Gender Issues in Education for Science and Technology: Current Situation and Prospects for Change[1]

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Girls and women remain substantially under-represented in mathematics, science, and technology in school and in the workplace. Although this problem is recognized, its complexity is widely underestimated and causes are not well understood. We review prevailing explanations, which tend to concentrate either on possible gender differentials in qualities such as self-confidence, or on school practices that allow boys to dominate classroom interaction and monopolize such technology as computers. We also identify disadvantageous features of higher education and the workplace. We then consider what is known about educational innovation, especially in the area of gender equity, and describe some interventions concerned with gender and science and technology education. Finally, we raise unresolved questions and issues about gender equity efforts in science and technology education and suggest directions for research.

Les filles et les femmes sont nettement sous-représentés en mathématiques, en science et en technologie à l'école et sur le marché du travail. Bien que ce problème soit reconnu, sa complexité est largement sous-estimée et ses causes ne sont pas bien comprises. Les auteurs passent en revue les explications qui ont présentement cours, lesquelles tendent à mettre en relief soit les différences qui existeraient entre les sexes pour ce qui est, par exemple, de la confiance en soi, soit les pratiques scolaires qui permettent aux garçons de dominer l'interaction en classe et de monopoliser la technologie, comme les ordinateurs. Les auteurs identifient également les caractéristiques désavantageuses de l'éducation supérieure et des milieux de travail. Ils se penchent ensuite sur les connaissances actuelles au sujet des innovations en éducation, particulièrement dans le domaine de l'égalité entre les sexes, et décrivent quelques interventions tenant compte du sexe dans l'enseignement des sciences et de la technologie. Ils terminent en soulevant quelques questions non réglées au sujet des efforts à faire en matière d'égalité des sexes dans les cours de science et de technologie et proposent des orientations pour la recherche.

There is now a great deal of general literature on gender and education (e.g., Acker, Megarry, Nisbet, & Hoyle, 1984; Gaskell & McLaren, 1991; Gaskell, McLaren, & Novogrodsky, 1989; Sadker, Sadker, & Klein, 1991). Our discussion here is more specifically directed to gender equity in education for science and technology, and to features of educational innovation and teachers' work that affect attempts to achieve such equity.[2]

We begin by briefly describing the most common formulations of "the problem," those that revolve around the unequal representation of women in scientific and technological education and careers. Next, we review alternative explanations in the literature. These explanations locate the source of the problem in attitudes or motivations; in school practices; or in conditions in the wider society. We then consider relevant interventions to increase gender equity and explore the barriers to change in educational institutions. Finally, we raise questions about such issues as the difficulty of systematically collecting data on outcomes of projects, and the gaps between much contemporary feminist thought and the design and practice of interventions.

THE PROBLEM

Of all topics featured in the literature on gender and education, the "arts/science split" (Byrne, 1978, p. 116) is one of the most frequently addressed. Although there are different formulations of the problem, the general issue is that females less often study mathematics, physical sciences, engineering, computer studies, and allied fields at every level of education from elementary school to graduate school (Robertson, 1988; Statistics Canada, 1990).

Consequently, women are under-represented in occupations requiring knowledge of or qualifications in these fields. For example, in 1986, women were 29% of the employed science and technology labour force in Canada, compared to their overall labour force participation of 43%. Moreover, many of these women are social scientists: only 7% of the workers in architecture, engineering, and related fields were women (Statistics Canada, 1989, pp. 27–28).

Such patterns must be approached with some caution, not least because they have been changing over the years in the direction of greater equity. Some sex differences in performance on mathematics tests, which once prompted complex bio-psychological theories of innate cognitive differences between males and females, have all but disappeared over time (Chipman & Thomas, 1987; Linn & Hyde, 1989; Sadker et al., 1991). The extent to which sex differences in performance or representation occur varies from country to country (Brandon, Newton, & Hammond, 1987; Hanna, 1989; Tamir, 1988).

Within countries, social class and ethnic differences complicate the picture (Chipman & Thomas, 1987; Linn, 1985; Oakes, 1990). For example, in the United States, Black and Hispanic high school and college students are relatively unlikely to specialize in mathematics and science (Oakes, 1990, p. 162). In contrast, Asian-American men and women are disproportionately found in university science and technology courses. Asian-American women "overselect" computer science (Chipman & Thomas, 1987, p. 398).

Although we lack comparable figures for Canadians of diverse ethnicity, it appears that patterns of participation in mathematics, science, and technology are complex, and that the role of schooling in deepening or mitigating disadvantage needs much closer examination. There is certainly evidence that educational inequality on grounds of gender, ethnicity, region, and class background occurs in Canada, as elsewhere (Wotherspoon, 1991).

POSSIBLE EXPLANATIONS

Social-Psychological Approaches

Although most commentators recognize that any explanation of differences in participation must take into account multiple influences at the individual, schooling, and societal level (Oakes, 1990), the most common framework has been a social-psychological one. The underlying assumption seems to be that whatever the full range of influences, in the last analysis a person must decide to do or not to do something, for instance to enrol in a science course. Eccles (1984) frames the decision to enrol in mathematics as a result of expectancies for successful performance and the subjective value of the task for the individual.

Some researchers claim that mathematics and science are not seen as congruent with female sex-role identity, a problem exacerbated whenever career-related choices must be made at such vulnerable ages as early adolescence (Robertson, 1988). Robertson points out that the pattern described in social-psychological studies of girls' characteristics — low self confidence, a belief that success is due to luck and failure to lack of ability, overestimating the difficulty of unfamiliar tasks, and hesitancy over risk-taking — is diametrically opposed to traits generally thought to promote success in scientific careers.

Lower self-confidence of women and girls is frequently remarked upon (Collis, 1991; Oakes, 1990; Robertson, 1988). Collis (1991) identified what she called the "We can but I can't" paradox: girls would strongly defend the abilities of their sex in general terms, but be hesitant about their own potential and choices. Steinkamp and Maehr (1984) report a similar finding.

