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ABSTRACT

The purpose of this paper is to argue that, given the role science and technology play in economic and social development in today's world, scientific and technological literacy must be given priority as an essential component of basic education. This paper begins by presenting some of the dilemmas posed by the role science technology plays in our daily lives. The argument is made that nothing short of revolutionary changes in our present education systems will be necessary to meet these challenges. The development of a community of scientists and the development of a scientific and technologically literate populace need to be the goal of all countries. Broadening the scope of basic education to include scientific and technological literacy is the first step. The background section attempts to provide a context for educational and political leaders to use in making policy. First, science and technology development are briefly defined and discussed, including the interaction between them. Secondly, an attempt is made to clearly and directly answer the question "Why should basic education be broadened to include science and technological literacy?" Finally, the background section of the paper spells out the essential areas of knowledge and skills that are basic and the concepts in these areas that need to be understood and learned by every citizen. The third section of the paper reviews some of the major facts and issues policy makers will find useful in planning for policy reformulation. A country-by-country review of current practices in science, mathematics and technology is followed with a discussion of what planning implementation considerations are necessary in order to include science, mathematics and technology in basic education. A similar review of the major facts and issues addresses teacher training and effective teaching and learning strategies for science, mathematics and technology in the primary school and/or adult education. Finally, issues and a summary of the research literature on women and scientific and technological literacy is presented. In section 4, the major issues involved in scientific and technological literacy (planning, prioritizing, and financing) are considered. The paper concludes with a challenge to the major issues involved inplanning, prioritizing, and financing are considered from the perspective of the policymaker. (40 references) (KR)

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WORLD CONFERENCE ON EDUCATION FOR ALL
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SCIENTIFIC AND TECHNOLOGICAL LITERACY : Education for Change

by Jane Bowyer

United Nations Educational, Scientific and Cultural Organization

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EXECUTIVE SUMMARY

The purpose of this paper is to argue that, given the role science and technology play in economic and social development in today's world, scientific and technological literacy *must* be given priority as an essential component of basic education. The world we live in is dominated by change related to development. Moreover, the pace and volume of change are constantly increasing because of science and technology. Today's young people must "keep up." They will be required to solve complex problems that have yet to be identified; many will work in jobs that do not yet exist. The children of tomorrow must be able to think flexibly, make decisions and design complex systems to deal with economic, political, and environmental changes. They will be required to make personal choices that involve information and analysis in areas of health, nutrition, family living and job related problems. Young people must not only be prepared to adapt to a changing world; they must be prepared to create new change for the benefit of humanity.

What should be the main ingredients of a basic education to prepare children and adults for a world that is constantly evolving? Skills in reading and writing, although necessary, are certainly not sufficient. It is proposed that scientific and technological literacy (which includes literacy in mathematics) form a cornerstone in the basic education of every person. Understanding science, mathematics and technology is one essential means of enabling individuals to continue and to control their own education in areas that directly affect them, their community, and the world. Access to scientific and technological literacy must begin in the early primary years and extend through non-formal adult learning for those who have not had the opportunity for formal schooling. It must be available for all: females, males, poor, rich, rural, urban, and persons from both developing and developed countries. Special priority must be given to two populations: the poor and rural people, particularly those who live in developing countries, and females in all parts of the world. Federico Mayor, the Director-General of Unesco, has said "Human resource development is at the very heart of the developing process ..." Every person in all societies must have the advantages of a basic education which includes scientific and technological literacy.

This paper begins by presenting some of the dilemmas posed by the role science and technology play in our daily lives. Although there is no doubt about the linkage between overall economic well-being and scientific and technological development, their global impact on countries is often uneven and can result in negative consequences. The argument is made that nothing short of revolutionary changes in our present educational systems will be necessary to meet these challenges. The development of a community of scientists *and* the development of a scientific and technologically literate populace need to be the goal of all countries. Broadening the scope of basic education to include scientific and technological literacy is the first step.

The background section of the paper attempts to provide a context for educational and political leaders to use in making policy. First, science and technology development are briefly defined and discussed, including the interaction between them. Secondly, an attempt is made to clearly and directly answer the question "Why should basic education be broadened to include science and technological literacy?" This is quite important for policy makers because the climate for bringing about radical changes in the thinking of the public, teachers, community leaders, and children concerning the expansion of basic education is going to require visionary planning and action. The 3 R's (reading, 'riting and 'rithmetic) are so traditionally linked with literacy that the idea of expanding it to include two subjects (science and technology) that have always been a "frill" in primary schools all over the world, will take major efforts in educating the public. Finally, the background section of the paper spells out the essential areas of knowledge and skills that are basic; concepts in these areas need to be understood and learned by every citizen. Applications and specific examples in each areas must be appropriate to the local community.

The third section of the paper reviews some of the major facts and issues policy makers will find useful in planning for policy reformulation. A country-by-country review of current pr 'ces in science, mathematics and technology is followed with a discussion of what planning and implementation considerations are necessary in order to include science, mathematics and technology in basic education. A similar review of the major facts and issues addresses teacher training and effective teaching and learning strategies for science, mathematics and technology in the primary school and/or adult education. Finally, issues and a summary of the research literature on women and scientific and technological literacy is presented. This includes a review of the causal factors for lack of participation of rural women in third world countries as well as women living in countries with fairly developed scientific/technologically based economies.

Section four summarizes the major relevant facts and issues policy makers must struggle with in order to bring about a change in the concept of basic education that will include scientific and technological literacy. Educational traditions, dwindling financial resources, human resources (the need for properly trained teachers), material resources, and logistics (especially in remote areas of the world that are inaccessible) are summarized. Finally, the major issues involved in *planning*, *prioritizing*, and *financing* are considered from the perspective of the policy maker.

The paper concludes with a challenge to the leadership in each society. In the final analysis, it is the leadership that must take responsibility for developing policy, creating the climate and implementing change so that scientific and technological education becomes a basic part of everyone's education. Each individual society must evolve a "custom-made" plan that meets its specific needs and is in harmony with the global context. Scientific and technological literacy is no longer a luxury; it is a necessity!

I. PROBLEM

Never before in the history of the world has the quality of people's lives been tied so directly to science and technology. Neither science nor technology is new to humankind: technology is as old as civilization and science and mathematics have roots that can be traced to the early Egyptian, Greek, Chinese and Arabic cultures. What *is new* is that today scientific and technological activities are essential aspects of the daily lives of all humans.

To understand the real impact of science and technology in our daily lives, it is necessary to view them within a broader political and socio-economic context. While contributing to development in all fields of human endeavour, science and technology present enormous challenges to modern societies. Economic development engendered by technological change is not always matched by social development, at least not for all members of the society. Industrialization is sometimes accompanied by massive migrations of persons because their jobs have been eliminated due to new technology. Similarly, the conversion to modern methods of production involving automation sometimes threatens employment and can lead to social unrest.

