PATTERNS OF WOMEN'S ENROLMENT IN UNIVERSITY MATHEMATICS, ENGINEERING AND COMPUTER SCIENCE IN CANADA, 1972-1995

by

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A thesis submitted in conformity with the requirements for the degree of Doctor of Education
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Abstract

Gender imbalance in the fields of mathematics, science, and technology is an issue of educational equity. It raises the disturbing possibility that the education system functions in ways which discourage women from pursuing mathematical and scientific careers. If true, this situation is not only unethical, but it also closes an expanding job market to women and, hence, limits their career choices. This thesis examined female enrolment in mathematics in Canadian universities by level of study and registration status, in an attempt to present factual characterization of the situation as a first step to furthering our understanding of the deterrents women face in what is traditionally perceived as a male subject. Women's current representation, as well as the extent of change in this representation over the study period, were compared with (i) men's enrolment in mathematics, and (ii) women's enrolment in all programs during the same time period. Trends in women's

enrolment in mathematics programs at each of the three levels of study and their progress through the education pipeline were contrasted with those in computer science and engineering programs.

A factual characterisation of women's enrolment in the three fields is presented. Findings indicate that patterns of women's enrolment in these three disciplines are vastly different, a fact which suggests that factors specific to each discipline interact with and modify the effects of the more general sociological and psychological obstacles impeding women's participation in these disciplines.

In the first chapter of this thesis, the objectives and the significance of this study are discussed. Chapter 2 offers a review of the relevant literature with the objective of furnishing a background for this study. In chapter 3, levels and trends of women's enrolment in all university programs, their enrolment in mathematics programs, and their progress through levels of study are investigated. In chapter 4, levels and trends of women's enrolment in computer science and engineering programs and their progress through levels of study are examined and contrasted with those in mathematics. Chapter 5 contains a discussion of barriers to women's participation in mathematics, engineering and computer science in light of the findings presented in chapters 3 and 4. This chapter also offers some recommendations and directions for future research.

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Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

1.1. Historical Backdrop

In 1982, the Science Council of Canada published "The Science Education of Women in Canada: A statement of concern," indicating the federal government's recognition of the serious under-representation of girls in high school science and mathematics classes. The statement cited some alarming statistics presented at a workshop sponsored by the Council. For example, in 1979, the number of high school girls studying senior mathematics in Ontario was 63% of that of the boys, and only 11% of grade 13 girls were studying physics. Reasons for concern included not only the impact of lack of knowledge in mathematics and science on the lives and careers of women, but also its impact on the economic welfare of the country as a whole. The report maintained that the absence of girls from high school mathematics and science courses leads to the under-representation of women in professional jobs, and that women who lack technical and scientific skills face a high risk of unemployment. The report stated also that there exists a shortage in skilled personnel needed to develop innovative and competitive industries, and that women form the largest under-utilized source of personnel for this labour market.

Gender imbalance in the fields of mathematics, science, and technology is also an issue of educational equity. It raises the disturbing possibility that the education system functions in ways which discourage women from pursuing mathematical and scientific careers. If true, this situation is not only unethical, but it also closes an expanding job market to women and, hence, limits their career choices. Education, especially in the fields of science and technology, leads to occupations of influence in our society. Those students excluded from the study of mathematics and science are effectively excluded from the occupations which influence social and economic change.

In 1994, twelve years after the publication of the Science Council's "Statement of Concern," women remained very much a minority among professionals employed in the natural sciences, engineering, and mathematics. In fact, just 19% of professionals in these occupations in 1994 were women, a figure which has changed little since 1982 (15%) (Statistics Canada. 1995b). In addition, it is unlikely that female representation in these occupations will increase in the near future, because women continue to account for relatively small proportions of total university enrolments in these fields.

1.2. Objectives of the Study

General objective

The aim of this thesis is to examine female participation in mathematics programs, at the bachelor, masters and doctoral levels in Canadian universities, in an attempt to present factual characterization of the situation as a first step to furthering our understanding of the deterrents women face in what is traditionally perceived as a male subject. Women's current representation in full- and part-time enrolment, as well as the extent of change in this representation over the study period, are examined and compared with

(i) men's enrolment in mathematics during the same time period, and

(ii) women's enrolment in all programs during the same time period.

Attempts are made to isolate discipline specific changes and gender specific changes from more general demographic and social trends. Women's presence in mathematics, at the bachelor, masters and doctoral levels, are contrasted with their presence in two other fields, which have also been viewed as non-traditional for women: computer science and engineering. Trends in women's enrolments in mathematics programs at each of the three levels of study are also contrasted with the trends in their enrolments in computer science and engineering programs. The flow of students through the education pipeline in each of the three disciplines is investigated with the objective of locating road blocks hindering women's progress.

Specific objectives

This work attempts to answer the following questions:

1. Does the increase in women's presence in university programs indicate a change in women's tendency to enrol in university education, or is it merely part of the more general shift in men's and women's tendency towards acquiring more education? In other words, is the increase in women's presence on university campuses over the study period gender specific?