Chipman and Thomas (1987) find that "interests," which emerge early, are a strong predictor of scientific and technological careers, and that men and women who become scientists are very similar in their interests and vocational values. It appears that either such interests are differentially distributed between the sexes, or some other factors intervene to deter women from such careers. Oakes (1990) points out, however, that liking for a subject can be misleading as a predictor. Black students in the United States are as positive or more positive than white students about mathematics and science but are less likely to pursue these subjects (Oakes, 1990, p. 172).

Social-psychological approaches have been criticized for operating with a "deficit model" of women's achievement that implicitly or explicitly denigrates women's choices, stances, and characteristics by regarding them as inferior to men's. The line between difference and deficit is hard to draw. Maines (1985), for example, argues that men can become narrowly focused on mathematical study, while women tend to spread their energies and attentions over a range of activities and social relations. As a consequence, for women, "inconsistency . . . is an ordinary and routine part of their lives" (Maines, 1985, p. 317). Such a statement certainly sounds like one of deficit, despite an intention to locate causes in "life structures" as well as some essential proclivities. Arguments about women's orientations may also pay insufficient attention to the contexts shaping these orientations, such as the gender-differentiated jobs available in the labour market.

School Influences

Timetabling of subjects, assessment procedures, teacher expectations and behaviour, peer pressures, unequal funding, and stereotyped textbooks are among the long list of schooling features thought to contribute to gender inequity. Teachers' attitudes and practices in particular have been singled out. A survey of secondary school teachers in Britain (Pratt, 1985) found teachers of mathematics, physical science, technical craft, and languages least in favour of equal-opportunities initiatives. Spear (1985) reported large numbers of science teachers agreed with statements advocating traditional roles for women. The team working on the GIST (Girls Into Science and Technology) project in the United Kingdom observed science teachers trying to attract boys' attention by suggesting that science was "macho" by, for instance, stressing its dangers (Whyte, 1985).

Many studies, although not all, report boys receive disproportionate teacher time and attention (Becker, 1981; Kelly, 1986; Measor, 1983; Sadker et al., 1991). Attempts have been made to clarify such findings; for example, some studies suggest that boys "call out" more, and teachers respond more to them (Sadker et al., 1991); or that it is particular children, especially those boys who present a discipline difficulty, who get the most attention. Grieb and Easly (1984) describe how certain learning styles and teaching styles mesh in the mathematics classes of elementary schools, so that the "pale male math maverick" (the white, middle-class boy) is allowed to develop his creativity while other children are confirmed in their preferences for routine, memorizing, and rule-following (see also Walkerdine, 1989).

Collis (1991) argues that secondary school policies requiring mathematics pre-requisites or co-requisites for work with computers, and locating computer resources in mathematics departments, reinforce masculine associations. If there is a single computing laboratory, it may become seen as a male territory. If computer resources are concentrated in the mathematics, science, and technology area of the curriculum, many girls have no access to them.

Other researchers have identified a boy-centred "computer culture" growing up in schools or within classrooms. Carmichael, Burnett, Higginson, Moore, and Pollard (1985), who observed computer use in 18 Ontario elementary school classrooms over two years, report some particularly disturbing findings. End-ofyear tests of computer knowledge showed boys at the junior and intermediate levels had higher average scores than girls. Classroom interactions at the Grade 7 site that produced the largest differences were examined in detail. The researchers reported that girls found the "challenge" assignments the teacher created uninteresting and sometimes missed their computer time because they were worried about completing their other school work. But a greater problem was the behaviour of the boys. "When it comes to computers, they are sharks," said one girl (p. 83). Aggressive strategies, such as starting to print when it was a girl's turn to use the keyboard, or telling the teacher if a girl's disk was left around the classroom, so that it would be locked away for several days as punishment, were reported. There was no sharing of knowledge or materials between the sexes. Boys kept the key to the cupboard with the manuals, discouraged girls with scathing comments, and manipulated girls by "trading" computers so that the girls ended up without a printer or with a machine they did not know how to use. The teacher seemed helpless and did not devise remedies. Other studies in Canada and the United States find similar patterns (Hawkins, 1985; Schoeneberger, 1984; Silvern, Williamson, & Countermine, 1988).

In this rather gloomy literature there are also some counter-trends and descriptions of good practice. In one experimental study of six- and seven-year-old children, Hughes, Brackenridge, Bibby, and Greenhough (1989) found that girl pairs did worse at operating a computer-controlled robot than did boy pairs or mixed pairs. In subsequent individual testing, girls who had first been in a mixed pair did significantly better than girls who had first worked with another girl. Other projects, for example, one in which children write notes for themselves and to one another via a communal computer data base, have successfully involved both girls and boys (Scardamalia et al., 1992).

Kahle (1985) considered the role of teachers in encouraging young women to study science in an examination of eight high school biology classes in the United State. "Good teachers make a difference," she comments (p. 70). The teachers were skilled, professionally active, confident, and knowledgeable. All shared certain practices: use of multiple textbooks, more laboratory and discussion activities, frequent evaluation of work, field trips, independent projects, and "attractive, well-equipped and maintained classrooms."

Other Influences

Research also suggests that the "problem" stems from factors outside the school. Cultural stereotyping of science as masculine is very strong (Frieze & Hanusa, 1984) and it is reinforced by many aspects of social life. Associations between computers and masculinity are reflected in patterns of computer use in children's homes, by computer magazines directed at males, and by computer games that stress aggressive and competitive themes (Cole & Griffin, 1987; Collis, 1991; Fetler, 1985). Studies in the United States find that boys have more exposure to computers at home as well as at school, and are more likely than girls to be sent to computer camps and summer classes (Fetler, 1985; Hess & Miura, 1985).

