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Gender Equity in Science and Technology for Development

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This book is dedicated to Stanislas Ruzenza,
a member of the Gender Working Group.
Professor Ruzenza died in June 1995,
a victim of civil strife in Burundi.

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Chapter 8

Schooling for what?

Education and career opportunities for women in science, technology, and engineering

Eva M. Rathgeber[1]

By 1990, on a global level, 36% of people employed in the formal sector were female. However, in most countries, women continue to be concentrated in lower level and less well-paid types of employment (ILO 1993). Almost universally, female participation in modern science- and technology-based occupations has been remarkably limited despite the important roles traditionally played by women in the development and management of tools and implements in households and in family autarkies. Although they have always been users and often developers of technology, women have rarely been recognized as central actors in science and technology (S&T).

Although historians of science have provided evidence of female scientific activity — as physicians in the Middle Ages, mathematicians in early modern Italy, and natural scientists in the 19th century (Mozans 1991) — female participation in S&T was discouraged during most of modern European history. Britain's Royal Society, established in 1662, did not admit women until 1945; even today only 2.9% of its Fellows are female: only seven women (3.5% of new Fellows) were elected in 1989–93. Britain's Royal Academy of Engineering has elected three women out of 901 Fellows. The American National Academy of Sciences has 1 750 living members, only 70 of them female (Holloway 1993). Where women have been involved in science, their contributions have often been minimized or overlooked. For example, Rosalind Franklin, the British X-ray crystallographer, provided critical information on the structure of DNA that enabled James Watson and Franklin Crick to undertake research on the double helix for which they later won a Nobel Prize. By the early

[1] I am indebted to Patricia Stamp of York University, Patricia Connelly of St Mary's University, and Eglal Rached, IDRC Cairo, for helpful comments on earlier versions of this paper.

1990s, only nine women had been awarded a Nobel Prize in science subjects, compared with more than 300 men.

Feminist theorists have emphasized the biased nature of science, pointing out that it is a human activity heavily influenced by prevailing social, political, and economic factors (Rosser 1988). Some have argued that a feminist science would differ from "masculine" science because of fundamental differences in female perspectives and female approaches to problem solving. Science, as commonly practiced, espouses an essentially male world view, and women scientists who wish to succeed must of necessity work within this view or perspective. One object of continuing debate is the preeminence of scientific method with its emphasis on "rational" thought processes. Definitions of rationality should be expanded to include at least some aspects of other cognitive styles and other "ways of knowing" (Brush 1991). For example, greater emphasis might be placed on evidence from other sources, including various types of intuition. To date, there has been little empirical exploration of whether female scientists really do work differently from male scientists or whether they bring different qualities or emphases to the scientific task (Sorensen 1992).

During the past decade, growing feminist concern with the exclusion of women from S&T has led to determined efforts to correct gender imbalances. However, attempts in North America to increase the numbers of female students in science and engineering programs have had mixed results. Indeed, in the late 1980s, the interest of all American freshman college students in science and engineering subjects declined by one-third during the previous two decades (Task Force on Women, Minorities, and the Handicapped in Science and Technology 1988). An increasingly large number of places in American science-training programs were being filled by foreign students.

Despite this decline in overall interest in science among American students, some critics have maintained that S&T will take women's concerns into account only when more women become scientists and technologists. However, the current model of S&T has been internalized by those (including both women and men) who have gone through and succeeded in the system. The mere fact of increasing the *numbers* of women scientists will not necessarily effect fundamental change in the *conception and practice* of science. If the current practice of S&T is to be reformed, then it will be necessary not only for more women to be represented, but also for a critical assessment to be undertaken of the underlying assumptions that guide the creation of S&T knowledge.

International efforts to integrate women into S&T

During the past 15 years, there has been increasing international concern about the more effective integration of women into S&T. Numerous international conferences have touched on the issue of gender and S&T and many governments have publicly acknowledged that effective development depends on the full utilization of all existing human resources. As such, there is a need to ensure that women's capabilities and strengths are recognized and put to full use. In this context, a number of United Nations (UN) conferences have emphasized the need for better integration of women into global economies.

The Vienna Programme of Action on Science and Technology for Development (UN 1979b) stressed the need for all types of training and education for women. Five years later, the report of the panel of the Advisory Committee on Science and Technology for Development (UN 1984) made a more specific set of recommendations including the participation of women in technical training; the establishment of special apprenticeship programs for women; and the support of women entrants into nontraditional areas such as engineering. The report also suggested a review of school curricula and textbooks; the encouragement of female participation in science clubs; and the development of science teaching materials that incorporate women's needs and perspectives.