2. What are the dimensions of the gender imbalance in enrolment in mathematics programs at the bachelor, masters, and doctoral levels? Have there been any changes in these dimensions over the study period?
3. To what extent do the above changes reflect shifts in women's tendency to major in mathematics, general shifts in both men's and women's tendency to major in mathematics, or the more general shifts towards acquiring a university education?
4. To what extent have women contributed to the expansion in the number of students studying on a part-time basis, in all programs and specifically in mathematics programs?
5. Are women in mathematics advancing to graduate levels at the same rate as men? At the same rate as women in other disciplines?
6. How does the representation of women in mathematics compare to their representation in computer science and in engineering at each of the three levels of study?
7. Have the gender gaps in these disciplines been closing over the period of study? At the same rate or at different rates?
8. How does the advancement of women through the education pipeline in mathematics differ from that in computer science and engineering? In other words, where, in the education pipeline, are the road blocks hindering women's advancement through the system?
9. To what degree do the above findings support the explanations and/or

justifications given in the literature for women's under-representation in these fields?

1.3. Significance of the Study

Efforts to ensure equity for women in learning environments at all levels must precede, or at least accompany, efforts to persuade them to pursue mathematical and scientific careers. To achieve gender equity in mathematics and related fields, obstacles deterring women from participating in these fields must be removed. Factual characterization of the magnitude of the gender gap in mathematics, of the change, if any, in this magnitude over time, and of the differences and similarities between the participation of women in mathematics programs and their participation in other mathematics related disciplines (in this thesis, engineering and computer sciences) is an essential first step toward understanding and appraising the reasons behind the paucity of women in these fields.

Studies on gender participation at the university level have traditionally contrasted the proportion of women in the combined fields of mathematics and sciences with their proportion in humanities and the social sciences. But the extent of the gender imbalance is not uniform across mathematical and scientific disciplines. These disciplines also vary in their curricula and the type of occupations to which they lead. For example, mathematics study may lead to a teaching career, which has traditionally been appealing to women, while a career in engineering may have a masculine connotation, which makes it less appealing. Hence, causes of the low participation of women in these disciplines might also vary. Examination of women's enrolment rates in mathematics, engineering and computer sciences separately will describe the gender imbalance in each of these disciplines. It may also help disentangle the causes of the imbalance specific to each discipline.

Since the publication of the Science Council's "Statement of Concern" in 1982, government agencies, professional associations, school boards, and post secondary institutions have launched intervention projects designed to increase young women's interests in mathematics and science, to encourage them to take mathematics and science courses, and to convince them to seek careers in these fields. The assumption that lack of mathematical knowledge is the reason for women's absence from professional and scientific jobs was used as the basis for most intervention programs across all provinces. Such programs range from career conferences which provide information regarding occupational opportunities to radical programs such as segregated mathematics classes. Little effort has been made to evaluate the effectiveness of these projects, and to assess their outcomes. Monitoring the change in women's presence in mathematics programs over a period of 23 years and contrasting this change with the changes in their presence in engineering and computer science will give an accurate picture of the progress to date, hence contribute to the evaluation of these intervention efforts.

The gender gap in mathematics participation increases at each higher level of educational achievement. This inevitably produces an unbalanced pool of qualified candidates for future faculty positions. Analysis of women's progress through the education levels in mathematics, and contrasting it with their progress in computer science and in engineering will enable us to determine at which education level women's progress is impeded in each of these three fields. Knowing where in the education pipeline these barriers might lie is a primary step on the road to removing them.

The study of past trends in enrolment provides a basis for future projections of university enrolment and of labour force supply of specific professions. These projections are used by labour market analysts and planners. They also provide educational policy makers with information that can be used in allocating resources to various sectors of the education system.

The premises of this thesis are that there is no known physical or intellectual barrier to the participation of women in mathematics, science and technology, that there should be equity for females and males in mathematics education and related professional experiences, and that increasing women's participation in these fields is desirable both for women and for society.

1.4. Data and Methods

Data collected by Statistics Canada on university enrolment at the bachelor, masters and doctoral levels, broken down by registration status, gender, field of study and province, for the years 1972/73 to 1994/95, were analysed for this thesis. The year 1972/73 was the first year in which Statistics Canada collected university enrolment data with a breakdown by gender. As defined by Statistics Canada, mathematics programs include pure and applied mathematics, statistics, and actuarial science programs. Engineering programs include chemical, civil, electrical, mechanical, and other engineering. Research for this dissertation began with the acquisition of electronic data files from Statistics Canada which contained raw enrolment figures, one record for each year, province, level of study, gender, subject of specialization, and registration status. Number of students enrolled then had to be aggregated over provinces and subject of specialization for each year, gender, level of study, and registration status in order to arrive at total university enrolment broken down by these latter variables. To calculate the number of students enrolled in each discipline in a specific year, records of specialization of interest for that year for each gender, level of study, and registration status were selected and aggregated over provinces and specialization. For example, records of enrolment in chemical, civil, mechanical, electrical, and other engineering in all provinces were added to give a total enrolment in engineering programs and this process was repeated for each year, gender, level of study and registration status.

Enrolment rates were inspected separately and in conjunction with the dependency ratio in order to isolate changes in enrolment trends due to shifts in the demographics of the Canadian population from changes in the tendency to enrol in university education. Dependency ratio reflects family size; it is the ratio between the sizes of the student age cohort and their parents' cohort. This ratio was found by Denton and Spencer (1992) to be the most influential predictor of university bachelor enrolment in Ontario during the period 1976 to 1989, the idea of the ratio being that a smaller family means more income and assets available per child to finance post secondary education. Data required for the calculation of the dependency ratio were obtained from Statistics Canada's tables of population estimates by age and sex (Statistics Canada, Catalogue No. 91-537) for the years 1972 to 1994.