Some writers also single out industrial and academic workplaces as strong reinforcers of the masculinity of science and technology. As Brush (1991) has shown, not only do women choose science and technology less often in school, but in both school and the workplace they encounter obstacles and disincentives not faced by men. Women in science and technology receive lower salaries, lower status, and poorer prospects of promotion than do men (Brush, 1991; Frieze & Hanusa, 1984; Matyas, 1985; Morrell, 1991; Scott, 1990). The "ordinary processes of science" (Scott, 1990), which often include dedication to a single goal at the expense of other activities, and the "micro-inequities" of everyday life (Matyas, 1985, p. 82) act to discourage women and confirm them in subordinate roles.

The university also comes under attack for its treatment of students. Several writers report that women who enter science and technology programs and graduate studies in universities leave them at a greater rate than do comparable men (Matyas, 1985; Morrell, 1991), or defect to non-science careers (Nevitte, Gibbons, & Codding, 1988). There are many contributions to the explanation of such outcomes, including bias of the Scholastic Aptitude Test (SAT), which underpredicts women's grades in university courses and leads to discrimination against them in admissions and scholarships (Brush, 1991); discomfort of being in a minority (Thomas, 1990); lesser likelihood of being accepted as a serious colleague (Matyas, 1985; Taylorson, 1984); fewer opportunities for funding and research experience (Matyas, 1985); sexist humour and language; textbooks that omit women's contributions (Morrell, 1991); and the scarcity of female role models and mentors (Frieze & Hanusa, 1984; Morrell, 1991).

Morrell (1991) notes that the women's studies movement has made few inroads into scientific subjects, with its main impact on scholarship and pedagogy being in education, the humanities, and social science. There is, however, a feminist critique of science that goes beyond the search for equity to question the assumptions and structure of the scientific and technological enterprise, particularly as it devalues other aspects of human existence in the pursuit of economic advance. There are arguments for a feminist science that would be communal and non-hierarchical and put social and environmental responsibility high on the agenda (Morrell, 1991).

ACCOMPLISHING CHANGE

The literature reviewed above describes an unsatisfactory situation with diverse causes. No single intervention is likely to alter such entrenched patterns of preference and possibility, and some causes are outside the realm of simple innovation. Nevertheless, it is clear that changes in women's options and status have occurred — such as the increase in their representation as students in higher education over time — and a gradual accumulation of small initiatives and alterations may help bring about social change. In this section we review some of these interventions and consider factors that might facilitate or impede them.

Educational Innovations and Teachers' Work

Most innovations are likely to be directed at children and young adults and take place in educational settings. Yet the history of planned educational change shows it is not easy to change situations in ways that will last. This is not entirely to be regretted, as reform efforts are not always progressive (Ball, 1987).

Accomplishing change requires alterations in materials, teaching approaches, and beliefs (Fullan & Stiegelbauer, 1991, p. 37). Beliefs are especially difficult to alter. There is evidence that teacher ideologies set limits on what changes teachers are likely to accept. For example, Pratt (1985) and Riddell (1992), in England, found teachers believed it would be wrong to intervene to alter preference of girls and boys for conventional fields of study and careers. They wanted to create a value-free environment in which pupils could exercise freedom of choice. A Canadian survey (Orpwood & Souque, undated, p. 17) of nearly 7,000 science teachers in the early 1980s found teachers unenthusiastic about giving special attention to girls' needs. Studies in Britain report that teachers are sceptical about initiatives to promote equal opportunities, and negative about feminism (Whyte, 1986). A particular problem with interventions concerned with equity is that they usually try to go beyond introducing new materials or resources, to imply that teachers' practices and beliefs are, or have been, grievously wrong (Hustler & Cuff, 1986, p. 182).

All interventions must contend with school and classroom realities. Many initiatives imposed from above do not do this well. Weinshank, Trumball, and Daly (1983) argue that the "modal conditions" of teaching are inimical to implementing innovation. Successful innovations require such conditions as support from the principal, time for planning, appropriate resources, and teachers willing to work together on a project they believe in. Miller and Lieberman (1988) point out that schools are complex cultures: "changing them is a complicated, non-linear, messy endeavor" (p. 7). Innovations need to take into account particular schools' circumstances, in terms of such features as size, clientele, location, resources, history, and ethos, as well as typical classroom conditions (Acker, 1988, 1990). Managing classroom complexity means that any innovations threatening classroom order may be rejected (Doyle & Ponder, 1977).

Introducing computers into classrooms seems particularly problematic, as computers disrupt patterns of classroom activity and teacher routine (Blackstock & Miller, 1989; Carmichael et al., 1985; Fullan, 1992; Olson & Pothaar, 1988). The teacher may be torn between attending to the needs of both the computer users and the remainder of the class, while a laboratory may present nightmarish logistics of scheduling and setting up many machines in a short time.

Teachers also have the problem of overload. In England and Wales, the imposition of a national curriculum and testing, together with changes in the financing and governance of schools, has increased the amount of work teachers do (Acker, 1990). In the United States, it has been argued that demands for accountability and conformity with political mandates have required more work in the same amount of time (Densmore, 1988). Apple and Jungck (1990) found that some teachers settled for a curriculum unit on computers that required little of them beyond pressing buttons on a tape-recorder because it gave them a breathing space and helped them cope with a heavy workload.

The message of this literature seems to be that innovations in schools have a greater chance of success if they are compatible with teachers' existing beliefs and conditions of work. This may be more likely when teachers themselves are the initiators. Fullan and Stiegelbauer (1991) point out, however, that although "top-down" initiatives may be resented and resisted, individual teacher initiatives may not be well enough supported or generalized to have lasting effects. More promising are initiatives that develop "simultaneous top-down/bottom-up approaches" (p. 201).