The Nairobi Forward-Looking Strategies for the Advancement of Women (UN 1985b) made similar recommendations: the promotion of literacy among women; the promotion of equal opportunity at all levels of education and careers; the elimination of gender stereotyping in education; and the introduction of programs to enable men to share responsibility for child-rearing and household maintenance. Such recommendations were aimed at creating an enabling environment for women to participate fully in S&T (as well as in other aspects of social, economic, and political life). More recently, the UN Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992 emphasized once again the key role of women in environmental preservation and stressed the need for measures to increase education and training opportunities in S&T, especially at the postsecondary level.

All of these recommendations emerging from major international gatherings have reinforced the centrality of women's contribution to economic, social, and political development. There especially has been overwhelming support for the provision of equal educational opportunities to enable women to acquire appropriate knowledge, skills, and training to participate in the practice (and formulation) of S&T.

Concurrently, since the 1970s, a growing number of networks and organizations have emerged, aimed at increasing women's participation in S&T. For example, the Association for Women in Science (AWIS) in the United States was founded in 1971 to promote equal opportunities for women to enter scientific professions and achieve their career goals. Some of AWIS's activities include the promotion of networking among female scientists, recognition and promotion of the achievements of women scientists, and the support of programs and laws intended to eradicate inequities encountered by women studying and working in the sciences. A similar role is played by the Third World Organization of Women in Science and Technology (TWOWS). Founded in the mid-1980s, TWOWS aims to survey and analyze the status and prospects of women in S&T in the Third World; improve access to education and training opportunities; increase the scientific productivity of women scientists in the Third World; and promote collaboration and communication among women scientists and technologists in the Third World and with the international scientific community as a whole. TWOWS was an active partner in organizing a conference on women in S&T, held in Cairo in 1993.

The International Women's Tribune Center (IWTC) in New York has also been an active proponent of women's participation in S&T, particularly in making it more easily comprehensible to less-educated and nonelite women. IWTC has put special emphasis on demystifying and popularizing S&T for and among women globally through the production of simplified texts that combine striking artwork with scientific information written in clear and concise language.

The Gender and Science and Technology Association is a global network that holds regular symposia on the role of women in S&T. It encourages research into all aspects of gender differentiation in science, technology, and employment and fosters gender equality and women's entry into science professions. Recruitment and retention of girls and women in science, engineering, and technology and the development of feminist perspectives on the practice of S&T have been particular areas of concern.

In March 1994, an international panel convened by the US National Research Council's Board on Science and Technology for International Development (BOSTID) in Washington identified five key areas for urgent corrective action. These included communication and dissemination of information; integration of local development and traditional S&T; education and training; facilitating opportunities for women in research; and access.

These represent just a sample of the many networks, organizations, and initiatives that are under way. The integration of women into S&T is a vital area of concern not only for scholars and policymakers but also for activists and development practitioners worldwide. Nonetheless, in virtually all regions of the world, the participation of women in S&T comes nowhere near reflecting their representation in the population.

The following recommendations, among others, have emerged from expert meetings, UN conferences, and various other international forums during the past 15 years. They have accurately diagnosed key weaknesses that have impeded the participation of women and girls in S&T.

- The social interactions within the family, in schools and churches, and in society at large through which girls and boys acquire a sense of their own role and place in society are potent factors in creating certain assumptions about the respective roles and responsibilities of women and men. Efforts must be made to ensure widespread gender sensitization to ensure that opportunities for girls are not abolished before they have even had a chance to discover their own potential.
- Curriculum materials must be redesigned to ensure that they are equally relevant for girls and boys. At the same time, science teachers must be sensitized to treat girls and boys the same way in the classroom. They must avoid assuming that girls will be less interested or less competent in science subjects, and they must provide opportunity for girls to find their own solutions to problems rather than giving them answers.
- Efforts must be made to recruit representative numbers of female science teachers at all levels, including at the tertiary level and in engineering faculties. The importance of role models both by including the achievements of female scientists and technologists in educational materials and as teachers and S&T professionals is critical in "normalizing" the concept of female opportunity and potential success in S&T. Similarly, role models and mentors can help young people develop self-esteem and a sense of capability. Efforts should be made not only to ensure that girls have opportunities to meet and interact with female S&T professionals, but also

that male professionals exhibit positive attitudes toward the idea of women in science.