Parity index as defined by the National Science Foundation (1984) is the number of students in a specified discipline expressed as a percentage of the number of students in all programs. It is used to isolate discipline specific shifts from general shifts in enrolment. Adjusted participation rate is computed as the ratio of parity index for women to parity index for men and is used to measure women's tendency to major in a specific discipline relative to men's. Parity indices and adjusted participation rates were examined in the current research in an attempt to disentangle discipline specific and gender specific changes from the more general trend of increased enrolments in Canadian universities.

Transition rates from the bachelor to the masters levels, expressed as the ratio of masters to bachelor enrolment, and from the masters to the doctoral levels, expressed as the ratio of doctoral to masters enrolment, were used to investigate the advancement of women through these post secondary education levels in mathematics, and to contrast this with their advancement in computer science and engineering.

Chapter 2 of this thesis offers a review of the relevant literature with the objective of furnishing a background for this study. In chapter 3, levels and trends of women's enrolment in university education in general and in mathematics programs in particular are investigated. Comparisons are made between (1) women and men, and (2) mathematics and all programs, as part of the investigation of both historical trends and current enrolment. Progress of women through levels of study is also examined with an eye to locating road blocks hindering women's progress. In chapter 4, levels and trends of women's enrolment in computer science and engineering programs are studied and contrasted with those in mathematics. Progress of women through levels of study in these two fields is examined and compared to their progress in mathematics and in all fields. Chapter 5 contains a discussion of barriers to women's participation in mathematics, engineering and computer science in light of the findings presented in chapters 3 and 4. This chapter also offers some recommendations and directions for future research.

Chapter 2

Literature Review

2.1. Introduction

The main purpose of this chapter is to review the literature on women's participation in university mathematics education with the objective of providing a context for this study. The organization of this review however, requires some explanation. The under-representation of women in mathematical and scientific fields is a phenomenon that manifests itself in most of the developed countries in spite of the many differences which exist in their social structures and educational systems. A thorough understanding of research findings with regard to women's career and educational choices demands that they be explained and interpreted within the contexts of the social structure and the education system in each individual country. Hence this review of the literature is separated by country. Such separation is important because it allows us to emphasize differences as well as similarities of research findings across cultures. This chapter starts with a general review of the literature, most of which is based on research conducted in the United States, it then gives a snapshot of the situation in several other countries, and ends with a review of Canadian literature; thus ensuring continuity with the remainder of this thesis which focuses on the analysis of Canadian data. A brief overview of the literature on women's participation in the fields of engineering and computer science, especially as it relates to their participation in mathematics, is presented in section 2.4. The last part of this chapter comes from economic and demographic literature, providing a summary of theories proposed by educational economists to explain individuals' educational and career choices.

2.2. General Review

2.2.1. High School

Concern over the absence of women from the scientific and technological work force was voiced in the United States in the early 1970s. In 1973 Lucy Sells, a Berkeley sociologist, reported that among a sample of applicants to the University of California, only 8% of the females had taken 4 years of high school mathematics courses whereas 57% of the males had done so. Without these courses, 92% of female applicants were not eligible for 22 out of the 44 programs offered at that University. Their choice was basically limited to five fields: humanities, social work, guidance and counselling, elementary education and music. Sells stated that high school mathematics courses were the "invisible filter," denying women entry to the sciences and other technology related fields. Inasmuch as mathematical competence is believed to be the key for increasing women's representation in professional occupations, researchers have taken considerable interest in gender differences in mathematics achievement and participation in advanced mathematics courses. The research findings regarding gender differences in achievement have been neither consistent nor definitive, and variations in the samples being tested and the nature of the tasks to be performed make cross-study comparisons difficult (Fennema and Leder, 1990). Some studies suggest that starting in adolescence, boys outperform girls and that these differences persist into adulthood (Maccoby and Jacklin, 1974; Meece, Eccles, Futterman, Goff, and Kaczala, 1982). Other studies point out that boys outperform girls in standardized tests, but when it comes to classroom tests it is girls rather than boys who get the higher grades (Kimball, 1989; Marsh, 1989). In a longitudinal study of a cohort of 7500 students who were tested in grade nine and retested in grade 12 in the early 1960s, it was found that mathematics course enrolment statistically accounted for nearly all the difference in mathematics performance at the end of high school (Wise, 1985).

Recent statistics suggest that the large gender difference in mathematics enrolment at the high school level has disappeared, at least for those interested in attending college or university. For example, the report "College-bound Seniors: 1993 Profile of SAT (Scholastic Aptitude Test) and Achievement Test Takers" published by the College Entrance Examination Board (CEEB) indicated that 51.8% of those who reported studying 4 or more years of secondary school mathematics were female. Recent statistics also indicate that a gender difference of about 0.4 standard deviation in SAT scores remains in spite of the diminished differences in course enrolment (Chipman, 1996). However, in a study conducted to investigate the validity of the SAT exam, Wainer and Steinberg (1992) found that the SAT under-predicted the performance of females relative to males in advanced as well as introductory college courses. In this study, among students in the same mathematics course who receive the same letter grade, females' SAT-M scores were 21 to 55 points lower than males'.

In a review of research results on gender differences in mathematics achievement, Feingold (1988) looked at standardized tests administered in the United States between 1960 and 1983 and found that gender differences have declined over the years surveyed. A thorough meta-analysis of 100 studies published between 1967 and 1987 on gender differences in mathematics achievement was carried out in 1990 by Hyde, Fennema and Lamon. The authors of this study conclude that (1) no gender differences in mathematics achievement are evident prior to secondary school, and (2) gender differences at the secondary school level have declined in recent years. Similar conclusions were arrived at by Linn and Hyde (1989) who used meta analysis and process analysis to summarize trends in cognitive and psychosocial gender differences. These researchers concluded that (1) gender differences in cognitive and psychosocial tasks are small and declining, (2) these differences are specific to cultural and situational contexts, and (3) gender differences in cognitive processes often reflect differences in course enrolment and training.