Although there is no doubt about the linkage between overall economic well-being and scientific and technological development, the global impact on countries is often uneven and can result in negative consequences. The gap between rich and poor among the countries of the world in some cases widens; even within the same country differences between rich and poor, urban and rural, are sometimes exacerbated. In the poorest rural areas in the developing world, technological change can be extremely significant in terms of socio-economic imbalances caused by distribution and equity problems. The questioning of cultural values, and the apparent inability of certain traditional cultures to assimilate changes while at the same time retaining their fundamental living principles creates additional problems.

The volume and scale of technological changes result in environmental changes. Deserts can be transformed into bountiful gardens and modern industrial plants created to produce efficient means of transportation for individuals and products. But transformed environments can also result in harmful side effects such as the destruction of forest life by acid rain, or the chemical pollution in rivers with disastrous effects on aquatic ecosystems and marine life. Problems of environmental pollution in relation to industrialization and the use of machines is steadily increasing over time. It is now at a level of global concern; human survival on our planet may be threatened.

These problems need to be analysed globally and locally; they need to be dealt with internationally and at the national and local levels. To accomplish this it is imperative that we have a world community of scientifically and technologically literate citizens. Our education must prepare generations of young people to create new science and technology for the economic progress of all.

And, simultaneously, new generations of literate adults must be equipped to solve problems precipitated by science and technology.

Although exciting discoveries and technological developments are taking place daily that are a tribute to human inventiveness, more than one-third of the world's adults and children have no access to the knowledge, skills and technologies that can improve the quality of their lives and help them shape and adapt better to social and cultural change. This situation is intolerable and can only change if scientific, mathematical, and technological literacy are a basic part of everyone's education.

Revolutionary changes in our present educational systems will be required. Formal and non-formal education must be redesigned to ensure lifelong learning. Mechanisms must be put into place to ensure an education that prepares people for change. All this must be done at a time when most educational budgets in the world are being cut. Unfortunately, misdirected educational adaptations are extremely costly in terms of financial and human resources, so planning and programming must begin now.

Education is a fundamental right of each human being: it provides the keys to unlocking knowledge and experience from previous generations; it provides the keys to unlocking doors to future generations by developing individuals' capacity to harness new knowledge in the service of the community. Scientific and technological literacy must be a fundamental part of basic education.

II. BACKGROUND

In order to understand the impact of scientific and technological changes on basic education, it is useful (1) to examine the nature of science and technology as human activities aimed at individual and collective development, (2) to analyse why basic education needs to be broadened to include science and technological literacy and (3) to define essential areas of scientific and technological knowledge and skills necessary for basic education.

Science and Technology Development

Science and technology are interrelated but contrasting activities. The role of science is essentially a quest for knowledge and uses a hypothetico-deductive method to arrive at a "scientific explanation". Essential features include: (1) making observations; (2) building concepts; (3) developing a theory linking the concepts; (4) deducing consequences and predicting effects; and (5) testing predictions. The process repeats itself and every new theory is linked to its predecessor to form an evolving body of knowledge. There is no simple scientific concept that stands in isolation; rather each is a component of a complex system of reasoning and experiments. The linking formalism is provided by mathematics. Science is open at both ends, pushing the frontiers of knowledge and, at the same time, revising the knowledge on which its progress is based. The role of science is to enlighten humanity.

The role of technology is to use existing knowledge to serve humanity. Today it is more and more concerned with the application of scientific knowledge to the general purpose of fulfilling an individual, community or national need. Thus airplanes, insecticides, preserved food, computers, wine, and bio-genetically produced vaccines are all direct products of technology. The know-how and creative processes (including designing), utilizing tools, resources and systems in order to solve problems, to enhance control over the natural and man-made environment, to alter the human condition - all these define technology (World Bank/British Council, 1989).

Although the development of technology follows an autonomous path that does not always coincide with the daily progress of science, there is no doubt that both interact and influence each other. Knowledge advances and science progresses through the use of technological appliances. For example, progress in knowledge is achieved through the use of telescopes and microscopes. And technology is changed due to the impact of new scientific discoveries and theories as in the case of semi-conductors and transistor theory.

It is not the place here to make an exhaustive survey of contemporary trends in science and technology. However, from the contents of various scientific reports and research papers, a number of areas of activity and innovations in science and technology can be identified. In science the areas of special interest are concerned mainly with the planet Earth, living phenomena, and the structure of matter. In technology, the areas of interest include computers and communications, energy and materials. A very important consideration stemming from the analysis of the contemporary growth areas in technology is the subject of the conservation and preservation of our natural environment.

Broadening the Scope of Basic Education to Include Science and Technological Literacy

The goal of basic education is to help ensure a safer, healthier, more prosperous and environmentally sound world. To accomplish this, every child, youth and adult needs to participate in educational opportunities designed to meet their basic learning needs. They need the knowledge, skills, values, and attitudes required to be able to survive, live and work in dignity in today's world. Every person needs the knowledge to make informed decisions, to improve the quality of their own life, and to continue learning (WCEFA/Preamble, 1990).

Traditional basic education with an emphasis on the 3 "R's" (reading, 'riting, and 'rithmetic) appeared to be sufficient for providing basic access to learning for living in the past. But in today's world, citizens want, need, and deserve more from their basic education. The rapid pace of technological change, which shows all signs of continuing unabated, by definition implies the rapid obsolescence of knowledge and the need for constant retraining of the work force. This is true for developing and developed countries. An expanded vision of basic education must be conceptualized and implemented. A start in this direction has been made. Key personnel (science curriculum developers and science teacher educators) participated in a conference organized by the Unesco Regional Office for Education in Asia and the Pacific. The purpose was to help develop an understanding of the "Science for All" concept and its implications regarding skills and attitudes for classroom practices and teacher training (Bangkok, Unesco, 1989; Fensham, 1981).

In the Framework for Action to Meet Basic Learning Needs (WCEFA, 1990), four components are identified as necessities for broadening the scope of basic education so that the diversity, complexity, and changing nature of basic learning needs of children and adults are met. Science and technological literacy can uniquely make substantial contributions in each of the five focus areas in terms of basic knowledge and skills.

"Learning begins at birth. Therefore, early child care and initial education are important. These can be provided through arrangements involving families, communities, or institutional programmes, as appropriate."

In India a non-formal education project for rural women was started because of problems associated with high infant mortality rates. Early marriages (from eleven years of age) and early pregnancies (average age of fourteen years) resulted in a 60% infant mortality rate for the first child. The practices and beliefs associated with this problem are deeply rooted in tradition and circumstance of rural life. Traditional science teaching alone could not solve the problem. It required the combination of (1) a practical medical treatment/instruction programme, (2) an education programme in basic health, nutrition, and infant care and child development, and (3) a supplementary feeding programme for the mothers (Rao,1987).

This example of scientific and technological literacy education for infant health corporates a non-traditional design that is multi-dimensional in terms of content, teaching methodologies, and learning environments. It is technologically appropriate and meets the basic learning needs of the women it serves.