- Special efforts should be made to involve girls and young women in science-related events such as science fairs or school science clubs. Girls should also receive information about S&T opportunities through school counselling, interaction with professional societies, and so forth.
- Efforts should be made to ensure that women are encouraged to participate in nontraditional careers, such as auto mechanics, construction trades, and so on. Girls who show an aptitude for or interest in such areas should be given opportunities to obtain appropriate training in technical colleges or as apprentices in the workplace. Similarly, women should be included, together with men, in industrial retraining exercises, when new technical skills are being taught.

However, progress in implementing these recommendation has, at best, been mixed. In some countries, efforts have been made to revise existing school systems and create opportunities for girls and women, but in others, the issue has received little or no attention. In many cases, prevailing cultural norms and practices have posed strong deterrents to reform.

Statistical evidence of the participation of women in S&T

Participation rates for women in science are relatively low in most countries. In Sweden, which has a long history of promoting equality between the sexes, women accounted for only 11% of employed nonacademic scientists and engineers in 1985. In Japan, by 1992, fewer than 8% of scientists and engineers were female, most of them employed in less-prestigious scientific institutions.

In the United States, by 1992, the figures were considerably higher, although still not representative of women's numbers in the general population. About 22% of nonacademic scientists and engineers were female; but although women constituted 36% of employed nonacademic scientists, they constituted only 8% of employed nonacademic engineers. In the United Kingdom, the numbers of women studying science and engineering were sufficiently low to warrant concentrated efforts to increase them in the late 1980s when science and mathematics became compulsory core subjects for all children aged 5 to 16 years. However, there has been only a slow increase in the proportion of girls choosing to study sciences to A level. As in the United States, girls who do choose to study sciences tend to concentrate in the biological sciences rather than in natural or physical sciences and engineering. In 1991–92, women in the United Kingdom constituted only 27% of full-time science postgraduate students and 10–25% of postgraduates in engineering, mathematics, and the physical sciences (Committee on Women in Science, Engineering and Technology 1993). Less is known about the numbers of women scientists in developing countries, but evidence suggests that trends parallel those in the industrialized countries, with a tendency toward even greater exclusion (Table 1).

In all countries, the number of women enrolled in medical and health-related fields is substantially higher than in engineering. However, the "medical and health-related" category used by the UN Educational, Scientific and Cultural Organisation (Unesco) does not differentiate between physicians and other types of health workers — such as nurses, physiotherapists, and social workers — making it difficult to assess the extent to which women are enrolled in the most prestigious and potentially well-remunerated area of health studies, that is, medicine. Unlike engineering, medical and health-related careers carry connotations of nurturing and social service. Even at an early age, girls tend to express a preference for careers with a strong element of social service.

Table 1. Proportion (%) of women enrolled in tertiary-level engineering, medical, and health-related courses in various countries, 1985.

Country	Engineering	Medical and health-related
Africa		
Côte d'Ivoire	3.6	32.2
Kenya	1.6	24.7
Senegal	14.0	34.6
Tunisia	9.6	52.2
Zambia	—	31.1
Caribbean and Latin America		
Jamaica	—	41.3
Chile	20.6	56.3
Colombia	26.5	56.6
Nicaragua	25.8	68.3
Asia		
Indonesia	16.4	32.0
Malaysia	14.0	47.0
Philippines	14.5	77.2
Sri Lanka	19.8	45.8

Source: Compiled from Unesco (1987).

It is worthy of note that the largest proportion of women engineers occurs in Central and Latin America, and the number of women of that region enrolled in the medical and health-related fields is also relatively high (Table 1). However, although relatively many women *study* engineering and medical and health-related subjects, they will not necessarily *work* in those areas after graduation. For Latin American women in particular, the linkage between higher education and productive employment needs further examination. With respect to Nicaragua, the participation of women in higher education was at an all-time high during the Contra war in the mid-1980s.

Based on Table 1, African women seem to have the lowest participation levels in science programs. This may be due to continuing deficiencies and inadequacies in the teaching of science to girls in many African countries.

In an analysis of 41 developing countries in Asia, Latin America and Africa, Gail Kelly (1991) presents some surprising statistics about enrolment of women in natural sciences and medical and health-related fields. For example, in eight countries (Afghanistan, Argentina, Cuba, El Salvador, Nicaragua, Panama, Philippines, and Singapore), 50% or more of the students enrolled in natural science subjects were women. The proportion of women in medical and health-related fields was even greater; in 13 countries, it exceeded 50% (Argentina, Barbados, Brazil, Cuba, Jordan, Laos, Lesotho, Madagascar, Malawi, Mozambique, Nicaragua, Panama, and the Philippines). However, in no country did female enrolment in engineering exceed 50%: Cuba has the highest proportion at 32%. As already noted, this low participation rate for women in engineering holds true in industrialized countries. For example, in the United States, there are fewer women in engineering than in any other science-based profession, and the feminist movement has had limited effect in encouraging male members of the profession to reexamine their assumptions and biases (Hynes 1992).