In 1977, the United States National Institute of Education initiated a special research grants program on women and mathematics (NIE, 1977). Findings of the NIE research projects and of other large scale studies challenged the key assumption underlying almost all of the research efforts during that period, that is, women's lower enrolment in high school mathematics courses is the reason for their absence from mathematics-related jobs. The number of women well-prepared in mathematics was found to exceed the number of women actually entering mathematics-related careers. This finding suggests that the problem of women's absence from these careers is more complex than just being the outcome of mathematics avoidance, and that the decision to enter such careers may precede and partially determine the decision to enrol in mathematics courses (Chipman, and Thomas, 1985).

Cross-cultural comparisons of mathematics achievement consistently indicate small differences within cultures and large differences across cultures (Kimball, 1995). Hanna, Kundiger and Larouche (1990) used data collected in the Second International Study of Mathematics on grade 12 students from 15 countries and found a significant country by sex interaction. In this study, the only trait that appeared to distinguish the countries with no gender differences from others was parental support for mathematics.

Other research initiatives focused on factors such as curriculum, teaching methods, and educational environment in relation to female participation in mathematics related courses (Fennema, 1977, 1985; Leder, 1982,1986). This research has also considered the effects of socio-cultural and educational factors, such as the impact of teachers' attitudes on student learning of mathematics (Becker, 1981; Walden and Walkerdine, 1985). For example, Kimball (1989) reported that girls tend to have fewer interactions with mathematics teachers than boys do. It is not clear, however, how this relates to girls' higher performance on classroom tests. The decision by some females to avoid mathematics courses in senior high school was found to be related to a lack of awareness of the need for and usefulness of mathematics in career choices (Lantz and Smith, 1981; Pedro, Wolleat, Fennema and Becker, 1981). Other factors found to contribute to mathematics avoidance in high school are gender role stereotyping, the perception that mathematics is a male domain, and inappropriate teaching methods (Fennema, 1977). In a meta-analysis of gender differences in attitudes, Janet Hyde and her colleagues (Hyde, Fennema, Ryan, Frost and Hopp, 1990) found that the average gender difference on the scale for mathematics as a male domain to be larger than any other attitude scale and much larger than the difference in mathematics achievement.

Psychological processes such as attributional patterns and lack of confidence in themselves as learners of mathematics are also suggested as possible inhibitors of female achievement. In a review of the literature on gender attributional patterns in relation to mathematics achievement, Leder (1992) states that when differences are found, females are more likely than males to attribute success to effort and failure to lack of ability, and that attribution of failure to lack of ability is unlikely to yield a belief in a high likelihood of a future success. Stipek and Gralinski (1991) also found that elementary and junior high school girls were less confident than boys that they would do well on a mathematics test they were about to take; in spite of the fact that their grades were similar, 43% of the girls and 34% of the boys rated their performance as poor. No significant gender differences in performance in mathematics were found by Marsh (1989) despite significant differences in the reported attitudes toward mathematics for his sample of high school students.

A concept which is closely related to students' attitude toward the study of mathematics is their interest in mathematics. Interest is a construct which involves links between the affective and cognitive domains. The most widely quoted definition of interest is the one given by Dewey (1913) as ".. the accompaniment of the identification, through action, of the self with some object or idea, because of the necessity of that object or idea for the maintenance of a self-initiated activity" (p. 14). In a paper published in 1990, Hidi shows that interest has profound effects on cognitive functioning and the facilitation of learning. Typical characteristics of interest include increased attention, greater concentration, pleasant feelings of applied effort, and increased willingness to learn. Rather than treating interest as general construct, Schiefele (1991) proposed that interest is a content-specific concept, relating to specific topics, tasks, or activities. As such, content-specific interest should be more responsive to changes in classroom and instructional factors than are general motives. Hidi and Baird (1988) distinguish between personal interest that students bring to the classroom and situational interest that they acquire in the classroom. It is this situational interest which researchers are trying to trigger, capture and hold. Research done in the area of interest and mathematics is based on the conviction that students' interest in learning mathematics is important, that mathematics curricula and teaching strategies should stimulate and expand students' interests, and that the situational interest triggered by environmental factors, may evoke or contribute to the development of long-lasting individual interests (Hidi, 1990). Enrolment data are frequently used as proxy measure of the relative levels of interest in various subjects. Lawton and Bordens (1995) examined gender differences in interests in science from kindergarten through to year 12 by analysing the content of more than one thousand projects entered in a regional science and engineering fair in Indiana over a 3-year period. Girls were more likely than boys to submit biology projects but less likely to submit physics projects. The gender difference in the choice of topic was small in the early childhood years and large at senior high school level. A second study, based on interviews with participants, ruled out the possibility of parental discrimination in topic selection. Research on a large sample of junior secondary students in Norway (Sjoberg, 1990) indicated boys' preference for mechanical topics and girls' preference for biological ones. Sjoberg also reported that: "... differences showed up also in the kind of context implied in the description of the subject matter. In general, girls were interested when the subject matter was placed in a context related to daily life or society. Relevance was very important for girls" (p. 5).

Explanations offered for the gender differences in science and technology interests vary between the notion that gender identity is formed in infancy at a deep psychological level (Harding and Sutoris, 1987) and the notion that gender roles are socially constructed and are influenced by political and economic agendas (Alloway, 1995).