"The main delivery system for the basic education of children is primary schooling. Therefore, primary education must be universal to ensure that the basic learning needs of all children are met. Supplementary alternative programmes can help meet the basic learning needs of children with limited or no access to formal schooling, provided that they share the standards of learning applied to schools, and are adequately supported."

Most of the people of Sierra Leone (Africa) live in the rural areas. Their life is difficult, and they are unable to produce enough rice to feed themselves and the rest of the country.

To improve the quality of rural life, the government asked UNDP and Unesco to help make primary education more relevant to the needs of the people.

A pilot project was set up at a rural teacher training college at Bunumbu. Teachers and villagers got together, and a new curriculum was developed, with stress on the practical and on self-help.

The Bunumbu influence is now spreading to the rest of the country. It is hoped that this will help to put to full use the resources, both human and natural, of Sierra Leone (Unesco. n.d.b.).

This example of primary school scientific and technological literacy education utilizes teacher trainers and the community in developing a technologically appropriate curriculum that will help actualize the natural and human resources available for the improvement of the quality of life for all.

"The basic learning needs of youth and adults are diverse and should be met through a variety of delivery systems. Literacy programmes are indispensable because literacy is a necessary skill in itself and the foundation of other life skills ... Other needs can be served by: skills training, apprenticeships, and specialized instruction on such topics as health, nutrition, population, safe water, the environment, family life, and other societal issues."

> In the villages of the Seti zone in Nepal which can be reached only on foot and are rarely visited, the people face a number of vital problems: food is limited, clean drinking water rare, hygiene minimal, health care practically unavailable, and education inadequate, especially for girls.
>
> To help them to improve their lives, a pilot education project was carried out by the government of Nepal and Unesco in five districts along the Seti river (Unesco. n.d.a.).

This example of basic education that features scientific and technological literacy utilized many techniques and environments for teaching the technical skills. Knowledge and skills to construct minimum facilities to ensure safe drinking water and the disposal of human wastes for healthy living is one example of the science technology curriculum content.

"All available instruments and channels of information, communications, and social action must be used to reinforce the above components, convey essential knowledge, and inform and educate people on social issues"

> Most of the science and mathematics teachers in "Silicon Valley," the location of many hi-tech industries in California, had never worked in jobs outside of schools. Their knowledge of science and technology was entirely what they learned in school settings. A consortia of local industries initiated a programme in conjunction with a teacher training institution to encourage teachers to learn first hand about science, technology and industry work attitudes and skills. Teachers were hired for substantial summer positions consistent with their educational background. A "mini-partnership" between the teacher and an industry mentor was structured so that the two could communicate and plan. Five percent of their allocated work time was provided, so they could prepare classroom application curricula of their industry experience.

> Computer equipment (modems) were supplied to each teacher to use during the school year so that the teacher's individual classroom and industry work setting could be in communication via the computer (Bowyer, 1985).

This example of science and technology literacy education, in this case directed at teachers, incorporates a community partnership design. One result is that direct information and communication channels were initiated and maintained in order to keep the science and technology education connected to practical work in the local environment.

The driving forces for change in the world are science and technology. They are integral parts of our everyday life. To flourish, science and technology require a climate of societal acceptance and the existence of a scientific community. Neither of these is possible without a scientifically and technologically literate population. This literacy is fundamental and basic to all people. Science and technology are part of the heritage and hope of humankind.

Essential Areas of Knowledge and Skills for Science and Technology

What does one need to know in order to survive, live, work, make decisions, learn, and improve the quality of life? Certainly one "recipe" will not fit all individuals in every part of the world. Progress is being made in identifying some areas of basic knowledge and generic skills and attitudes in science and technology that can form a framework. Specific content and examples must evolve from individual, societal, and personal needs.

Since technology is as old as civilization, one may wonder why it is suddenly deemed necessary to include it as a basic in everyone's education. Likewise, science, a seemingly esoteric subject that is difficult for most is being elevated to a "basic." The following example is offered to explain in part what knowledge and skills in science and technology can do.

> The "invention" of sowing seeds was one of the greatest human achievements. Astute peasants knew how to select the best seeds for propagation early in the history of civilization. Their knowledge was based on experience accumulated slowly over a long period of time. Since the scientific revolution, however, it is possible to use experimentation in combination with trial and error experience in the pursuit of progress. Both experience and experimentation demand careful observation and intelligent drawing of conclusions. But, experience by trial and error is very time consuming. Planned experimentation allows for quicker and more reliable deductions. Today farmers concerned with selecting the best seeds to grow in a particular area

> have the possibility of being informed by the science of genetics. Indeed, through genetic engineering the desired properties can be directly manipulated in the seed or plant.

In this example, through linking science knowledge (genetics), scientific processes (experimentation), and technology (genetic engineering), the health, prosperity, and work life of farmers is improved .. that is, *if* a scientifically and technologically literate population exists in the local region that can understand and translate science/technology "know-how" into practical problem solving.

A set of basic topics for scientific and technological literacy was identified and investigated in detail for their applicability to teaching for the goals of development (Bangalore Conference on Science and Technology Education and Future Human Needs, 1987). The basic science/technology knowledge topic areas are:

(1) **Health**
(2) **Food and Agriculture**
(3) **Energy**
(4) **Land, Water and Mineral Resources**
(5) **Industry and Technology**
(6) **The Environment**
(7) **Information Transfer**
(8) **Ethics and Social Responsibilities**

Clearly knowledge in these topics has the potential for improving traditional ways of carrying out economic or life-sustaining activities. This knowledge can also bring new possibilities for livelihood and offer the prospects for an improved community life overall. These topic areas meet the criteria for knowledge in scientific and technological literacy.

The following example (Jesuitas, 1987) of implementing a science/technology curricula for both primary age and adult learners that needs all seven knowledge areas presented above follows.

> The Institute for Science and Mathematics Education Development of the University of the Philippines implemented a science/technology curriculum. The first step involved a needs and resources assessment of the community. Data from the assessment were analysed to identify specific local problems and implications for curriculum planning. The needs assessment revealed that the local drinking water contained an extremely high number of foliform bacteria. Sources of drinking water

for individuals in the area were shallow wells and a few tanks for catching rainwater running off from the galvanized tin roofs of houses.

The subsequent curriculum content developed for the primary level included the following: (1) Awareness of the micro-organisms in the community's water supply; (2) Knowledge about the micro-organisms and their role in the spread of disease; (3) Methods for keeping water safe to drink; and (4) Solar distillation of water to demonstrate the purification of water, the water cycle and the production of pure water for emergencies.

Curriculum content for the adult learners focused more on things adults can do to solve the problem. These include (1) Contacting the National Administration to present the community's problems; (2) Designing ways to make water potable: boiling, using clean containers; (3) Designing sanitation activities to keep water free from faecal contamination; (4) Designing a system to evaluate the results of the water supply; and (5) Knowledge of health implications.