Education and cultural factors

Educational disparities between girls and boys at all levels are a primary cause of female underrepresentation in the sciences. In many parts of the world, female enrolment is substantially lower, especially at the secondary level and even where they are proportionately represented, girls' secondary education often differs from that of boys. There appears to be a stronger correlation between parental income and social status and school enrolment for girls than for boys (Kelly

1984); during the 1980s, girls were disproportionately affected by the imposition of structural adjustment policies and education user fees in various countries. Where poor parents have had to choose between educating sons and daughters, the preference usually has been for male education. Data from Kenya's Central Bureau of Statistics reveal that, by 1989, there was already a slight drop in the proportion of girls attending secondary school. In Tanzania, during the 1980s with the imposition of structural adjustment policies, there was a dual effect of lower school enrolments and higher drop-out rates (Meena 1991).

There is considerable evidence that girls receive less-intensive training in science and mathematics at the primary and secondary levels. Studies in Canada, the United Kingdom, and the United States have revealed that girls routinely get less attention from teachers and that teachers often give answers directly to girls but provide boys with further information to enable them to solve problems for themselves. Male attitudes, particularly among peers, can have a negative effect on girls' aspirations in science. In a study of secondary school students in Swaziland, Smith (1988) found that gender biases with respect to "appropriate" male and female occupations were held much more strongly by boys than by girls.

Although girls' science achievement levels frequently equal or exceed those of boys in early primary school, they commonly drop in secondary school. To understand this trend, sociologists of education have studied classroom interactions between girls and boys and students and teachers. In Britain, adolescent boys consistently undermined girls' efforts to participate in science classes by making disparaging remarks and indicating that they considered science to be a male domain (Kelly 1985). There is evidence, however, that girls' performance in science is more likely to remain stable in single-sex schools where, in the absence of male students, girls face less pressure to conform to predetermined "feminine" roles. Science teaching in such schools can have a positive impact. In Nigeria, for example, girls enrolled in science programs at university were more likely to have attended single-sex secondary schools (Erinosho 1993).

In Kenya, the number of girls attending secondary schools increased in the 1980s, but they were more likely to be at unaided *harambee* schools with inadequate teachers and facilities, especially for science (Kinyanjui 1993). Even relatively prosperous girls' secondary schools often do not offer science courses, sometimes because of difficulty in finding qualified female staff to teach sciences (Eshiwani 1989). Analysis of the Kenya Certificate of Education Examination results for 1985 and 1986 showed that girls chose subjects that were less cost-intensive to teach. Moreover, curricular changes in the mid-1980s reduced the amount of compulsory time spent on sciences from 17 to 12 class-periods per week, creating greater pressure on students to be self-motivated and to work independently outside the classroom. More than 75% of the girls who sat for mathematics exams in 1985 and 1986 failed (Kinyanjui 1993).

Girls tend to be more attracted to science if they see it as socially relevant. A British study showed that girls were less interested in science that involved defense-funded work or animal experimentation (Wellcome Trust 1994); a Nigerian study revealed that "usefulness" was one of the three most important factors (together with personal interest and ability) influencing female university students' choice of a career in science (Erinosho 1993). In Swaziland, male secondary-school students were much more likely than girls to think that success in science would lead to a good job (Smith 1988). Finally, girls tend to perceive science as a male-dominated area with very long working hours (Wellcome Trust 1994). All of these studies suggest significant attitudinal differences between male and female students at secondary and tertiary levels. In general, girls have a stronger interest in people and social issues, whereas boys often show interest in tinkering and understanding the mechanical foundations of technology (Kelly 1985). However, science curricula tend to be structured to appeal primarily to boys. If more girls are to be attracted into science, then school science courses must appeal to the interests and tastes of both boys and girls. In most countries, these differences have not been taken into account in science-curriculum design.