2.2.2. University

As for the University undergraduate level, research done in the United States indicates that women have been well represented in mathematics for the past four decades (Chipman and Thomas, 1985). This fact represents another challenge to the assumption that mathematics avoidance is responsible for women's low participation in mathematics-related fields such as engineering and physical sciences. It is, in fact, a challenge to the assumption of mathematics avoidance itself. For example, in 1991 women received 54.1% of all bachelor degrees awarded, and 47.2% of bachelor degrees awarded in mathematics. In 1950, women received 24% of all bachelor degrees awarded, and a proportionate 22.6% of bachelor degrees awarded in mathematics (Chipman, 1996).

With the gender gaps in mathematics enrolment and mathematics achievement at the high school level almost closed, and with the near absence of gender imbalance in undergraduate mathematics enrolment and graduation, the remaining discrepancy seems to be at the graduate level. Statistics show that in 1990 in the United States, women received 53% of all masters degrees awarded but only 40% of masters degrees in mathematics. In the same year, women received 36% of all doctorate degrees but only 18% of mathematics doctorates (Chipman, 1996).

Several explanations of the gender imbalance at the graduate level have been proposed. Chipman (1996) suggests that lower employment expectations, lack of female role models, having different career intentions, and/or less academic standing are possible reasons for women's low participation in graduate mathematics programs. Uncertainty about the length of time required to complete a dissertation, especially in the field of mathematics, lack of role models, and differential financial support constitute other factors discouraging women from pursuing graduate studies (Gray, 1995). Gray (1995) suggested that lack of support and discrimination practices sway women to drop out of the field even after they are hired.

Studies about feelings toward mathematics have consistently found that although female students like mathematics as well as males do, they have less confidence in themselves as learners of mathematics (Chipman and Wilson, 1985; Hyde, Fennema, Ryan, Frost, and Hopp, 1990). Chipman, Krantz, and Silver (1992, 1993) studied the influence of mathematics anxiety/confidence on career interests and major selections of the select population of Barnard College students (mean QSAT about 600). The authors report that QSAT score had no effect on expressed interest in a scientific career at the time of college entrance, whereas mathematics anxiety/confidence did have a significant effect. The same picture held true for biological science majors at the end of college. For actual physical science majors at the end of college, both QSAT and mathematics anxiety/confidence showed significant effect on the choice of major. Zappert and Stansbury (1984) report on results of a survey of graduate students in science, engineering, and medicine at Stanford University, where 9% of the students were in mathematics programs. These authors report that men and women face different obstacles and pressures in their graduate careers, and that despite similar academic backgrounds, women felt less competent and less confident about their abilities. Also, Luchins (1979) reports that women who had received doctoral degrees in mathematics thought that their theses were not worthy of publication even when others, including their supervisors, thought they were. Women were also found to be more dependent on support features of the academic environment, particularly relations with the advisor.

In a study done at the University of Michigan (Manis, Thomas, Sloat and Davis, 1989), "personal enjoyment and interest" received the highest rating in a list of factors regarded as important by students of both sexes in their choice of subject specialization; 89% rated this as 4 or 5 on a 5-point scale of importance and 43% identified it as the single most important factor. Parent encouragement, identification with a role model, having a close relationship with a father or a brother who had encouraged their interest in mathematics and science are among the factors which were repeatedly mentioned in men's and women's biographical accounts which were collected by Schofield and Parnaby (1986) and used in drawing insights into factors which influenced their choice of sciences or humanities subjects.

2.3. The Situation in Other Countries

Concern over the under-representation of women in scientific and technological fields has been voiced throughout most of the developed countries for over two decades. Since each country has its own social structure and education system which vary in many ways from those in other countries, a full understanding of gender differences in education and the work force demands that research findings be explained and interpreted within the context of that individual society. This section offers a general outline of available literature on the situation in some other countries, the purpose of which is to draw on some common themes with regard to women's presence in mathematical and scientific fields.

Australia. There are considerable differences in high school mathematics curriculum and assessment among various states in Australia. There is also considerable variation among states in women's participation rates and in the level of mathematics studied (Gaffney and Gill, 1996). Nonetheless, men tend to enrol in advanced mathematics courses about twice as frequently as women do in all states except the Australian Capital Territory. Such advanced courses are required for the study of higher mathematics at university, engineering, and science. Men also outnumber women in intermediate level mathematics courses in most states. Such courses lead to a wide range of university programs such as medicine, architecture, and journalism.

At the university level, women constituted 53.4% of the student population in Australia in 1993. However, their distribution across disciplines is far from even as they dominate areas such as education, health, and the arts and are under-represented in science, engineering and architecture. In 1990, women's share of enrolment in science (including mathematics) undergraduate programs was 40% and in engineering 10% (Gaffney and Gill, 1996). The authors also noted that in every field, the representation of women was significantly lower at the postgraduate level.

In faculty positions in 1993, 32.6% of all academic staff in Australian universities were women. However, most of these women held lecturer positions as the percentage of women in positions above senior lecturer was only 15.4%. Women are also over represented in non tenurable and part-time positions (Gaffney and Gill, 1996). These authors stated that the low participation of women in science, engineering, and technology is seen by the government as an equity issue. Consequently, legislation concerning sex discrimination, affirmative action, and equal opportunities were passed and that all publicly funded universities are required to adhere to them.