In addition to the science and technology knowledge areas, specific knowledge in skills and processes of science and technology are necessary for literacy. These are identical to those used by scientists and technologists in their daily work as they search for new knowledge and solutions (Layton, 1989; Unesco, 1983):

(1) **Experimentation**

(2) **Hypothetical-Deductive Reasoning**

(3) **Theory Building**

(4) **Problem Solving**

(5) **Critical Evaluation**

(6) **Design**

(7) **Creativity**

(8) **Communications**

All of these processes were taught as part of the Philippine drinking water curriculum example above.

The eight topic areas of knowledge and the eight topic areas of process-skills in science and technology are each composed of a multitude of specific concepts that will form a framework for each person to use in day-to-day living. This knowledge that develops one's capacity to learn for present needs and for creating future change meets the primary criteria for inclusion in literacy education.

An example of specific knowledge a person might learn in primary school in a technology curriculum follows. Of course, local environment, traditions, and connections between them and the major ideas one wants to impart are the premise from which all science/technology curriculum evolves.

> Students are first introduced to the concepts associated with simple tools. Concepts such as levers, momentum, forces, inclines, planes and gravity from the science of physics for example are basic. Details of the mathematics of the simple tools also are important to introduce early. This is followed with learning about how more complicated machines are built from these simple parts.
>
> Applications of simple tools to the bigger conceptual and global considerations associated with technology are then introduced. Global considerations include learning an array of new knowledge concepts such as: resource management, full employment, meaningful work for everyone, machines can displace familiar tools; old jobs may be replaced with new ones involving reduced responsibilities; alternative uses of resources, recycling, exploitation of the many for a few, the human and financial costs of technology, ecological implication (i.e. the Aswan dam controls the flooding of the Nile but resulted in an associated health problem due to the build up

of a particular snail), implications of the global economy, world trade, and the interdependency in resources among nations of the world (Karplus, 1990).

All of the knowledge content noted in this example has general implications for everyone in terms of building a framework of general technology concepts. What is missing is the specific connectedness to a particular community or region. The importance of tailoring goals and curriculum to individual countries, nations and communities cannot be stressed enough. The strength and usefulness of the educational programmes shaped by such content and goals will be directly proportional to the fit with local situations and needs. Planning programmes to meet basic learning needs must be specific so that all individuals are enabled to continue and control their own education and work.

III. REVIEW OF FACTS, ISSUES, AND POLICY CONSIDERATIONS

A. Current Curricula Practices in Science, Mathematics and Technology

A.1 The Facts

An international study (Unesco, 1986) to determine the degree to which science, mathematics, and technology are currently taught in the schools, was recently concluded by Unesco at the recommendation of the International Congress on Science and Technology Education and National Development. The results provide a good basis from which to begin considering curricula needs in the area of scientific and technological literacy. Data from almost 100 countries including African and Arab States, the Asian and Pacific Region, Europe Latin America and the Caribbean give a global picture from which to begin identifying issues for consideration for future curriculum planning.

Science. It appears that at the secondary level science is firmly entrenched in the school curricula worldwide. However, in the early levels of schooling, science is rarely taught. This is extremely serious because for many, particularly in developing countries, primary education is the only formal education a child receives.

The study reveals differences from country to country in terms of both how much time is allocated to the teaching of science at the secondary level and in whether science courses are compulsory or self-selected. Globally, the average allocated teaching time in Grades 7, 8, and 9 is six hours, on the average, per week. It ranges from one half-hour of classwork per week in some countries to ten hours per week in others.

Particularly in the Arab Region, Africa, and Asia and the Pacific, it is common for integrated science courses to be compulsory in the lower secondary grades. In some of these countries alternative terminal courses are available for those who wish to take additional coursework. Another option is for science coursework selection to be entirely at the discretion of the individual student. In Australia and Romania for example, separate course in physics, chemistry and biology, courses in physical science, biological sciences and integrated sciences are all possibilities from which a student may choose. Regardless of whether the courses are self-selected or required by the school, a number of countries offer a sampling of non-traditional sciences classes. These include agriculture in Africa and in Latin America; geology in Greece, Kuwait, Qatar, Venezuela; astronomy in Cuba, Uruguay and the USSR; cosmology in Greece; earth and space science in the Republic of Korea and the United Arab Emirates; and ecology in Portugal.

Mathematics and Numeracy. The international survey indicates that mathematics is a component of basic education in all parts of the world. It is taught an average of four hours per week at all grade levels from the early primary years through secondary school. As is the case with science, there is a diversity of emphasis from country to country so that a range of between one hour of instruction per week to seven hours per week can exist.

Although mathematics is firmly embedded in the schools, first as arithmetic in the primary school, then as mathematics in the secondary, most governments are not satisfied with their programmes. Children who attend school learn calculation skills, i.e. to "do their sums," but few learn how to apply these skills to solving problems in their everyday lives. As adults, few utilize the computational skills learned in school.

Literacy in mathematics is called numeracy. In different economic contexts numeracy takes on different shades of meaning. Some countries consider people numerate if they can do their sums. In other countries, numeracy means being able to solve daily life problems using a pocket calculator. It is even being extended to include the use of the microcomputer in some cases. In societies where technology such as calculators and microcomputers are in general use in the work place, these same tools must be in schools; if simpler, non-electronic tools such as the abacus are used in the workplace, such tools must be the media of instruction in schools. Otherwise students will be deprived of needed training and become skeptical of the relevance of school to their later life and work.

Technology. The most surprising finding from the Unesco global survey relates to the place of technology in the school curricula. Universally, country by country, region by region, it appears that technology education is almost totally absent. Interestingly, teachers and administrators who responded to the Unesco survey-study questionnaire had a great deal of trouble attaching a meaning to the term "technology." Because of the long tradition in schools for teaching manual skills such as working in wood or with needle and thread for example, respondees often listed these *technical courses* as *technology courses*. The United Kingdom, France, Germany and Sweden are all countries that are beginning to make progress in implementing technology into the curriculum. In the case of France, it is a priority of the National Ministry of Education to abandon the policy of giving training in manual and technical skills. In its place, education in such technological activities as informatics, electronic, mechanics, and nutrition is provided. The change will be gradual as it is dependent upon the rate at which the schools can be re-equipped and the teachers re-trained.

A.2. Issues and Policy Considerations

Planning and implementing a science, mathematics and technology education programme to fit the needs of basic education is an urgent priority. As was noted in the Unesco study, science in the early levels of schooling is rarely taught, numeracy is neglected universally in favour of traditional arithmetic, and technology, for all practical purposes, is non-existent. Expanding the concept of basic education to include these knowedge and skill bases will require a multi-dimensional approach of extraordinary scope.

Science. The highest priority in the area of science is implementation at the primary education level. All persons must have access to the appropriate scientific knowledge and skills for everyday living in their particular society. This may mean diverting financial resources and emphasis from the secondary science programmes already in place. Unfortunately, particularly in developing countries, the content and goals of secondary science are often "imported" and thus have little relevance to the everyday lives of the students. However, because they are "in place," and "look like good science," a shift in curriculum focus to the primary level will certainly meet opposition.