Research has shown the significance of cultural and socioeconomic factors in steering women toward science careers. In the United States, foreign graduate students from Africa and Asia cited strong family pressure to enrol in science programs (Bellisari 1991). Similar pressure existed for African-American and Asian-American students, but not for students of European background. African and Asian foreign students also regarded national development goals as an incentive to pursue science-based careers. The close linkages between science, technology, and development have been emphasized for several decades and the message apparently has been internalized by many young people. However, in Africa, girls specializing in natural sciences tend to come from more affluent socioeconomic backgrounds and to have better educated parents with less strongly held notions of sex-role stereotypes (Erinosho 1993). If this is the case, then it would seem that it is mostly girls coming from social elites who even have the option to contribute to national development through pursuit of careers in S&T.

Most girls have few role models of successful female scientists. Sex role stereotyping in school textbooks continues to be significant, and girls are rarely depicted as active participants in science textbook illustrations (Kelly 1985). More commonly they are shown as participant observers or as amazed onlookers. With the exception of Madame Marie Curie, few if any female scientists are identified for students. In Africa, where women are key subsistence food farmers, texts rarely even portray them as farmers. In some cases, curricular expectations differ for men and women. For example, at a Kenyan technical institute training junior-level agricultural officers, women were required to take practicals in home economics whereas men took agricultural engineering (Bahemuka et al. 1992). Prevailing stereotypes of "appropriate" roles for girls and boys, men and women continue to inform the design of education programs at all levels, especially in countries where the influence of feminist thinking on curricular reform is still at an early stage. Even in the United States, in 1985, women constituted only 13% of science faculty and 2% of engineering faculty (Task Force on Women, Minorities, and the Handicapped in Science and Technology 1988). Women have a much higher drop-out rate from science and engineering graduate programs than their male counterparts. One reason may be a lack of female role models.

Finally, in developing countries, girls are faced with a variety of factors that conspire to reduce their participation in higher education and in S&T. These include higher opportunity costs for girls to stay in school in the loss of their labour both in the productive sector and in the household. Teenage pregnancy and a range of socioeconomic, religious, and cultural influences all affect parental decisions to educate daughters. In some countries, legal constraints also make it difficult for women to work in certain industries or under certain kinds of conditions. For example, until quite recently, in many African countries women, were prohibited from working between the hours of 6 p.m. and 6 a.m. In other countries, Islamic law prohibits the employment of women in situations where they will have to interact with men. Such obstacles create a further set of structural barriers to full participation of women in economic development and S&T.

The following factors all influence the success of girls in S&T programs:

- ✦ Poor science teaching in schools and differential treatment from teachers;
- ✦ Strong social pressure against excellence in science because it is seen as "unfeminine";
- ✦ Science curricula designed to relate to the interests of boys rather than girls;

- Socioeconomic and family background;
- Lack of female role models; and
- Cultural expectations.

Most of these issues were identified as deterrents to the participation of women in S&T by the ad hoc panel of experts organized by the UN Advisory Committee on Science and Technology for Development and the American Association for the Advancement of Science. The panel made recommendations directly aimed at ameliorating the situation (UN 1984). However, most were implemented only partially or not at all. If such recommendations are to have an effect, they must be accompanied by a strong political will.

Women in S&T careers

Women's experiences as scientists in the workplace usually differ from those of men. In the United States, female scientists are more likely to be unemployed or underemployed, and their salaries are lower than those of equally qualified males (White 1992). By 1990, women constituted only 4% of employed engineers and 30% of employed scientists, although by 1986 women had earned 30% of all first degrees in science and engineering. Moreover, employed female scientists and engineers tended to be young; in 1990, 39% of employed PhDs in science and engineering were under the age of 40, compared with 25% of their male counterparts (White 1992).

In Britain, the trend is similar. The proportion of women scientists decreases at higher levels in industry, the civil service, and academia (Committee on Women in Science, Engineering and Technology 1993). The only scientific occupation in which women outnumber men is that of laboratory technician. Moreover, between 1980 and 1990, the proportion of women employed in engineering actually fell. In the civil service, women scientists are also underrepresented; in 1992, they constituted only 9% of "senior scientific officers." In British universities in 1991, of 24 000 full-time academic staff, women accounted for only 15.5% in the biological and physical sciences, chemistry, mathematics, computing, engineering, technology, and subjects allied to medicine.

Less information is available about employment opportunities for women scientists in developing countries. Moreover, it is difficult to ascertain whether women are underrepresented because they are few in number or because employers discriminate against them, or perhaps both. For example, Ghana's Council for Scientific and Industrial Research employs 171 scientists, only 17 of them female and 9 of those in food research (Beoku-Betts and Logan 1993), but given the fact that the pool of female science graduates is low to begin with, this may be an accurate reflection of the proportion of female science graduates.