United Kingdom. In 1988, the General Certificate of Secondary Education (GCSE) was introduced for children at age 16. In mathematics at GCSE, students are entered for one of three tiers with restricted grade ranges: higher tier (grades A-D), intermediate tier (grades C-F), and foundation tier (grades E-G). A grade of A to C is needed for entry into a wide range of university programs (Smart, 1996). In England and Wales, in 1992, only 35% of A-level entries for mathematics were women. Moreover, the percentage of women studying mathematics decreases at higher levels. For example, in 1992/93 in the United Kingdom (including Scotland and Northern Ireland), only 26% and 20% of undergraduate and graduate students in mathematics were women. In the same year in British (including Scottish) universities, only 5 full-time mathematics professors out of 261 were women (1.9%) and 13 full-time mathematics readers/senior lecturers out of 403 were women (3.2%). These percentages have remained almost unchanged since 1987 (Smart, 1996).

Taber (1991) reviewed studies carried out in England during the preceding decade and found consistent and marked preferences by boys for mechanical topics and by girls for biological ones. However, there are exceptions to this generalisation. Dramatic, dangerous, or gory biological topics, such as dinosaurs, spiders, and dissection appeal to boys, while physical science topics which are aesthetically appealing (rainbows, chromatology) are of interest to girls.

Sweden. In a paper published in 1996, Barbro Grevholm states that women's grades in mathematics at the end of compulsory school and in upper secondary school are higher than men's and in undergraduate mathematics courses they are as good as men's. Women's participation in mathematics and science however, is far from equal to men's. In Sweden, a student who wants to study university mathematics, science or technology must either finish the natural science program in upper secondary school or complete a year of extra courses after finishing the upper secondary school social science program. In 1994, women constituted only 33% of students graduating from the natural science program. In 1992, 26% of students in undergraduate mathematics programs were women. Within mathematics, the percentage of women ranged between 19% in mathematics/computer science and 100% in mathematics/statistics. In the same year, at the graduate level, 30% of students in mathematics were women.

In general, although more women than men participate in higher education in Sweden, the choice of education is gender dependent. About 64% of the basic university degrees are awarded to women but the distributions of men and women in various subject areas vary considerably with women dominating in teaching, nursing, and social welfare, and men dominating in science and technology (Grevholm, 1995).

In faculty positions, only 5% of the mathematics lecturers with permanent positions are women compared with about 20% in other subjects. There are no female professors of mathematics in Sweden, compared with 8% in other subjects (Grevholm, 1995).

Despite the fact that there is full consensus in support of the goal of equal opportunity, and despite the absence of formal and economic obstacles hindering women from pursuing higher education in Sweden, Hedman (1988) maintains that there still exist many obstacles, mostly invisible ones, which prohibit women from reaching higher positions in education and research. One of these obstacles is that teaching and research within higher education are traditionally male domains. That is, men have presented the norm for students, teachers, researchers, and decision makers high up in the hierarchy. Also, sex role stereotyping still determines to a great extent the choice of both education and occupation, and dictates men's and women's degrees of responsibility for and participation in the care of home and children. Grevholm (1995) states that women are usually employed in less favourable environments with less pay and lower status than men with comparable education.

Hedman (1988) stresses the importance of collecting relevant statistics describing the total picture of the situation of women and men within all areas of education and research, including effects of education on job opportunities and salaries for women and men. She advocates that awareness of gender issues should be raised on all levels and in all areas, and as one component of the teaching at the university level.

New Zealand. Purser and Wily (1990), in a study carried out during the period 1972/73 to 1985/86, reported a decrease in the number of male mathematics graduates at all levels from 232 to 157, but an increase in female mathematics graduates during the same period from 62 to 75. That is, the percent of female mathematics graduates increased from 21 in 1972/73 to 35 in 1987-88. Only 17% of female mathematics graduates continue in full-time study towards another degree in 1985/86 (10 students), as opposed to 35% of male graduates in the same year (52 students). In 1992, women made up 54% of all first year university students in New Zealand whereas their proportion in first year mathematics courses ranged between 26% and 40%. This range remains unchanged in third-year mathematics courses (Clark, 1996).

In 1994, 12% (22 of 181) of the academic staff at the lecturer level or above in university mathematics/statistics programs were women. Of the 36 full and associate professors of mathematics or statistics, none were women. In 1993, in all disciplines, 16 of 361 full professors were women (4%), and 32 of 374 associate professors were women (9%) (Clark, 1996).

Federal Republic of Germany. In Germany, students may opt for either a standard or an advanced mathematics course starting in grades 11 or 12. In 1992/93, in North Rhine Westphalia, one of the most highly populated German states, girls made up 55.4% of enrolment in standard mathematics courses and only 35.8% of enrolment in advanced courses (these are percentages of enrolment in Gymnasium schools which are the schools leading to university education). Similar figures come from other states in which enrolment statistics are broken down by gender. The percentage of women mathematics teachers at state schools in the state of Baden-Wurttemberg in 1991 for example, was only 20%. At the university level, the percentage of women mathematics teachers is marginal (Niederdrenk-Felgner, 1996). Niederdrenk-Felgner (1996) indicated the marked lack of role models as a main factor behind the decision made by secondary school girls against taking advanced mathematics courses. The author also stated that girls tend to lack self-confidence regarding their mathematical abilities and that the plans they have for their lives remain within the scope of traditional ideas that are perceived by them as socially accepted.

In spite of the many differences in social structures and education systems which exist in the above mentioned countries, common themes emerge. These include (1) concern for the paucity of women in the mathematics, science and technology arenas, as both workers in the work force and students in university programs, (2) lesser presence of women at each higher level of study, (3) lack of role models for girls in these fields, usually expressed in terms of women's scanty share of university academic positions, and (4) the adoption of intervention strategies aimed at correcting the situation by encouraging young women to participate in mathematics and science courses, and government policies aimed at removing formal obstacles hindering women's pursuit of a career in these fields.

