THE EQUATION

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Ces cinq dernières années, différentes études ont été publiées sur les aptitudes et la réussite des femmes en mathématiques, en science et en technologie. Ces études montrent que les filles choisissent de ne pas se diriger vers les domaines scientifiques, et qu'il y a une disproportion très nette entre le pourcentage des femmes inscrites dans les programmes d'études supérieures scientifiques, et leurs aptitudes. C'est pourquoi le monde de la science est encore un monde masculin. Cette situation n'est cependant pas inéluctable: l'auteure recommande certaines stratégies pour encourager la participation féminine en mathématiques, en science et en technologie.

Through the early spring bleakness of northern Europe, a low cream-coloured Lancia streaks at perilous speed en route from Sweden to England. The driver is a beautiful woman with large, deep-blue eyes, delicately fair skin, and shoulder-length black hair showing a few traces of silver. On the seat beside her, set casually in a disarray of scarf, sunglasses, topcoat, handbag, chocolate, and a jar of yogurt, is an unexceptional-looking carton containing carefully packed, highly virulent research organisms. She negotiates successive border crossings without incident or delay as she responds to officers' questions with widened sparkling eyes, whimsical comments, and irresistible charm. On reaching London, the car goes directly to a research laboratory, and she commits the harmless-looking carton to the care of research scientists, with directions for its use.

The woman is a scientist whose distinction is recognized throughout the scientific world. Born in the United States, she earned a Ph.D. in biochemistry there and proceeded to Cambridge where she earned another Ph.D., in microbiology. She directs research projects in England and Sweden and travels throughout the world in response to invitations to lecture.

This woman is one of the very few women who have achieved distinction in science. In Canada, the percentage of women candidates for doctoral degrees in mathematics, physical sciences, and engineering is miniscule. In the United States only 10 per cent of doctoral degrees in mathematics are earned by women; the percentages for physical sciences are only slightly higher. Percentages of women in advanced study of science throughout the world show similar limited participation.

Several compendia of research related to ability and achievement of women in mathematics, science, and technology have been published in the last five years. Among the conclusions reached in these surveys are that gender differences in mathematical ability and achievement increase with age from preschool to adolescence; significantly fewer girls than boys choose mathematics and science options in senior-secondary school; and average and median marks for girls who do elect these options are higher than those for boys at this level. This higher rate of success for girls is attributed to the tendencies for boys to take these courses and for only the ablest girls to do so. In universities, the majority of girls in science are in biology, often preparatory to nursing or medicine; significantly fewer study mathematics, the physical sciences, or engineering.

The world of science is still a man's world. It remains so, not because women are trying but failing to become part of it, but because girls are abandoning science in secondary school. There are several theories about why girls tend not to choose courses in science and mathematics: girls have less innate potential than boys for achievement in science and mathematics; society does not expect or encourage girls to achieve as well as boys in these subjects; science is presented in schools in ways more suited to boys than girls; girls have less favourable attitudes toward science than boys. More succinctly, girls don't do science and mathematics because they can't; because they aren't allowed to; or because they don't want to.

The explanation that girls are not allowed to pursue science and mathematics is argued by those who interpret the situation in political terms. They postulate that higher education, particularly in science and mathematics, leads to positions of privilege and power and traditionally is the preserve of middle and upper-class white males. This argument is made explicitly in "Science Education: Did She Drop Out or Was She Pushed?" and is implicit throughout the book, *Alice through the Microscope* (London: Virago, 1980), in which the article appears.

The other hypotheses are, in essence, "nature-nurture" controversies, inextricably related and impossible to resolve. When it is society's belief that boys are good at mathematics, science, and technology, while girls are not, and should not be, girls have good reason for not choosing the "masculine" subjects.

In earlier societies, the task of conditioning children for their gender roles was accomplished by family and church. In our society, the teaching of family and church is reinforced by many other powerful persuaders, not the least of which are the reported findings of psychological and sociological research to determine and define sex differences. A range of character traits and behaviours are deemed to be "masculine," and those traits and behaviours thought of as opposite are assumed to be "feminine." Qualities and behaviours that society values, such as ability in science and mathematics, are identified as masculine; those that society undervalues or scorns are feminine. These unacknowledged assumptions underlie and shape research done to investigate and identify sex differences. One rarely hears of research that focusses on similarities between the sexes. Just as social and sexual attitudes of nineteenth-century middle-class Viennese society influenced Freud's theories of human sexuality, so, too, much of the psychological research to determine sex differences is contaminated by assumptions on the part of the researchers. Thus it has been guilty of male bias in the selection of variables, in the methods used, and in the interpretations of its results; and it has had the effect of reinforcing sex stereotyping.