Women in academic science careers in the United States are less likely to be promoted to high rank and, in general, their professional advancement is much slower than that of men (see Brush 1991). In 1990–91, only 17% of female full-time faculty at US universities were full professors, compared with 44% of the men. In developing countries, the situation is similar. For example, only 10% of Côte d'Ivoire's full professors in 1987–88 were female (Beoku-Betts and Logan 1993). In the Chinese Academia Sinica, there are 286 female directors or deputy directors of research laboratories, accounting for 11.9% of the total (Guan Tao 1992). During the past decade, there has been a steady, if modest, increase in the numbers of women scientists engaged in all sectors of research and industrial production. In China as elsewhere, however, women scientists are most likely to be concentrated in the biological sciences. For example in 1992, 47.3% of the Chinese Academy of Medical Sciences's research projects were led by women. Moreover, there is some evidence that, as provisions for maternity leave and other benefits become enshrined in Chinese law, there is a growing tendency for employers to prefer to hire men. A Colombian study on research funding for social scientists found that over a 7-year period in the 1980s, three male investigators were funded for each female investigator, even though the numbers of male and female investigators and the quality of their research was equal (BOSTID 1994).

A similar situation is emerging in some of the countries of Eastern Europe in face of growing unemployment. In Romania in 1994, 60% of the unemployed are women, and those who continue to be employed have sometimes kept their jobs only because they accepted lower salaries. In times of economic stress, women are often the first to be released from the workforce under the (often wrong) assumption that they will be supported by working husbands. Moreover, women are likely to receive fewer benefits such as for housing or tax allowances, as it is assumed that they will live with and be supported by husbands (BOSTID 1994).

In all countries, employment prospects for female scientists are negatively affected by their need to combine professional and home responsibilities. Employers often assume that women's commitment to science will be less sustained than that of male colleagues, particularly if they are married and have families. This can have an effect not only on their decision to hire women scientists but also on the type of work to which women are assigned. Women's employment and promotion opportunities are frequently curtailed or hampered when they take time out for childbearing and rearing. Sweden has made an attempt to equalize the situation for men and women with historic legislation in 1994 that fathers must take compulsory leave after the birth of a child. Another positive advancement during the past decade has been the increasing acceptance of family-planning policies in many developing countries.

Finally, the interruptions of daily domestic life that are a reality for most working wives and mothers, are highly disruptive to the pursuit of science, especially scientific research (Arianrhod 1992). Periods of uninterrupted laboratory time are difficult to reconcile with the daily demands of domestic life. Are women expected to make greater sacrifices than their male colleagues to succeed in science? Marriage and motherhood create pressures, expectations, and obligations that are sometimes at odds with total dedication to scientific research. Although there are many examples of women who manage to reconcile domestic and professional lives, it requires considerable organizational skill. This gives further credibility to the argument that neither the practice nor content of science is neutral and reinforces the feminist appeal for a rethinking of the fundamental assumptions of science.

Women scientists are often at a disadvantage in the workplace. They have a more difficult time finding employment; they receive lower salaries and slower promotions; and they must reconcile their private and public lives in an unobtrusive way. However, to a considerable extent these problems lend themselves to legislation. In fact, as noted above, Sweden has already made some progress in this direction.

Learning S&T on the job

Although the main focus of this work is on the integration of women into S&T careers through access to and participation in formal science training, it is important to consider some of the other media through which S&T skills are transmitted. During the past decade, efforts have been made in many countries to integrate women into nontraditional, S&T-based careers. One successful example is that of the Jamaican Women's Construction Collective, which has provided poor Jamaican women with carpentry, masonry, and other construction skills. Graduates of the program have been able to apply for higher paying jobs in the construction industry, although they have faced some discrimination in the workplace because many Jamaican employers are skeptical about hiring women for work traditionally defined as men's. Again, this is an area where legislation could be helpful.

Another example comes from the Sarvodaya Movement in Sri Lanka, which has conducted workshops in water-pump maintenance for young women, teaching them plumbing and welding. The objectives of such initiatives have been to create new sources of employment for poor women, break down existing sex-role stereotypes, and ensure that women share with men the everyday skills essential to the maintenance of communities. The Sri Lankan project came about when it became apparent that men did not place high priority on the repair of water pumps because they viewed water as a female responsibility in most households. Because women's interests were more immediately involved, it was logical that they acquire the skills needed to repair pumps themselves. Groups of young women learned theory and machine-shop work, as well as pump assembly, installation, monitoring, and repair. Women handpump technicians then became educators, change agents, and role models in their own communities.