Adding of primary science to the basic education curricula will require enormous effort on the part of political and educational leaders and teacher educators. The traditional resistence to including science in young children's education is totally accepted by a majority of teachers and the public. Creating appropriate curricula that fit the basic educational needs of citizens in a particular society will require much more than merely "inserting" a clear-cut, ready-made syllabus into the plan. Knowledge of science and technology concepts *appropriate* to the culture must be filtered out and transformed into learning experiences that use a methodology syntonic with the discovery of new knowledge in the discipline of science. The United Kingdom is providing leadership in this direction by creating science curricula for the primary level that focuses on science and technology literacy (Science in the National Curriculum, 1989 a); the United States is beginning to address the issues at the policy level (Science For All Americans: Project 2061, 1989).

Mathematics and Numeracy. Mathematics is the one area of scientific and technological literacy that already exists as a "basic" in education all over the world. A critical issue for policy makers in providing leadership in mathematics education is the re-education of primary teachers so that they understand and accept the need to make a significant shift in what they consider appropriate mathematics content. The teachers must simultaneously become knowledgeable in numeracy as it relates to their specific group of students. Support and exchange of curricula ideas on a regional, national and international level in the area of mathematics and numeracy would be extremely useful. One wonders for example, how the children in Japan achieve such high levels of proficiency in mathematics when, in grades seven through ten, they are taught on the average for only 2.8 hours per week compared to the average of 4 hours per week in other countries of the world. (Unesco, 1986).

Technology. Technology education is certainly the most challenging and demanding of the "tri-part" science, mathematics and technology education plan to be incorporated in basic education. There is no precedence in school for teaching it and, as a concept, it is little understood. Technical education, with which it is often confused, is a misconception that is in serious need of clarification.

There are three major issues confronting policy makers and educational leaders regarding the implementation of technology into the basic primary education curriculum: development of "appropriate" technology, identification of specific knowledge and skill content, and teacher resistance and re-education. Appropriate technology refers to the necessity of the curriculum content to be country-specific, if not in its general aims, at least in its content selection and teaching methodologies. If the local technology is agriculture, for example, student understanding of logic circuit decision-making is not priority content. However, if the country wants to computerize, this topic may be reprioritized.

Identifying specific knowledge and skills to be studied in technology education presents a particularly "thorny" problem. The concept of technology exists in multiple-knowledge bases that include knowledge of simple tools, physics principles, design, economics, decision making, and mechanical, mathematical and political control mechanisms to mention only a few. Creating the general components of the technology curriculum and then identifying specific content to meet the appropriate technology needs of a particular region will require a totally new way of conceptualizing and developing curriculum.

Finally, teacher resistance and re-education are key to the implementation of technology as part of the basic education programme. From a practical perspective, teachers already have too much material to "cover" in the existing school day. To add another curriculum content, particularly one that is unfamiliar in traditional primary education, will require teachers to rethink their understanding of what is basic to their students in today's world. And finally, teachers of course must be provided with appropriate teaching materials, given support in their development of knowledge about technology at the local, national and international levels, and their development of knowledge about what methodologies are best used to teach technology. This is a "tall order" for teacher educators.

B. Teacher Development for Science, Mathematics and Technology Teaching in Basic Education

B.1 The Facts

The areas of teacher education research selected for inclusion in this review have been purposefully limited. In considering the task of introducing new subject matter and new methodologies in the form of primary science, numeracy, and technology, two areas of research appear to have special relevance for the scope of changes that will be necessary in the teaching profession: (1) fundamental knowledge that the teacher must understand in order to be effective; and (2) appropriate changes in the actual teaching environments that will facilitate teacher development at the preservice and inservice levels.

Basic Knowledge. A recent major research focus in teacher education leaves no doubt that effective teachers must have expertise in both the subject matter they teach and in teacher knowledge. (Hashweh, 1985; Schulman, 1987) Subject matter knowledge refers to expert knowledge of the entire field as well as specific expertise in individual topics. Studies suggest that this knowledge gives teachers the power to be flexible with the content they teach. They are also able to make intellectual leaps and connections as for example between chemistry and biology in a discussion of acid rain. Subject matter expertise in the area of science, numeracy, and technology in both the formal and non-formal education sectors requires teachers to be:

(1) Knowledgeable in one or more science subjects

(2) Knowledgeable in numeracy

(3) Knowledgeable in the appropriate technology of the country and region

(4) Knowledgeable in the relationships between science,numeracy and technology

(5) Knowledgeable about the social and economic implications of science and technology

Lack of subject matter expertise on the part of the teacher quickly encourages students and teacher alike to rely on the textbook as the sole authority. Unfortunately, science is not a subject that can be understood just from reading a book. Analyses of science texts in common use in some countries indicate that formal concepts are often introduced as "vocabulary words" to be memorized, not learned or understood. A teacher who is knowledgeable in the subject matter is essential.

According to the most recent research, teacher knowledge in addition to subject matter knowledge is also necessary for optimum learning to occur. Teacher knowledge refers to expertise in the complex knowledge and skills needed to transform specific subject matter into a form which can be learned by students. Unfortunately, subject matter cannot be directly transplanted from the teacher's head to the students' heads. The need for specific teacher knowledge preparation is necessary. Examples of teacher expertise include the ability to develop learning experiences (curriculum) and select appropriate materials to match students' intellectual and experiential levels. Teaching scientific and technological literacy requires sufficient teacher knowledge so that teachers are:

(1) Able to interpret and teach in a technological and social context

(2) Competent in skills for a variety of classroom teaching and learning modes

(3) Flexible in personal style

(4) Able to cope with changes and incorporate these changes in curriculum and instruction

(5) Able to evaluate student learning

Providing teachers with the opportunity to work in community technology projects during the summer months is an excellent way to upgrade teacher's subject matter knowledge, particularly with regard to technology and science. Research on a population of teachers in developed countries with industrial experience indicates that they are much more adept in their teacher knowledge; they found that the "right answer" paradigm, which has become a school norm, is not terribly useful in the work world. Brainstorming, approximating solutions and co-operative problem-solving, for example, are much more usual practices in the technological sphere.

Teaching Environments. Teacher education research studies strongly suggest two mechanisms for inclusion in teacher preparation programmes that will enhance lifelong teacher learning: teacher reflection and teacher collegiality.

The research on teacher reflection (Bowyer, 1988; Richert, 1989) refers to the process of thinking about teaching in order to learn from one's experiences. Drawn initially from the work of John Dewey, the idea of enquiry is commonplace to science teaching. "Teaching as enquiry" posits a model of teaching as a fundamentally intellectual rather than routine task. In such a model, teachers are expected to think about their work or reflect on it in order to make sense of and learn from their experiences in the classroom. Reflective teacher practitioners use journals, student work, video taped lessons, and peer feedback to provide the rich detail of the complex teaching act in order to actively reflect on the events. Other profesional activities that facilitate innovation and reflection on the role of science and technology education for all are professional associations, institutes, and networks.