Girls, then, are persuaded that they do not have the ability to achieve excellence in mathematics and science and that to pursue these areas of interest will raise doubts about their feminine identity. Sexual identity is the paramount preoccupation and psychological task of adolescence, that period when high-school course selections are made. It is also the period when girls' performance on tests of mathematical achievement and disposition toward mathematics show a decline.

During the past ten years, the concept of innate polar differences between the sexes has lost ground to concepts that virtually every sex difference, other

DOESN'T BALANCE

Photo: Ontario Women's Directorate Resource Centre

than anatomical or physiological, is attributable to conditioning and socialization and that intrasex group differences are significantly greater than intersex group differences. However, the question of whether girls' ability to do science and mathematics is equal to boys' ability continues to be debated, and most investigations of this question focus on spatial ability. Some studies find girls showing superiority or parity on tests of spatial ability; others find boys showing superiority. It has not yet been proven, however, that spatial ability is the only, or even the most significant, factor in a predisposition to achievement in mathematics and science.

The lack of consensus on the question of sex differences in ability to do science and mathematics is clearly demonstrated in two issues of *Science* magazine. The December, 1980, issue published conclusions drawn from the Study of Mathematically Precocious Youth that tested almost ten thousand mathematically gifted boys and girls over a period of eight years and concluded that sex differences in mathematics result from superior male ability in spatial tasks and that this superiority is probably attributable both to heredity (endogeneous) and to environment (exogenous). In the April, 1981, issue, somewhat acerbic correspondence from distinguished scholars of various disciplines in prestigious universities in the United States and the United Kingdom takes issue with every point.

Whether this controversy is settled tomorrow or is carried on forever is of little consequence to the current generation of girls. The damage has been done. These views received wide publicity in academic circles and, in oversimplified form, in news media. The stereotyping is thus reinforced, and girls continue to be affected by the same negative forces they have always been subjected to. Girls gifted in mathematics and science will suffer gradual diminution of their potential and erosion of their confidence, their resolve, and their dreams of outstanding achievement in scientific research or theoretical mathematics.

Studies have shown what happens to girls in many mathematics classrooms. Teachers expecting sex-related differences in achievement treat boys and girls differently. High-achieving boys receive significantly more attention than equally high-achieving girls and other boys and girls. There is an observable pattern: teachers expect differences between male and female students; they treat boys and girls on the basis of these expectations; and students respond accordingly. A further negative influence is exerted by parents who also tend to have lower expectations for their daughters than for their sons.

However much research is done to determine sex differences in ability in mathematics and science, it will not alter the fact that there are girls with sufficiently high degrees of ability to pursue successful careers in mathematics, science, and technology. Even girls with limited ability require some education in mathematics and science to function successfully and responsibly in their daily lives. That girls gifted in science and mathematics have the opportunity to develop their potential is vital not only to these girls but also to society as a whole. Science and technology, dominated by men and governed by attitudes and values traditionally identified as "masculine," are directed by commercial, industrial, and military interests. Funds made available for medical, social, and environmental research are small compared to what is spent on research that has commercial, industrial, and military applications. With an increased proportion of women in prestigious and influential positions in science and technology, attitudes and values traditionally identified as "feminine" – nurturing rather than aggressive or combative, co-operative rather than competitive – would direct research more toward human benefit.

How, then, can girls be encouraged and helped to develop their abilities in mathematics and science? Clearly, the perception of mathematics and science as masculine domains and of scientists as men or "unfeminine" women must be changed. To these ends, women's groups have organized "media watch" committees to protest whatever reinforces sex-role stereotyping, and education committees to bring women scientists into the school for "Career Day" presentations. Professional groups such as Women in Science and Engineering and the Science and Education Committee of the Science Council of Canada are providing career information to girls and examining how mathematics and science are presented in schools.