Despite such success stories, it is relatively rare for women to be given technical training outside formal education systems. Although women are often employed in industries undergoing technical change, they rarely benefit from corporate-sponsored programs to retrain workers and upgrade their skills. For example, some aspects of Japanese JIT (just-in-time) technology were introduced into two small- and medium-sized Argentinean factories (Roldan 1993). The JIT system requires multiskilled labourers who can rotate between jobs and carry out different functions. In both factories, women were kept in the same positions or even phased out while men were given training to enable them to rotate between jobs and become multiskilled. Women were excluded because it was assumed that they did not have the basic technical competence to learn many skills. The firms considered it cheaper to invest in training men, even those with low bases of technical knowledge. In an electronic plant with an all-female labour force, although the (male) production manager was aware of Japanese techniques, he did not plan to adopt them because it would be too costly to provide technical training for women (Roldan 1993). Thus he was willing to forgo the potential benefits of the technologies to avoid having to invest in technical training for women. In Argentina, the introduction of new production technologies seems to be weakening the position of women in the labour force and leading toward a masculinization of factory labour.

The computer explosion of the past decade provides another example. Although facility with desktop computers is based on a mastery of typing, a skill that has been strongly associated with women throughout most of the 20th century, computers have become another area of male dominance. In the United States, although boys and girls show equal interest in computers in early primary school, girls' interest tends to decline after age 10 or 11 while that of boys continues to grow. Not surprisingly, the computer games industry is aimed primarily at boys, with great emphasis on games of violence and destruction.

To a significant extent, the exclusion of girls and women from participation at higher levels in the computer industry reflects general sex-role stereotyping and the assumption that women are "not technical." It is often assumed that women will not even desire such training because it is "unfeminine" and "too difficult." Various strategies have been employed to break down such stereotypes and to encourage an interest among girls in the computer industry — which is projected to be a significant employer into the 21st century. In Australia, week-long computer holidays are organized annually for groups of young girls. In Australian secondary schools, educational videos showing women successfully at work in the computer industry and questioning traditional stereotypes about women computer professionals have been shown to girls with positive results. In the United States, some schools have experimented with the establishment of individual mentor programs; others have set up girls-only hours in computer labs.

On-the-job technical training is frequently acquired through formal apprenticeship or informal mentoring, whereby an older worker teaches a younger one. In most countries, both systems are heavily dominated by men. Apprenticeship programs, which grew out of the medieval trade guilds, have always been male-oriented and, although there are examples of efforts in many countries to provide opportunities for young women, these are difficult to legislate or enforce in the private sector, where most apprenticeship opportunities arise. With respect to mentoring, given the separation of the sexes that occurs as part of childhood socialization processes in most societies, it is not surprising that older men prefer to train young men rather than young women. However, this means that an important potential source of technical learning is less accessible to women. Again, it is difficult to legislate on this matter because mentoring is commonly an unstructured and voluntary undertaking.

Finally, the profusion of new information technologies provides a rich source of instructional media for the transfer of S&T knowledge and skills. These include computer-aided learning systems, transmission of training courses into factories by satellite, interactive video, and various other methods. If women are given equal opportunity to benefit from such courses, they should be able to acquire new technical skills and knowledge to enable them to compete effectively for better-paid positions in the industrial workplace. At the same time, however, older technologies including radio should be used systematically in developing countries to demystify aspects of S&T for rural women. There is also much scope for the use of popular education materials and popular theatre, songs, and dance to impart S&T information. For example, a Ugandan dance company currently is teaching soil conservation techniques to rural men and women through expressive dance performances.

Areas for further research

Would S&T indeed be different if women had a greater voice? It seems evident that the problem goes beyond a mere increase in the numbers of female scientists and technologists. There is need for a complete reconceptualization and reorganization of the culture of S&T. This must encompass the provision of space for alternative viewpoints and perspectives and the humanization of an area that traditionally has considered itself to be "neutral" and beyond the reach of immediate social, cultural, political, and economic manipulation. There is abundant historical evidence that science has never really been neutral, but the challenge lies in persuading its practitioners to accept this and to work from that basis rather than assuming its neutrality.