The research on teacher collegiality (Lanier & Little, 1986) refers to a school culture in which there is a premium placed on teachers talking, observing and in general interacting frequently and easily with each other concerning the details of their work. Teacher collegiality, according to the research, is an attribute associated with outstanding schools. Because of traditional school architecture (isolated classrooms behind closed doors), and school scheduling, it is uncommon for teacher collegiality to occur naturally (Goodlad, 1984). Research on successful business and industrial strategies suggest that innovation is directly fostered with increased opportunities for professionals to interact on both formal and informal occasions. Teachers in general are not used to this dynamic and therefore will need to develop confidence and trust in their colleagues and in themselves so that collegiality becomes an accepted part of the profession.

B.2. Issues and Policy Considerations

Teachers are the "keystone" in student learning; teacher education is the necessary link which precipitates effective teaching. Currently well qualified science and mathematics teachers at both the primary and secondary levels are in short supply in most parts of the world. This situation will be exacerbated with the introduction of primary science, numeracy, and technology into the basic education curriculum. Radical changes in teacher education will be required to facilitate an understanding and redefinition of basic educaiton that includes scientific and technological literacy.

A priority issue for teacher training programmes is to reconceptualize the time frame for teacher development. A prescribed one or two-year training programme followed up by occasional "one-shot" inservice presentations will not be adequate preparation for teaching basic education for a changing curriculum. Teacher development needs to be considered on a continuum beginning with the novice in college and ending when the teacher stops teaching. Teachers will need continuing support with time for experience to be gained, absorbed and reflected upon; there are no short cuts (Power, 1988a).

A critical responsibility of teachers will be curriculum development for basic education. If the curriculum becomes "fixed" or static, the notion of "education for change" will automatically wither. The curriculum and teaching methodologies must evolve with the changing society and it is the teacher leader in the community who must incorporate and orchestrate these changes.

Policy considerations concerning teacher recruitment, design of teacher preparation programmes, whether to have "specialist" teachers for science and technology or "generalists" at the primary level, how to "train the teacher trainers;" and mechanisms for "continuing" teacher education are only the beginning. In reconceptualizing teacher education to truly meet the needs of a basic education in a changing society, issues that are yet to be invented must surface. Creative use of the community is probably an untapped resource that deserves attention at the highest levels. Multiple use of community buildings, local technology work sites, shared teacher-worker expertise, and blending formal and non-formal learning are possible starters for consideration (Power, 1988b).

C. Effective Teaching and Learning for Scientific and Technological Literacy

C.1. The Facts

It has been pointed out repeatedly by teachers, researchers, and students, that the problem of adopting a traditional approach to science teaching is that: "to many young minds, this traditional approach is so remote from the world in which they live that they decide that the whole business ... is quite irrelevant". (Wenham, 1984). Effective teaching of science, mathematics, and technology must be based on learning principles that derive from systematic research and from well-tested craft experience. The teaching methodology must be consistent with the spirit and character of scientific enquiry and scientific values.

Learning Principles. Two major learning principles concerning the education of children in the formal education sector are identified here because they are particularly important to scientific literacy teaching and learning. The first comes from the cognitive development literature. Children between the ages of 5 and 15 are in the process of evolving mental structures which allow them to think logically. (Karplus, 1978; Piaget, 1957 and 1970). This phenomenon is universal and it results in children and adults' thinking to be qualitatively different. Because we cannot see the changes that are taking place inside the brain, nor remember from our own experience the patterns of reasoning we used at five years of age compared to those used at ten, it is necessary for teachers to know the research. This, in combination with careful listening and observing of children in their classrooms, will allow teachers to infer the type of reasoning a particular child is using with an individual problem. Students will have difficulty understanding certain mathematical and scientific concepts and processes if these are introduced too early or without sufficient prior concrete experiences. (Karplus, 1968). Unknowingly teachers may label their students as lazy or stupid because they cannot understand the material being taught in spite of clear explanations. Teachers need to understand how mental structures develop in mathematics and science and to use this knowledge to guide them in their teaching decisions.

A second learning principle important to scientific literacy teaching and learning also relates to what children have inside their heads when they come into the classroom. There is now an extensive literature, based on studies throughout the world, which indicates that students develop ideas about natural phenomena well before they are taught science and mathematics in school. (Driver, 1985). In some cases, these ideas (variously referred to as preconceptions, intuitions, alternative frameworks, mini-theories and naive theories) are in keeping with what is to be taught. In other cases, there are significant differences between the students' notions and the science they will meet in school. For example, it is very common for people to believe that plants can only get their energy for growth from the soil. Even when they observe plants growing in the air or in water, this original construct is not necessarily changed. Although teachers can ignore students' prior ideas and base teaching solely on the structure of the subject itself, research suggests that in spite of a well-organized presentation, many prior ideas persist even through the university level. Students compartmentalize everyday "knowing" from "right answers to school questions". It is desirable to start with students' prior ideas as the starting point in learning, and for instruction to be designed so as to enable initial ideas to develop and change.

<u>Teaching Methodology</u>. Process-based learning (Harlen, 1989) is the term that describes instruction designed to be consistent with the spirit and character of scientific enquiry. It also projects a more human view of science. Process-based learning consists of experiences that engage the thinking, imagination and interest of pupils as well as leading them to an understanding of key concepts and principles in science and mathematics. In this approach the student constructs the

knowledge that comprises ideas and, as long as there is evidence to support them, it is accepted. However, this knowledge is open to change as necessitated by new evidence. Scientific knowledge is experienced and recognized as a product of human activity and thought. Process-based learning includes starting with questions about phenomena rather than with answers to be learned; engaging students actively in the use of hypotheses, the collection and use of evidence, and the design of investigations and processes; providing students with hands-on experience with mechanical, electronic, and optical tools; placing a premium on students' curiosity and creativity; and frequently using a student team approach to learning.

C.2 Issues and Policy Considerations

Traditional science teaching approaches are insufficient to meet the basic learning needs for all students in the areas of science, mathematics and technology. The implications and issues for policy leaders centre on designing a teacher training plan that ensures that all teachers understand the basic learning principles and methodologies needed for effective teaching and learning.

Special attention is called here to specific teaching and learning issues policy leaders need to consider regarding non-formal education for adult learners. Non-formal education programmes need to be planned quite differently in many respects from formal education programmes. The learners already know a great deal about the areas of science which are important to them. They are already raising crops, raising children and managing their lives. Adult education needs to be designed so that the students can use and develop what they already know. A major issue for policy leaders, if science, mathematics, and technology are to assist adults to achieve empowerment in relation to real-life tasks and problems, is accessibility to the learners in ways that respect these priorities and meanings. Another major policy area involves the teachers of non-formal learners.