2.4. Research Conducted in Canada

2.4.1. High School

In the early 1980s, concerned reports about the low representation of women in the fields of mathematics, science, and technology quoted statistics collected by Scott (1982). Scott's statistics were based on data provided by the provincial ministries of British Columbia, Ontario, New Brunswick, Newfoundland, and Nova Scotia; they included a breakdown of enrolment in mathematics and science courses by gender for the year 1979/80. The data however, were incomplete, and regional variations could not be examined because courses in different provinces are not equivalent. The ages of the students sampled were also different, as some provinces have 11 years of schooling, while most have 12 and Ontario has 13 years (Scott, 1982).

Several studies were carried out in the late 1970s and early 1980s within various school boards (Wiggan, Kryger, Gamery, Morris, Clifford and Getty, 1983; Glaze, 1979; Larter and Fitzgerald, 1979; Sayer, 1980). These studies investigated enrolment in mathematics courses, mathematics anxiety, career aspirations and expectations, and attitudes toward work and employment, all at the high school level. Wiggan et al (1983) analysed course enrolment statistics on 30,000 students in 27 Toronto Board schools and found significant gender differences in mathematics participation in grades 12 and 13. Female enrolment in mathematics courses in grade 13 ranged from 26.5% in algebra to 42% in mathematics of investment. The authors also found that 'the higher the grade, the smaller the proportion of females who took mathematics' (p.15). In a study carried out by Glaze (1979), a questionnaire about career aspirations was completed by 1167 high school girls living in Metropolitan Toronto and Middlesex county. Almost half of the girls said that they aspired to "upper class" positions but less than one third said they expected to attain them. About 10% of the girls in the survey expected to have "low class" occupations. Larter and Fitzgerald (1979) found that career expectations of high school girls correlate with their level of study, i.e basic versus general and advanced courses. Sayer (1980) investigated career awareness of 93 grade nine girls living in Toronto and reported that they named a total of 72 different career aspirations, but 34.8% of their responses were: secretary, stewardess, teacher, or social worker, which are the traditional female jobs. Authors of all four studies reported that girls' responses revealed gross misunderstandings and lack of awareness regarding general knowledge about women in the labour force.

Since the early 1980s, government agencies, professional associations, school boards, post-secondary institutions, businesses, and industries have promoted the implementation of, and in some cases adopted new programs specifically designed to increase young women's interests in mathematics and science, and encourage them to pursue careers in these fields. Remedial measures have been adopted to increase student awareness of the importance of taking mathematics courses and means have been taken to combat the deleterious effects of mathematics anxiety and mathematics avoidance. These measures range from career conferences, which provide information regarding occupational opportunities, to radical programs such as segregated mathematics classes. A handbook of 14 existing intervention programmes was compiled by York University in 1988. An example of such programs is W.I.S.H.(Women In Science, Hopefully), which was initiated in 1984 at York University, and was funded by the Ontario Women's Directorate.

The Canadian document "Towards a Labour Force Strategy: A Framework for Training for Women" lists measures deemed necessary to achieve equity between men and women in learning environments at all levels. This report was endorsed by the Canadian First Ministers, who have been monitoring its implementation through annual reports. A survey of policies and practices regarding women's issues in education was prepared for the Secretariat of the Council of Ministers of Education, Canada, in 1987. The survey listed the policies, programs, and legislations that were implemented by each province to address these issues, and concluded that the area of greatest communality among the provinces is the existence of programs for the elimination of sex bias and stereotyping in textbooks. In provinces where science and mathematics courses are optional, programs to encourage women to take them are implemented. The assumption that the absence of women from professional and scientific jobs is a result of a lack of mathematical knowledge was made by Canadian researchers and educators, and was used as the basis for many of the corrective and guidance programs across all provinces.

During the last 10 years or so, a number of research initiatives have been directed to the issue of gender and mathematics education. These initiatives have explored the relationships to be found among affective variables, such as students' feelings toward mathematics, their confidence in themselves as learners of mathematics, their perceptions of the usefulness of mathematics, and the bases for students' decisions to enrol in mathematics courses. These studies were carried out with the intention of suggesting strategies to increase women's participation in mathematics. In 1989, a report on the participation of girls and women in mathematics, science, and technology was prepared by the Status of Women Canada, Manitoba Women's Directorate. This report stated that the problem of under-representation of girls and women in mathematics, science and technology is still present, in spite of interventions aimed at correcting it. The report also stated that 85% of post-secondary programs are closed to students who do not successfully complete high school mathematics and science courses. These are the programs that produce qualified personnel suitable for the scientific and technological job market.

The Better Idea Book, which was published by the Canadian Teacher Federation in 1992, presents the most recent and inclusive national data available on high school mathematics and science enrolment and success rates broken down by gender. Nevertheless, the data are still incomplete, and there are too many unmatched variables to assume a common basis for regional comparisons. The authors of this document conclude that many more women are eligible for post-secondary mathematics and science studies than choose to undertake them, and that factors other than lack of pre-requisites influence post-secondary education decisions and, ultimately, career choices. The Better Idea Book authors also recommended the collection and reporting of detailed and specific data on gender, participation, and success rates.