Gender Equity Initiatives

Initiatives concerned with gender equity, some of which focus on access to or outcomes in technology and science, have become fairly common in recent years in number of countries. Intervention projects in the United States have been credited with a rise in high school girls' propensity to follow a full four-year mathematics program (Kahle, 1985), and with strategies that significantly increase girls' use of computers (Sanders & Stone, 1986). From some of these programs have come suggestions of the key features of successful interventions: highly motivated teachers, strong academic emphasis, multiple strategies, and an appreciation of the social context into which technology is being introduced (Cole & Griffin, 1987; Stage, Krainberg, Eccles, & Becker, 1984).

The Idea Book (Robertson, 1988) gives brief descriptions of projects and names of contact individuals in Canada, and an annotated bibliography prepared for the Ontario Women's Directorate (McAuley, 1990) gives descriptions of curriculum resources and background materials. There has been some support at a policy level — for instance, from the Science Council of Canada (1982, 1984). Provinces have tried to eliminate sex stereotyping in textbooks and curriculum guidelines, and to broaden career goals of young women. Teachers' federations have also been leaders in encouraging teachers to develop bias-free materials and classrooms (Julien, 1987).

Interesting initiatives from British Columbia are described in a special issue of *Women's Education des femmes* (Clarke, 1991a) on "Girls in Science."

"Women Do Math" is a one-day conference on scientific careers, held annually at Simon Fraser University. Since 1987 it has been attended by between 350 and 400 young women in Grades 9 and 10, together with their parents and teachers (Szpitun, 1991). The emphasis is on presenting mathematics as beautiful, enjoyable, accessible, and necessary. Conferences mix talks, workshops, and discussions, stressing career opportunities, women as role models, and the uses of mathematics thought to appeal to girls. The program has developed into a version called "Ms Infinity," serving smaller and more far-flung communities in British Columbia and Whitehorse, Yukon. Another program in Vancouver, sponsored by the Society for Canadian Women in Science and Technology, is aimed at girls aged 9 to 12. It consists of a series of half-day summer workshops with small classes and female instructors, and features activities like fixing bicycles or mixing cement. The program has produced a book of workshop activities intended for community groups (Vickers, 1991).

Ontario has also been an innovative province. The special issue of *Women's Education des femmes* describes workshops and conferences in several parts of the province designed to encourage girls' participation in mathematics, science, and technology (Beam, 1991; Leek & Dalton, 1991; McCartney, 1991). Julien (1987) describes policy initiatives and agencies supporting gender equity, including the Equal Opportunity/Affirmative Action Unit of the Ontario Ministry of Education and the Ontario Women's Directorate.

Individual school boards in Ontario have set up innovative programs, including girls-only math classes, women speakers visiting schools, and career conferences (Julien, 1987, p. 27). York University has directed "Careerscope" and "Science Odyssey" programs, which feature speakers and visits to the university campus, at young women in Grades 9 and 10 (Women in Science, undated). Wiggan (1986) describes other Toronto-area initiatives, including those concentrating on dissemination of information, workshops for teachers and others, and career conferences for female students.

The City of York Board of Education has provided support for elementary school teachers trying to integrate computers into their teaching, via guidelines, computer assistants, and women instructors on professional development courses (Rhodes, 1991). The Toronto Board has a coordinator for women's studies and individual schools appoint a women's studies representative (Gaskell et al., 1989, pp. 53–54). Another initiative in Toronto and other Ontario Boards is "Expanding Your Horizons," conferences aiming to encourage young women students to consider careers in mathematics, science, and computer technology.

QUESTIONS AND ISSUES

Earlier in this article, we reviewed competing explanations for the under-representation of girls and women in science and technology, discussed literature on efforts to increase gender equity through intervention projects, setting these in a context of what is known about implementing educational innovations, and described selected Canadian initiatives. In the remainder of this article we examine the likelihood that such initiatives will bring about greater equity. We consider questions about the scope and durability of the initiatives; the suitability of their targets; the difficulties of assessing outcomes; and the underlying conceptual or theoretical frameworks. We make some suggestions for a research agenda arising from such consideration.

Intervention projects, such as those described in Robertson (1988), McAuley (1990), and the special issue of *Women's Education des femmes* (Clarke, 1991a), take several forms. Individual teachers and schools may experiment with curricular revisions or single-sex groupings for mathematics classes. School boards may provide booklets or inservice courses to aid teachers who wish to innovate. Boards, universities, and professional groups sponsor day courses or summer workshops for young women. Any of these organizations may try to provide role models by, for instance, inviting women scientists as speakers, and on occasion arranging for job shadowing or periods of attachment to university departments. Most of these interventions are directed at encouraging young women to consider courses and careers in science and technology as appropriate choices.

Several features of such interventions are particularly noticeable. The group targeted for change is most often young women, especially those in the middle or high school years, rather than boys, parents, or teachers. There were few references to preservice or inservice teacher education programs. In fact, Julien (1987) notes the gaps in equity training in teacher education. Moreover, projects seem on the whole to be small-scale and without a reliable source of extended funding. Those initiated at school level may be especially ephemeral, given the difficulties surrounding educational innovation described earlier and the rarity of practitioners writing about their work in a form that receives wide circulation.

Another difficult question is the appropriate stage and location for interventions. Early adolescence is frequently singled out as a crucial time (Oakes, 1990; Robertson, 1988) but studies also point both to the importance of the early years and to the "chilly climate" of higher education. Interventions outside school settings are certainly conceivable, for example, in museums or in the community. Some thought might be given to the many adult women who were denied a chance to study science in their own schooling. Ursula Franklin comments that "schools are not the only place to learn," pointing out that many adult women working as environmental advocates are not scientists and have acquired their skills and knowledge through their own research efforts (Clarke, 1991b).