Accessibility of scientific and technological literacy programmes in the non-formal sector is essential. This may mean that the teaching and learning will go on as part of a sewing circle gathering, at a site set up for inoculating children to prevent the spread of a particular disease, or at the seaside where fishermen are struggling to get their "catch" into the homes of customers in as fresh a condition as possible.

Teaching in non-formal programmes requires that the teacher and those who prepare the teaching and learning materials understand the local problem both factually and as it is understood by the learners. Flexibility is a must for these teachers. A learning environment might be under a tree with a kerosene lantern for light or a well equipped corporate laboratory. Regardless of the setting, before new understandings can be introduced, the teacher must first find out what existing ideas about causality are understood by the learners and deal with these. It is also necessary to express the concepts of science in the language commonly used by the learners unless new vocabulary is essential for understanding. Providing lots of examples and demonstrations of the important concepts and giving particular attention to assisting and encouraging adults to express and discuss their new information is important to the learning process. Scientific literacy implies not only the possession of knowledge but its sharing and application.

D. Women and Scientific and Technological Literacy

D.1 Background

An extensive body of research literature is now available concerning the status of women in the area of science and technology education and work. Research progress is being made in understanding some of the causal factors associated with the lack of participation of women at all levels and in all societies in the life of science and technology. The research summarizied here focuses on the rural women in third world countries and women living in countries with fairly developed scientific and technologically based economies. Although life situations and some causal factors vary among the women of the world, all share the fate of scientific and technological illiteracy.

Current Situation. According to the latest official estimate (1989), one quarter of the world's adult population is illiterate, that is, lacking in skills to read and write. The majority of these illiterates are women. In developing countries an estimated 49% all women are illiterate. (WCEFA, 1990).

In the area of scientific and technological illiteracy the rate is considerably higher for both developed and developing countries. Illiteracy for women in the areas of science and technology is the rule rather than the exception. In all countries, female scientists and technologists are rare.

There is no question that women can excel in science and technology. Barbara McClintock won the Nobel prize for medicine and physiology in 1983 as Rosalyn Yalow had done in 1977; Marie Curie won Nobels in 1903 and 1911 for her work in Radium and discovering two new elements, and Johanna Dobereiner won the Unesco prize in 1989 for her work at increasing crop yields through biological nitrogen fixation. These women represent only a few who have made significant contributions to the fields of science and mathematics. However, there is no question that increasing the general level of scientific/technological literacy and numbers of female scientists and technologists is crucial. Precluding almost half of the population from active participation in the life and knowledge of science and technology is a severe loss for individuals and for societies. As noted in the Unesco book, **Learning To Be** (1972), "Lack of understanding of technological methods makes one more and more dependent on others in daily life, narrows employment possibilities and increases the potentially harmful effects of the unrestrained application of technology".

Focus on Third World Rural Women. The following set of facts concerning the part rural women play in food production in the Third World was presented at the Bangalore Conference on "Science and Technology Education and Future Human Needs" (Rao, 1987).

- Women have been credited by some historians of agriculture with being the first to domesticate crop plants, thereby initiating the art and science of farming. They have played and continue to play a key role in the conservation of basic life support systems such as land, water, flora and fauna.

- It is estimated that the 52% of Asian women engaged in farming are predominently in subsistence production. In Africa, subsistence farming is almost entirely in the hands of women. In Nepal 57% of subsistence agriculture is by women.

- Rural women work more hours per day than men because of their traditional duties (household work and child care) in addition to farm work. They are also the traditional food processors and the cooks.

Without the total intellectual and physical participation of women, it will be dificult to implement alternative systems of land management to cultivate new crops, arrest gene and soil erosion, promote the care of the soil and health of economic plants and farm animals. Unfortunately rural women currently lack access to innovations in agricultural methods. They are not included in training programmes that introduce modern technology. Most agricultural and rural extension programmes have a bias against including women, even though women's productive and managerial roles in agriculture are extensive.

Causal Factors. The causes for disparities between the sexes in knowledge and professional participation in science and technology are multiple and complex. No simple cause-effect relationship explains the phenomena. However, extensive research has given us a very good understanding of the situation (Rao, 1985; Harlen, 1989; Jacobsen, 1985; Hoffman, 1987).

The exclusion of rural women from science and agricultural technology is well documented. The following are cited as factors for this unfortunate situation: the perception of women's primary role at home and the stress of her domestic work; lack of access to education and training; lack of access to means of production; sociocultural barriers, the burden of daily tasks, and women's acceptance of the division of labour at home.

Originally one of the strongest contenders to emerge in the research literature to explain male domination in science and mathematics was the biological factor. It was suggested that inherent differences in brain structure or capacity particularly related to visual-spatial ability were responsible. Three areas of research evidence combine to discredit this biological variable as the causal factor: (1) the observed performance differences could equally well be a result of differences in treatment of boys and girls in their early years; (2) the differences are not found in all cultures and (3) the attempts made to improve spatial abilities resulted in girls responding the same ways as boys.

Research evidence indicates that socially determined factors are responsible for the disparity between the sexes in participation in mathematics, science and technology. The causal factors have been classified under the headings of the masculine image of science; the reinforcement of sex-linked personality characteristics; and the conventional identification of occupations and hobbies as either masculine or feminine.

Unfortunately, the masculine image of science is a false view often presented in textbooks, television, newspapers, and classrooms. Science and mathematics are linked with isolated facts, principles, theories, theorems and laws. These "appear" to be incontrovertible truths with the implication that they were formulated by coldly logical scientists in a rigidly objective manner. The facts are that scientific knowledge and scientists are often tentative, controversial, and open to disproof. Scientists use their minds creatively allowing imagination, feelings, intuition and serendipity to creat patterns. Stereotypic male personality traits include the desire for control, objectivity, lack of emotional expression and stronger interest in objects than human relationships. These sex linked personality characteristics get linked to a false view of science portrayed in the media and in many classrooms.

Prevailing societal attitudes with regard to male domination of science and technology get constant reinforcement from parents, teachers, the career world and even girls and boys. Research has clearly established that these attitudes begin at a very early age. They are observed in preschool, primary and secondary school. By the age of ten, differences in attitudes of all girls and boys to technological and science subjects is already substantial. Even if girls are convinced that mathematics are useful and important for their future, many are equally convinced they cannot learn them. When women do pursue science or engineering careers, they definitively have an "upstream swim". Even in high school, they must fight cultural and sociological barriers, and by graduate school, they find themselves sorely isolated. With a dearth of female professors, the young women have few role models and, in addition, often face subtle discrimination from male teachers.

D.2. Issues and Policy Considerations

In order to break the vicious circle of illiteracy it will be necessary to take a comprehensive, multilevel action approach. Parents, teachers, school administrators, regional national educational leaders must give highest priority to female participation in science, mathematics and technology. Non-formal learning must be directed at female participation. And given the pervasiveness of societal attitudes and beliefs regarding science and females, newspaper writers, textbook authors, television producers - all who live and participate in the world must value this goal and act on it if there is to be a change.

