Osin, L. 1998. *Computers in Education in Developing Countries: Why and How?* World Bank, Education and Technology Technical Notes Series 3. Washington, D.C.

Potashnik, M. 1996. *Chile's Learning Network.* World Bank, Education and Technology Series. Washington, D.C.

Serageldin, I., and A. Steer, eds. 1998. *Making Development Sustainable: From Concepts to Action.* World Bank Environmentally Sustainable Development Occasional Paper Series No. 2. Washington, D.C.

Serageldin, I., T.Husain, J. Martin-Brown, L. Ospina, and J. Damlamian, eds. 1998. *Organizing Knowledge for Environmentally and Socially Sustainable Development*. Washington, D.C.: World Bank.

Scottish Consultative Council on the Curriculum. 1995. *5–14 Catalogue: Environmental Studies—Three Catalogues on Social Subjects, Science, and Health Education*. Dundee, Scotland.

Contributors

Professor Eleonora Badilla, Coordinator
Center for Educational Innovation
Omar Dengo Foundation
Universidad de Costa Rica
San Jose, Costa Rica
e-mail: ebadilla@rad.fod.ac.cr

Dr. Samuel Bajah, Director
Institute of Education
University of Ibadan
Nigeria
e-mail: silori@ibadan.skannet.com

Dr. Warren Beasley
Graduate School of Education
The University of Queensland
Brisbane, Australia
e-mail: w.beasley@mailbox.uq.edu.au

Dr. Boris Berenfeld
The Concord Consortium
Concord, Massachusetts
United States
e-mail: boris@concord.org

Dr. John D. Bradley, Director
RADMASTE Centre
University of Witwatersrand
Johannesburg
Private Bag 3, WITS 2050
South Africa

Jacob Bregman
Education Specialist, LCSHD
The World Bank
1818 H Street, NW
Washington, D.C. 20433
United States
e-mail: Jbregman@worldbank.org

Dr. Raul Cerón F.
Department of Chemistry
Universidad de Santiago de Chile
Santiago, Chile

Dr. Leo P. de Feiter
Vrije Universiteit Amsterdam
Centre for Development Co-operation Services
De Boelelaan 1115
1081 HV Amsterdam
The Netherlands
e-mail: l.de_Feiter@dienst.vu.nl

Dr. Eduardo Doryan
Central American Institute of
Business Administration (INCAE)
San Jose, Costa Rica
e-mail: edoryan@sol.racsa.co.cr

Dr. Roger G. H. Downer, President
University of Limerick
Limerick, Ireland
e-mail: roger downer@ul.ie

Morten Fisker
Consultant, HDNED
The World Bank
1818 H Street, NW
Washington, D.C. 20433
United States
e-mail: mfisker@worldbank.org

Natalia E. Gapanovitch, Head
Laboratory of Environmental Education
Center of Poly-discipline Training Intensive Methods
Krasnoyarsk, Russia
e-mail: tarasova@glas.apc.org

Dr. Andoni Garritz
Facultad de Química, UNAM
México, D.F. 04510
e-mail: andoni@servidor.unam.mx

Dr. Sascha A. Glazar
Faculty of Education
University of Ljubljana
Slovenia

Dr. Sarah J. Howie
Education and Training Systemic Studies
Human Sciences Research Council
Private Bag X41
Pretoria 0001, South Africa
e-mail: SJHowie@beauty.hsrc.ac.za

Dr. Manuel Martínez M.
Department of Chemistry
Universidad de Santiago de Chile
Santiago, Chile
e-mail: mamartin@lauca.usach.cl

Kenneth Ncube
Department of Mathematics and Science Education
University of Zimbabwe

Karma Rana
Asian Institute of Technology
Bangkok, Thailand
e-mail: karma@ait.ac.th

Dr. Krishna V. Sane
UNESCO-Nehru Professor for Science Capacity Building
Jawahar Lal Nehru Centre for Advanced Scientific Research
Bangalore-560 064
India
e-mail: kvsane@hotmail.com

Vicente Talanquer
Facultad de Química, UNAM
México, D.F. 04510
e-mail: vicente@zenon.pquim.unam.mx

Professor Natalia P. Tarasova, Head
Department for the Problems of Sustainable Development
D. Mendeleev University of Chemical Technology of Russia
Moscow, Russia

Dr. Erik W. Thulstrup
Department of Life Sciences and Chemistry
Roskilde University, POB 260
DK-4000 Roskilde
Denmark
e-mail:ewt@virgil.ruc.dk

Dr. Margareta Vrtacnik
Faculty of Natural Sciences and Engineering
University of Ljubljana
Slovenia
e-mail: metka.vrtacnik@guest.ames.si

Sylvia A. Ware, Director
Division of Education and International Activities
American Chemical Society
1155 Sixteenth Street, NW
Washington, D.C. 20036
United States
e-mail: s_ware@acs.org