A problematic feature of innovations is the difficulty of assessing eventual outcomes. Not often do we have a means of generalizing across projects to see what "works," especially in the long run. For example, if the purpose of an intervention is to encourage girls into scientific careers, how many of the target group end up in such careers? To what extent could their career outcomes be attributed to the project? If such an outcome is not forthcoming, are there reasons that could be tackled by other projects or are they outside the scope of educational innovations?

All projects want to claim success, and they may be forced to stress their positive features in order to secure funding. Sometimes, however, more is learned from projects that do not entirely achieve their goals. For example, Leek and Dalton (1991) describe a program for girls in elementary schools in an honest and self-critical account, noting difficulties of follow-up and evaluation, barriers to integrating the program with school curricula, and apparent resistance among teachers to highlighting the gender-specific features of the intervention. The organizers continue to question their own activity: how best to provide support to local communities, what role there should be for a coordinator and steering committee, and so forth.

Rarely asked, it seems, is what explicit or implicit theories lie behind innovation efforts. Most projects seem to be broadly feminist in nature, if we take feminism to refer simply to an understanding that girls and women suffer systematic social injustice because of their sex (Richards, 1980). Descriptions of feminist theory typically make distinctions among, for example, liberal, socialist, and radical feminist perspectives (Acker, 1987). In recent years, postmodern critiques have questioned the idea of a unitary female "subject" and the usefulness of any feminist "grand theories," while women of colour have attacked the white, middle-class bias of theories claiming to apply to all women.

Bryson and de Castell (in press) have described four discourses concerning gender and technology. We draw upon their work here to explore the implications for interventions in science and technology education. The first discourse, "positivism/technicism," focuses largely on efforts to encourage girls to increase their representation in technology and education. Clearly, many innovations described in the literature could be characterized as operating out of such a discourse. Most concentrate on altering textbooks and curriculum materials on one hand, and providing role models and better career guidance on the other (Julien, 1987), with a strong emphasis on convincing girls that science and technology provide appropriate destinations for women. Such interventions might also be said to use a liberal feminist model of change, one which aims to alter attitudes and to reduce stereotyped thinking rather than to mount fundamental challenges to social structures.

A problem with such an approach might be that increasing girls' interests in science without enabling them to acquire appropriate skills and learning strategies could be counterproductive (Kahle, 1987). Another problem is that the nature and practice of science and technology may go unquestioned if the goal is simply to attract women into these fields. A third difficulty is the implicit suggestion that girls' choices are irrational and rooted in individual characteristics (the "deficit model"), rather than socially shaped.

The second discourse, which Bryson and de Castell call "constructivist," stresses the incompatibility between "women's ways of knowing" (Belenky, Clinchy, Goldberger, & Tarule, 1986) and typical practices of technology. Feminist accounts of women's "ways" tend to suggest that women, by nature or socialization, have preferences for cooperative, caring, connected approaches to learning and working. Certainly some feminist critiques of science teaching have drawn upon such perspectives, for example, in noting that girls are less interested than boys in imposing their "will over the machine" (the computer) or competing to finish a task first (Bernhard, 1990). Such writers as Morrell (1991) believe that the uncritical equation of scientific and technical advance with economic prosperity rationalizes a neglect of such traditional (caring) women's occupations as social work and nursing, which remain underpaid and undervalued. Some interventions follow the constructivist approach in taking up the notion that girls or women should learn separately from men, according to different principles. Others attempt to devise "female-friendly" curricula and pedagogies (Rosser, 1990).

There are some difficulties with the constructivist approach. It suffers from essentialism in its assumptions about women (or men) as a category, and celebrates a way of operating derived from oppression. Applications to education rest on a reification of "styles" or "ways" of learning. Moreover, as Bryson and de Castell point out, "learning styles" are not good explanations for failure or alienation of groups disenfranchised economically or by racism. However, such approaches strongly challenge establishment science and technology. Any interventions adopting this particular feminist critique will face a task more difficult than simply encouraging female participation — the task of reworking science and technology.

Bryson and de Castell's third discourse is the "critical" approach to equity, wherein gender and other social divisions are regarded as produced and maintained by such institutions as schools. Kessler, Ashenden, Connell, and Dowsett (1985), for example, develop a concept of "gender regimes" to describe patterns of practices that define "acceptable" masculinity and femininity within schools. These patterns are hegemonic (taken for granted, like the air we breathe) but simultaneously open to resistance and change. Whether scientific and technological subjects are seen as an appropriate part of gendered expectations for young women would be a feature of a gender regime in a particular school at a particular point in history.

Critical approaches have the advantage of moving us away from the assumption that whatever men do is "better" and that women need to learn how to emulate them, in turn reflecting an ideology of individual free choice (Riddell, 1992). Instead, they emphasize factors constraining such choices for some people, and the responsibilities of institutions, workplaces, the state, the scientific community, and so forth. Educational technology is no longer seen as necessarily positive or even as neutral. For example, some think that computers in schools become part of existing patterns of compliance and control, and reinforce divisions of ability, social class, and gender (Coles & Griffin, 1987; Hinkling-Hudson, 1992). Teachers, too, can be victims of oppressive practices, as seen in the Apple and Jungck (1990) study mentioned earlier and in other literature on the deleterious consequences of outside pressures for educational "reform."

Critical approaches typically emphasize individuals' and groups' power to transcend their situations through deeper understanding of the forces around them, a stance that might be regarded as overly optimistic, or containing internal contradictions, in light of the generally pessimistic portrait these same critics paint. It is also sometimes unclear whether the technology itself is the villain, or whether technology is simply one more feature of schooling that can be badly used.

It is not immediately obvious how educational interventions could fit the critical model, apart from teacher efforts to eradicate inequalities currently associated with the curriculum. Perhaps students could be helped to grasp the dynamics of a socially unjust society, and to see science and technology as a means to an end (social justice). Or perhaps the focus could be on attacking the aggressive and excluding strategies boys use, as described in some research on children's use of computers. How might interventions be designed to affect boys and men? Designing interventions from a critical perspective would be a challenging task, a long way from simply encouraging girls to elect science options.