Reaching rural women through continuing education needs to be one of the highest priorities for policy leaders in third world countries. Two major issues in planning programmes involve (1) creating time in the women's work schedules for non-formal education and (2) overcoming biases against women participating in extension programmes currently offered to men. The educational and political leadership in developing, agrarian countries also need to support changes in goals and priorities in favour of an agriculturally based science curriculum in the formal education sector. Appropriate curriculum materials for these programmes are not abundant. Issues to consider in this regard include increasing co-operation betweens schools and development agencies, and involving in more international dissemination of rural agricultural science curricula units and evaluation reports.

IV. SUMMARY

POLICY REFORMULATION TO BROADEN THE SCOPE OF BASIC EDUCATION

A. RELEVANT FACTS

1. Appropriate Technology

a) Developing countries' economies create little demand for indigenous technology but rely instead on imported technologies.

b) Appropriate technologies geared to the requirements of a particular country necessitate a custom-designed science, mathematics, and technology education component that fits the country's needs and available resources.

2. Educational Traditions

a) The majority of women, the poor, and persons living in rural areas are excluded from participating in science, mathematics, and technological education and hence precluded from positions in the workplace where those skills and knowledge are needed.

b) The dominant mode for teaching and learning in most countries can be summed up as follows: "teaching is talking" and "learning is listening." This is *not* the choice methodology for teaching science, mathematics, and technology.

c) In most countries, science is seldom taught at the primary level, technology is rarely taught at any level, and mathematics does not stress numeracy.

d) The majority of persons, particularly in developing countries, receive only a primary education; science and technology education must be prioritized at this level.

e) Large sums of money, particularly in developing countries, are currently set aside for the "higher" education of a minority of students in spite of the recognized deficiencies resulting from "imported" curricula.

3. <u>Financial Resources</u>

a) Educational funding is shrinking in most parts of the world.

b) Funding is needed for both training and for capital expenditures for adequate science/technology basic curriculum reform.

c) It is necessary to rely principally on internal resources for funding and development. Priority must be given to low-cost equipment and facilities.

4. <u>Human Resources</u>

a) Science, mathematics, and technology teachers in most parts of the world, particularly at the primary level, are underprepared in the knowledge of the subject matter and knowledge of how to appropriately teach the subject matter.

b) Teacher trainers need to reform teacher development programmes to incorporate a strong component of scientific, mathematical and technological literacy education for prospective and practising teachers.

c) Administrators, head masters, curriculum inspectors and directors of education must be involved in reform if efforts to expand the concept of basic education to include science, mathematics and technology are to be successful.

d) Community involvement of local industry, agricultural, and technology workers is an important link in developing a quality scientific and technological literacy component in a basic education programme.

e) Strong educational and political leadership is necessary to change current goals and priorities to include agriculturally and technologically appropriate components in the basic curriculum.

5. <u>Material Resources</u>

a) Regional teacher development centres and curriculum development centres, or their equivalent, must be provided for in a comprehensive educational plan.

b) Learning environments for formal and non-formal education must be adequately equipped to support the teaching of science, technology and mathematics. However, because of financial limitation, *emphasis must be placed on procuring low-cost materials.*

c) Indigenous materials are most appropriate for use but must be capable of "teaching the concept."

d) Equipment and curricula material will vary from country to country depending on local science and technology needs.

6. **Logistics**

a) Servicing remote areas presents problems in terms of disseminating curriculum materials, teacher training, and monitoring progress.

b) Non-formal education for adults must be available at times and places that are practical for already overburdened workers.

c) Formal schooling for students in remote areas requires special attention in terms of teacher incentive and transportation.

B. MAJOR ISSUES

1. **Planning**

a) Develop realistic time line for meeting short-range and long-range goals aimed at including science and technology in the basic curriculum.

b) Get necessary commitments to science and technological reform efforts to be sustained over time to ensure the development of a strong science knowledge base and technologically appropriate skill base for all citizens in a country.

c) Develop administrative structures necessary to ensure that the policy recommendations are transformed into plans that eventually are implemented into science and technology instruction at the individual student level.

d) Develop strategies necessary to bring about policy reform in the firmly entrenched areas with histories of long educational tradition (see A.2. a-e).

e) Design strategies to ensure educational equity for under-represented populations in science and technology education.

f) Develop mechanisms to precipitate appropriate interaction among community and educational systems for scientific and technological literacy for all.

2. **Prioritizing**

a) Criteria to govern the difficult task of allocating the limited resources available among the many competing demands for a successful science/technology curriculum reform effort in basic education.

b) Curricula trade-offs possible in order that science and technology education be included in the basic curricula.

c) Developing an overall strategic plan that prioritizes: (1) curriculum development; (2) teacher training; and (3) community involvement.

3. **Financing**

a) Identifying possible traditional and non-traditional funding sources for creating scientific and technological reforms in basic education.

b) Leverage human, financial and materials resources to achieve a first rate scientific and technological component into the basic education curriculum.

V. CONCLUSIONS

In the broadest sense, science and technology extend our abilities to change the world: to cut, shape, or put together materials; to move things from one place to another; to reach farther with our hands, voices, senses and minds. But is scientific and technological literacy really a possibility for everyone? Is it possible for children from peasant farming families living in remote settlements who survive by subsistence agriculture and fishing? Is it possible for children from urban families living in deplorable slum conditions? Most of these rural and urban children do not complete primary school. Most grow up to be impoverished and unemployed adults. Can expanding the concept of basic education to include scientific and technological literacy really make a difference to these children?

It may well be that the *only* hope for change in these children's lives is the incorporation of science and technology into the basic education for everyone. As this paper has made perfectly clear, we are *not* talking about traditional science education taught in traditional ways with traditional materials. We are talking about a new vision of educational literacy that includes science and technology for the purpose of offering a better understanding and, where possible, more control over everyday situations and problems. Only science and technology literacy can provide a clearer perception of problems and solutions. Scientific, mathematical, and technological concepts can help people of all ages to better understand their world. It is human nature to enquire and innovate. These processes are at the heart of science and science-based technologies. Scientific and technological literacy will empower people to enquire and innovate more systematically and effectively.

Schools are now trapped ... trapped in an academic-didactic structure equilibrium. Schools, historically, have a tendency to be rigid and tradition-bound. A new vision for basic literacy and education is required. A new equilibrium position can only be achieved by a comprehensive set of adjustments to all major components of the system including school organization, teacher training, curriculum, and teacher-student relationships. The new equilibrium needs to result in greater employment possibilities and community involvement. Increased importance given to scientific and technological literacy in basic education *can* develop scientific knowledge and skills and a practical capability leading the way to further development in the educational system and in the world of work. In the final analysis, it is the leadership in each society that must take responsibility for developing policy and implementing scientific and technological educational plans that are syntonic with each individual society and in harmony with the global context.

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