There is also a need for science and scientists to move beyond the conceptual boundaries imposed by formal training and to recognize the significant contributions that have always been made (and continue to be made) by grassroots practitioners — many of them women. Science tends to be organized in an inherently hierarchical and elitist fashion. In developing countries, extension of technology (in agriculture, health, or other areas) is almost exclusively one way. Scientists or technologists rarely examine existing agricultural or health practices with the thought that they can provide valuable insights or understanding about human-survival strategies. Instead there is always an assumption that knowledge held by the scientist or technologist is of a higher order than that held by the practitioner. This assumption is the foundation stone upon which most extension services have been built.

It might be argued that S&T facts are often presented in deliberately arcane language aimed at creating "insiders" who have the training and expertise to understand and "outsiders" who do not. Women are frequently relegated to the latter status and, although they may have much to gain from understanding the mechanical details of a particular technology, for example, it is rare that efforts are made to explain these in such a way as to be nonthreatening and comprehensible. Instead, women's lack of understanding is once again seen as an example of their intrinsically "nontechnical" nature. We need to demystify and democratize scientific knowledge and involve women as agents of change.

Although, there is already a substantial amount of published information on women and S&T, there continue to be key areas and issues about which relatively little hard evidence is available. Such questions must be examined, both generally and specifically, in the context of existing social and cultural conditions in different countries. Some of the research questions worthy of further study follow.

- Do women scientists have different perspectives and work patterns than their male colleagues? Is there a female world view or perspective that would change the way "science" is currently done?
- What happens to female S&T graduates? Do they get the same types of jobs as their male colleagues? Do they necessarily work in S&T at all? Do they advance at the same rates?
- How can science curricula be designed to account for the interests of both girls and boys?
- Do girls in developing countries and in industrialized countries study S&T for different reasons? What are the key motivating factors?
- Is it more expensive to train women than men on-the-job? Do women actually bring an inferior basis of technical knowledge to such training?
- What have been the experiences of girls and women in technical apprenticeship programs? Are women adequately served by existing programs or should such programs be organized differently?
- Do women benefit from on-the-job mentoring? How can such mentoring be effectively encouraged and nurtured?
- How can the everyday experiences of women in household management, agriculture, and informal-sector employment be validated as work that requires a level of S&T expertise?

Recommendations

As discussed above, lack of political will remains a compelling reason for the exclusion or underrepresentation of women and girls in S&T. Although many recommendations have been aimed at amelioration of this situation, there has been relatively little effective implementation, especially in developing countries. Many governments have emphasized the importance of S&T policy without recognizing the inherent gender biases in their own systems. For example, although attention has been given to the development of more effective science teaching, it has rarely been accompanied by gender analysis. Consequently, there remains a necessity for science education curricula to be reorganized at the primary, secondary, and tertiary levels. Although girls often perform as well as boys in science and mathematics in the early years, their interest declines as they become older. There also seems to be a strong correlation between girls' interest in S&T and the extent to which they see these issues as related to social and community concerns. Thus, there is a strong argument for the redesign of science education materials to focus on the role of S&T in societal development and more specifically on the *usefulness* and *relevance* of S&T in everyday life rather than on the capacity of *man* to *master machine*.

In its efforts to improve the current situation, the UN Commission on Science and Technology should consider the following suggestions.

- All governments should make an explicit commitment to ensure that women and girls are given equal opportunities to participate in S&T programs. Specific targets should be established for enrolment of girls in science programs at secondary and tertiary levels and for the employment of women in government S&T establishments.
- To improve the level of comparative international statistics, all governments should collect systematic data about the number of girls enrolled in science education programs and the number of women employed in the S&T sector.
- Agencies throughout the UN system should ensure that they employ representative numbers of women in S&T positions and that women are given equal opportunity for promotion into management positions. Women's childbearing and rearing responsibilities should not be used as the basis of discrimination against them. Daycare centres should be provided where possible and special efforts should be made to accommodate women's dual responsibilities through the

institution of part-time work, job-sharing, flexible hours, or other creative possibilities.

- UN agencies that provide research grants, scholarships, or professional development grants (including conference participation grants) should systematically ensure that at least half of the grants go to female applicants. If necessary, special efforts should be made to attract such applicants. Also, where necessary, agencies should be flexible in setting the terms of the grants to accommodate women's dual responsibilities.
- The technical work done by women both in the household and in the productive sector should be recognized by the UN system as having an S&T base and be valued accordingly. For example, women farmers should be seen as decision-makers who make science-based choices, taking into account local soil, water, and weather conditions, availability of inputs, availability of labour-saving technologies, and so forth. Similarly, work done by women in the household should be seen as based on knowledge of nutrition, health, child survival, and so on, rather than as work devoid of expertise.