The fourth discourse is "postmodernism," and is probably incompatible with the other three. Here taken-for-granted dualisms—such as male and female—and normally accepted bodies of knowledge (including "science" and "technology") are themselves under question. Identity no longer resembles the essentialist descriptions in the constructivist accounts and is seen as constantly shifting and made up of multiple inputs based on sex, race, class, age, sexual orientation, and so forth.

We may not be able to respond to all aspects of the postmodern critique, but at a basic level, we can begin to question the emphasis on "girls as girls" in so many intervention projects. How many projects take account of class, culture, and ethnicity? As feminist theory moves toward much greater consideration of ways in which women (and men) are multiply positioned and influenced by complex identities (Alcoff, 1988), intervention projects are challenged to become more aware of such issues. For example, Weiler's (1988) description of a feminist teacher's difficulties responding to competing class, gender, and race sensitivities and subjectivities of her students raises thorny issues for innovators.

Our review of unresolved questions and issues concerning gender and science and technology education suggests to us that a research agenda might be devised to take on board some of these issues. We have made tentative plans to collect data on a range of innovations in a given geographical area. These projects would range from individual teachers' efforts to such large-scale interventions as summer schools. We would like to see whether projects have attempted to assess outcomes and to make some comparisons among projects to see what factors might be associated with certain kinds of outcomes.

It would also be worthwhile to find out if networks exist among innovators or whether efforts are typically isolated and unsupported. We would like teachers and others to tell us how they came to devise or implement innovations, and how their working conditions have facilitated or impeded their efforts. We would also be interested in theoretical frameworks behind the innovations. Have, for example, projects considered class and ethnic variation as well as gender divisions? Are they ever aimed at changing boys' behaviours? Have they found ways to avoid the deficit model or to challenge practices of science and technology? Do they claim to build a pedagogy on "women's ways"? Do they ever work from a critical or postmodern standpoint?

There is much still to be understood about gender and educational interventions in science and technology. Doubtless in part it is the benefit of hindsight, but our review of the literature on gender equity, the accomplishment of change, and specific interventions concerning science and technology suggests to us that there is a difference, one highly significant for prospects for change *in practice*, between what research so far has told us, and what we actually need to know.

NOTES

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[2] Some issues discussed in this article are also raised, with special attention to computer education, in "Gender Equity and Computers in Context," a conference paper we presented at the Seventh Gender and Science and Technology (GASAT) Conference, Waterloo, Ontario, 31 July–5 August 1993.

REFERENCES

Acker, S. (1987). Feminist theory and the study of gender and education. *International Review of Education, 33,* 419–435.

Acker, S. (1988). Teachers, gender and resistance. *British Journal of Sociology of Education, 9,* 307–322.

Acker, S. (1990). Teachers' culture in an English primary school. *British Journal of Sociology of Education, 11,* 257–273.

Acker, S., Megarry, J., Nisbet, S., & Hoyle, E. (Eds.). (1984). *World yearbook of education, 1984: Women and education.* London: Kogan Page.

Alcoff, L. (1988). Cultural feminism vs. post-structuralism. In E. Minnich, J. O'Barr, & R. Rosenfeld (Eds.), *Reconstructing the academy* (pp. 257–288). Chicago: University of Chicago Press.

Apple, M., & Jungck, S. (1990). "You don't have to be a teacher to teach this unit": Teaching, technology and gender in the classroom. *American Educational Research Journal, 27,* 227–251.

Ball, S. J. (1987). *The micro-politics of the school.* London: Methuen.

Beam, M. (1991). Reducing the risk: Cooperative education strategies for girls in math, science and technology. *Women's Education des femmes, 9,* 9–12.

Becker, J. (1981). Differential treatment of females and males in mathematics classes. *Journal for Research in Mathematics Education, 12,* 40–53.

Belenky, M., Clinchy, B., Goldberger, N., & Tarule, J. (1986). *Women's ways of knowing: The development of self, voice, and mind.* New York: Basic Books.

Bernhard, J. (1990) *Gender stereotypes and computer usage: Preschoolers learning Logo.* Unpublished doctoral dissertation, Ontario Institute for Studies in Education, University of Toronto, Toronto.

Blackstock, J., & Miller, L. (1989). *Yes, but are they learning anything?* (Interim Report from the Kingston Regional Pilot Test Centre, No. 3). Ottawa: Queen's Printer for Ontario.

Brandon, P., Newton, B., & Hammond, O. (1987). Children's mathematics achievement in Hawaii: Sex differences favoring girls. *American Educational Research Journal, 24,* 437–461.

Brush, S. G. (1991). Women in science and engineering. *American Scientist, 79,* 404–419.

Bryson, M., & de Castell, S. (in press). So we've got a chip on our shoulder: Sexing the texts of educational technologies. In J. Willinsky & J. Gaskell (Eds.), *Gender enriches curriculum.* New York: Teachers College Press.

Byrne, E. (1978). *Women and education.* London: Tavistock.

Carmichael, H., Burnett, J., Higginson, W., Moore, B., & Pollard, P. (1985). *Computers, children and classrooms: A multisite evaluation of the creative use of microcomputers by elementary school children* (Final Report). Toronto: Ontario Ministry of Education.

Chipman, S., & Thomas, V. (1987). The participation of women and minorities in mathematical, scientific and technical fields. In E. Rothkopf (Ed.), *Review of Research in Education, vol. 14* (pp. 387–430). Washington, DC: American Educational Research Association.

Clarke, J. (Ed.). (1991a). Girls in science: Discovering their choices. *Women's Education des femmes, 9* [Special Issue].

Clarke, J. (1991b). "I would emphasize the joy of science": An interview with Ursula Franklin. *Women's Education des femmes, 9,* 5–8.