Research suggests that interest in science and mathematics should be stimulated and developed in early elementary school and that senior-elementary curricula should emphasize stimulating and practical science activities. More science and mathematics graduates should be encouraged to enter elementary-school teaching. Specialists from secondary-school panels might be given responsibility for some of the science curriculum in elementary classes. Secondary-school science and mathematics students could develop units of study and present them to elementary classes. Senior-elementary students, boys and girls, could be challenged to make presentations involving science and mathematics to younger elementary students. In these ways, interest in mathematics and science would be stimulated, the acceptability of these subjects as appropriate areas of interest for both boys and girls established, and girls' confidence in their abilities strengthened sufficiently to withstand the cultural forces that assail them so relentlessly just before and during adolescence.

For many students, educational aspirations are defined, with considerable influence from parents, during the transition from elementary to secondary school; and secondary-school course selections are made on the basis of the

student's highest educational goal, high-school graduation, a college diploma, or a university degree. Intervention at this junction is critical, particularly for economically and culturally disadvantaged students. Therefore, career-counselling presentations for students and their parents featuring information about careers in mathematics, science, and technology, and stressing the appropriateness of these careers for girls as well as boys could be effective, particularly in conjunction with information about financial assistance available for post-secondary education.

During high school, career workshops and role-clarification groups should be available for senior girls to provide images and models of women who successfully combine marriage and career and of women who have not had to produce offspring to be "fulfilled." Also recommended is increased collaboration between universities and secondary schools to facilitate pre-college summer programs such as those for gifted high-school students offered by several American universities. Such transitional programs would help reduce the number of academically gifted females who abandon formal education upon graduation from high school.

Though it may appear contradictory, one way of compensating for disadvantages suffered through sexist attitudes and practices is to provide "girls-only" classes in mathematics and science. Girls are more comfortable, creative, and productive in science and mathematics classes where they are free from comparison and competition with boys. Studies in Britain show greater participation in science and mathematics among students in all-girl schools. A project carried out at the University of Missouri-Kansas City providing a first-year university mathematics program for women produced positive results. The all-female experimental section covered more material more thoroughly than the regular sections; students helped and encouraged one another; students and instructors alike enjoyed the classes and formed strong commitments to the group and its achievements; and there was a much higher enrolment of women from this class than of women from non-experimental sections for subsequent mathematics courses. Similar separate sections or courses for girls at the grade-nine and grade-eleven levels would result in higher enrolment in senior-secondary mathematics and science courses, in subsequent greater participation of women in advanced study in mathematics and science, and in wider recognition not only that girls can "do" science and mathematics, but that their involvement in these fields is appropriate, desirable, and in the best interests of society.

The highly publicized study, the conclusions of which appeared in *Science* in 1980, produced data showing that 43 per cent of the top 3 per cent of students tested for mathematical achievement were girls. This point was not made in the report of the study, and certainly was not publicized in the popular media, nor was the implication, that there are a great many girls gifted with mathematical ability, explored. This ignoring of findings encouraging to girls is typical of research in sex differences. Rather than trying to determine, identify, quantify, and explain sex differences, researchers should address more vital questions. Why is the sex difference in achievement in scientific fields so large, when sex differences in intellectual ability are so small? What must be done to help girls and women toward achievement commensurate with their abilities?

The brilliant woman sketched at the beginning of this article is unique in her gifts, interests, and style; and her uniqueness is cause for rejoicing; but her ability is not unique, nor should her level of achievement be so rare.

Further Reading:

Camilla Persson Benbow and Julian C. Stanley. "Sex Differences in Mathematical Ability: Fact or Artifact?" *Science*, 1980, 210, 1262-1264.

Lynn H. Fox, Linda Brody and Dianne Tobin, eds. *Women and the Mathematical Mystique*. Baltimore: The Johns Hopkins University Press, 1980.

A. Kelly. *Girls and Science: An International Study of Sex Differences in School Science Achievement*. Stockholm: Almquist & Wiksell International, 1978.

Science Council of Canada, *Who Turns the Wheel?* Proceedings of a Workshop on the Science Education of Women in Canada. Ottawa, 1982.

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