Cole, M., & Griffin, P. (1987). *Contextual factors in education: Improving science and mathematics education for minorities and women.* Madison: University of Wisconsin, Wisconsin Center for Education Research.

Collis, B. (1991). Adolescent females and computers: Real and perceived barriers. In J. Gaskell & A. McLaren (Eds.), *Women and education: A Canadian perspective* (2nd ed.; pp. 147–161). Calgary: Detselig.

Densmore, K. (1988). Professionalism, proletarianization and teacher work. In T. Popkewitz (Ed.), *Critical studies in teacher education* (pp. 130–160). Lewes: Falmer.

Doyle, W., & Ponder, G. (1977). The practicality ethic in teacher decision-making. *Interchange, 8,* 1–12.

Eccles, J. (1984). Sex differences in mathematics participation. In M. Steinkamp & M. Maehr (Eds.), *Advances in motivation and achievement* (pp. 93–137). Greenwich, CT: JAI Press.

Fetler, M. (1985). Sex differences on the California statewide assessment of computer literacy. *Sex Roles, 13,* 181–191.

Frieze, M., & Hanusa, B. (1984). Women scientists: Overcoming barriers. In M. Steinkamp & M. Maehr (Eds.), *Advances in motivation and achievement* (pp. 139–163). Greenwich, CT: JAI Press.

Fullan, M. (1992). *Successful school improvement.* Toronto: OISE Press.

Fullan, M., & Stiegelbauer, S. (1991). *The new meaning of educational change.* New York: Teachers College Press.

Gaskell, J., & McLaren, A. (Eds.). (1991). *Women and education: A Canadian perspective* (2nd Ed.). Calgary: Detselig.

Gaskell, J., McLaren, A., & Novogrodsky, M. (1989). *Claiming an education: Feminism and Canadian schools.* Toronto: Our Schools/Our Selves Education Foundation and Garamond Press.

Grieb, A., & Easley, J. (1984). A primary school impediment to mathematical equity: Case studies in rule-dependent socialization. In M. Steinkamp & M. Maehr (Eds.), *Advances in motivation and achievement* (pp. 317–362). Greenwich, CT: JAI Press.

Hanna, G. (1989). Mathematics achievement of girls and boys in grade eight: Results from twenty countries. *Educational Studies in Mathematics, 20,* 225–232.

Hawkins, J. (1985). Computers and girls: Rethinking the issues. *Sex Roles, 13,* 163–180.

Hess, R. D., & Miura, I. (1985). Gender differences in enrollment in computer camps and classes. *Sex Roles, 13,* 193–203.

Hickling-Hudson, A. (1992). Rich schools, poor schools, boys and girls: Computer education in Australian secondary schools. *Journal of Education Policy, 7,* 1–21.

Hughes, M., Brackenridge, A., Bibby, A., & Greenhough, P. (1989). Girls, boys and turtles: Gender effects in young children learning with Logo. In C. Hoyles (Ed.), *Girls and computers* (pp. 31–39). London: University of London Institute of Education.

Hustler, D., & Cuff, T. (1986). Teachers' perceptions of the GIST project. In D. Hustler, T. Cassidy, & T. Cuff (Eds.), *Action research in classrooms and schools* (pp. 172–182). London: Allen & Unwin.

Julien, L. (1987). *Women's issues in education in Canada: A survey of policies and practices at the elementary and secondary levels.* Toronto: Council of Ministers of Education.

Kahle, J. B. (1985). Retention of girls in science: Case studies of secondary teachers. In J. B. Kahle (Ed.), *Women in science: A report from the field.* Philadelphia: Falmer.

Kahle, J. B. (1987). SCORES: A project for change. *International Journal of Science Education, 9,* 325–333.

Kelly, A. (1986, September). *Gender differences in teacher-pupil interactions: A meta-analytic review.* Paper presented to the Annual Meeting of the British Educational Research Association, Bristol.

Kessler, S., Ashendon, D., Connell, R., & Dowsett, G. (1985). Gender relations in secondary schooling. *Sociology of Education, 58,* 34–48.

Leek, B., & Dalton, J. (1991). Here today . . . where tomorrow? *Women's Education des femmes, 9,* 17–20.

Linn, M. (1985). Fostering equitable consequences from computer learning environments. *Sex Roles, 13,* 229–240.

Linn, M., & Hyde, J. (1989). Gender, mathematics and science. *Educational Researcher, 18,* 17–27.

Maines, D. (1985). Preliminary notes on a theory of informal barriers for women in mathematics. *Educational Studies in Mathematics, 16,* 314–320.

Matyas, M. L. (1985). Factors affecting female achievement and interest in scientific careers. In J. B. Kahle (Ed.), *Women in science: A report from the field* (pp. 27–48). Lewes: Falmer.

McAuley, B. (1990). *Background materials and curriculum resources to encourage females into the fields of mathematics, science and technology: An annotated bibliography.* Toronto: Ontario Women's Directorate.

McCartney, A. (1991). Female scientists are real people! Introducing girls to science careers. *Women's Education des femmes, 9,* 21–23.

Measor, L. (1983). Gender and the sciences: Pupils' gender-based conceptions of school subjects. In M. Hammersley & A. Hargreaves (Eds.), *Curriculum Practice.* Lewes: Falmer.

Miller, L., & Lieberman, A. (1988). School improvement in the United States: Nuance and numbers. *Qualitative Studies in Education, 1,* 3–19.

Morrell, C. (1991). Uncommon knowledge: Women in science and women's studies at the University of Saskatchewan. In T. Wotherspoon (Ed.), *Hitting the books: The politics of educational retrenchment* (pp. 169–188). Toronto: Garamond.

Nevitte, N., Gibbons, R., & Codding, P. W. (1988). The career goals of female science students in Canada. *Canadian Journal of Higher Education, 18,* 31–48.

Oakes, J. (1990). Opportunities, achievement, and choice: Women and minority students in science and mathematics. In C. B. Cazden (Ed.), *Review of Research in Education: Vol. 16* (pp. 153–222). Washington, DC: American Educational Research Association.

Olson, J., & Pothaar, D. (1988). *Schools, computers, and learning projects: Integrating computers in the junior division curriculum* (Interim Report from the Kingston Regional Pilot Test Centre, No. 2). Toronto: Ontario Ministry of Education.

Orpwood, G. W. F., & Souque, J.-P. (Undated). *Science education in Canadian schools: Summary of background study* (No. 52). Ottawa: Science Council of Canada.

Pratt, J. (1985). The attitudes of teachers. In J. Whyte, R. Deem, L. Kant, & M. Cruickshank (Eds.), *Girl-friendly schooling* (pp. 24–35). London: Methuen.

Rhodes, S. (1991). Design and information technology in the elementary classroom. *Women's Education des femmes, 9,* 43–45.

Richards, J. R. (1980). *The sceptical feminist.* London: Routledge & Kegan Paul.

Riddell, S. (1992). *Gender and the politics of curriculum.* London: Routledge.

Robertson, H.-J. (1988). *The idea book: A resource for improving the participation and success of female students in math, science and technology.* Ottawa: Canadian Teachers' Federation.

Rosser, S. (1990). *Female-friendly science.* Elmsford, NY: Pergamon.

Sadker, M., Sadker, D., & Klein, S. (1991). The issue of gender in elementary and secondary education. In G. Grant (Ed.), *Review of Research in Education: Vol. 17* (pp. 269–234). Washington, DC: American Educational Research Association.

Sanders, J. S., & Stone, A. (1986). *The neuter computer: Computers for girls and boys.* New York: Neal-Schuman.

Scardamalia, M., Bereiter, C., Brett, C., Burtis, J., Calhoun, C., & Smith-Lea, N. (1992). Educational applications of a networked communal database. *Interaction Learning Environments, 2,* 45–71.

Schoeneberger, M. (1984). Teaching science at Seaward Elementary School. In J. Olson & T. Russell (Eds.), *Science education in Canadian schools: Vol. 3. Case studies of science teaching* (pp. 30–64). Ottawa: Science Council of Canada.

Science Council of Canada. (1982). *Who turns the wheel?* Ottawa: Science Council of Canada.

Science Council of Canada. (1984). *Science for every student: Educating Canadians for tomorrow's world.* Ottawa: Canadian Government Publishing Centre.

Scott, J. (1990). Disadvantagement of women by the ordinary processes of science. In M. Ainley (Ed.), *Despite the odds: Essays on Canadian women and science.* Montreal: Véhicule Press.

Silvern, S. B., Williamson, P. A., & Countermine, T. M. (1988). Young children's interaction with a microcomputer. *Early Child Development and Care, 32,* 23–35.

Spear, M. (1985). Teachers' attitudes towards girls and technology. In J. Whyte, R. Deem, L. Kant, & M. Cruickshank (Eds.), *Girl-friendly schooling* (pp. 36–44). London: Methuen.

Stage, E. K., Krainberg, N., Eccles, J., & Becker, J. R. (1984). Increasing the participation and achievement of girls and women in math, science and engineering. In S. Klein (Ed.), *Handbook for achieving sex equality through education* (pp. 237–268). Baltimore: Johns Hopkins University Press.

Statistics Canada. (1989). *Science and technology indicators 1988* (Catalogue 88-201). Ottawa: Minister of Supply and Services.

Statistics Canada. (1990). *Education in Canada: A statistical review for 1988–89* (Catalogue 81-229). Ottawa: Minister of Supply and Services.

Steinkamp, M., & Maehr, M. (1984). Gender differences in motivational orientations toward achievement in school science: A qualitative synthesis. *American Educational Research Journal, 21,* 39–59.

Szpitun, L. (1991). Women do math and Ms infinity. *Women's Education des femmes, 9,* 35–38.

Tamir, P. (1988). Gender differences in high school science in Israel. *British Educational Research Journal, 14,* 127–140.

Taylorson, D. (1984). The professional socialization, integration and identity of women PhD candidates. In S. Acker & D. Warren-Piper (Eds.), *Is higher education fair to women?* (pp. 143–162). Guildford: Society for Research into Higher Education.

Thomas, K. (1990). *Gender and subject in higher education.* Milton Keynes: Open University Press.

Vickers, M. (1990). Summer science for girls. *Women's Education des femmes, 9,* 51–52.

Walkerdine, V. (1989). *Counting girls out.* London: Virago.

Weiler, K. (1988). *Women teaching for change: Gender, class and power.* South Hadley, MA: Bergin & Garvey.

Weinschank, A., Trumbull, E., & Daly, P. (1983). The role of the teacher in school change. In L. Shulman & G. Sykes (Eds.), *Handbook of teaching and policy* (pp. 300–314). New York: Longman.

Whyte, J. (1985). Girl-friendly science and the girl-friendly school. In J. Whyte, R. Deem, L. Kant, & M. Cruickshank (Eds.), *Girl-friendly schooling* (pp. 77–92). London: Methuen.

Whyte, J. (1986). *Girls into science and technology: The story of a project.* London: Routledge & Kegan Paul.

Wiggan, J. (1986). Local initiatives to effect change. In D. Ellis (Ed.), *Math 4 girls.* Toronto: Ontario Educational Research Council.

Women in Science, Hopefully. (Undated). *Strategies: Intervention techniques to retain women in mathematics and science studies.* Downsview, ON: York University Office of Admissions/Liaison.

Wotherspoon, T. (1991). Educational reorganization and retrenchment. In T. Wotherspoon (Ed.), *Hitting the books* (pp. 15–34). Toronto: Garamond.

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