In 1994, the Council of Ontario Universities Committee on the status of women in Ontario submitted a report to the minister of finance on women's role in economic recovery. This report maintained that women continue to be under-represented in the fields of engineering, applied sciences, mathematics, and the physical sciences, and suggested that the recent increases in enrolment of women in scientific and technological areas are the results of such special initiatives as outreach programs in schools and special scholarships at the university level.

Remedial and prevention activities targeting high school girls continue in various school boards. No effort has been made to evaluate these programs, and questions regarding their effectiveness are left unanswered.

Data-based studies assessing the dimensions of the gender imbalance in enrolment and achievement, and their trends over time are non-existent particularly at the provincial and the national levels.

2.4.2. University

With approximately 1.3 million post-secondary students, Canada ranks second only to the USA in the proportion of its population enrolled in post-secondary education. Both countries have nearly twice as many post-secondary students relative to their populations, as most other developed countries (Human Resources Development Canada, 1993. p. 32).

Women are remaining in the education system in unprecedented numbers. Whereas in the academic year 1972/73, 43% of the bachelor students in all fields of study were women, in 1994/95 this percentage reached 56%. While male enrolment at the bachelor level increased by 33% between the years 1972/73 and 1994/95, female enrolment increased by 127%. Women's share in part-time enrolment is larger than their share in full-time enrolment. According to Statistics Canada report "Women in Canada, 1995", in 1992/93, 63% of part-time undergraduates and 52% of part-time graduate students were women.

Relatively few students of either sex major in mathematics. In 1993/94, of all university students, less than 2% were majoring in mathematics. This is probably why published statistics usually combine mathematics, computer science, chemistry, physics and geology in one category labelled mathematics and physical sciences. Moreover, studies on gender participation have traditionally contrasted participation levels in the fields of mathematics and sciences combined with participation levels in humanities and social sciences. This clustering of disciplines does not convey an accurate account of gender imbalance or of the extent of its change in recent years. For example, the Statistics Canada report on the profile of post-secondary education, 1993 edition, states "In the fields of engineering and applied sciences and mathematics and physical sciences, women form only small minorities of degree recipients" (p. 18). Women's share of bachelor degrees awarded in mathematics and physical sciences as quoted by the report is 29%. While women's share of bachelor degrees in mathematics in that year was 39%, their share of bachelor degrees in physics was 14% and in computer science 20%. This indicates that women's representation is vastly different in these disciplines, and that the frequently quoted average percentage is not an accurate indicator of women's participation in any one of them. Only recently, researchers have started to study participation rates in specific disciplines, more particularly in engineering areas. Differences in participation rates and trends among mathematical and scientific disciplines are starting to emerge.

In terms of academic degrees in mathematics in 1994/95, women earned 40% of the bachelor's degrees, 32% of the master's degrees, but only 15% of the doctorates. This suggests that gender imbalance increases at the higher level of graduate studies.

With the percentage of women decreasing at each higher level of study, the proportion of women among university professors who may serve as role models to female students will also remain low (Hanna, 1993). In 1992/93, only 8% of full time faculty in mathematics and physical sciences in Ontario universities were women (Council of Ontario Universities, 1996).

Little is known about gender differences in enrolment and graduation levels in mathematics programs in Canadian universities. Trends of enrolment and graduation levels over time, whether these trends are different for full-time and part-time students, and whether they vary from province to province have not been investigated. Are women adequately represented in undergraduate mathematics programs? Do women mathematicians drop out of the education system at the graduate level? Is gender imbalance greater in mathematics graduate programs than in other graduate programs? If so, what are the plausible causes of this problem? All these questions are left unanswered.

2.5. Women in Engineering and Computer Sciences

Like mathematics, the fields of engineering and computer sciences have traditionally been viewed as male domains. While women's under-representation in engineering is well documented, their under-representation in computer sciences has only recently started drawing researchers' attention.

But the dimensions of the gender imbalance are not uniform across these three fields. For example, according to the 1991 census, women constituted 45% of employed workers in Canada, but they constituted only 9% of employed engineers and 40% of mathematicians. Computing occupations, i.e. programmers, analysts, scientists and related jobs are all grouped together; women's share of these occupations in 1990 was 34% (Statistics Canada, 1991). In the U.S., in 1987/88, women constituted 30% of employed computer scientists. At the doctoral level, 10% of employed computer scientists, 10% of mathematicians, and only 2.5% of engineers were women (Pearl, Pollack, Riskin, Thomas, Wolf and Wu, 1990).

The disparity in the gender imbalance in these three fields is also apparent in university enrolment statistics. In 1994/95, about 1.6% of students of both sexes on Canadian campuses majored in mathematics, 2.4% majored in computer sciences, and 8% majored in engineering. During the same year, women's share of enrolment at the bachelor level was 40% in mathematics, 20% in computer sciences, and 18% in engineering.

The gender gap in computer sciences is particularly puzzling. Computer technology is, after all, a new field with no long history of sexism to overcome. However, a boy-centred "computer culture" settling in classrooms, reinforced by boys' aggressive behaviour to monopolize computer time and discourage girls is described by several researchers (Acker and Oatley, 1993; Carmichael, Burnett, Higginson, Moore, and Pollard, 1985).

The under-representation of women in engineering and computer sciences is alarming for at least three reasons. First, it raises the distressing possibility that these fields function in ways that discourage or hinder women from becoming part of them. If this is the case, it is imperative to ensure that fair and equal treatment be provided to all current and potential participants. Second, practices that exclude women are not only unethical, but they are likely to impede the discipline's progress as potential contributors to the field are discouraged from participation. Third, according to the U.S. Department of Labour, computer scientists and systems analysts will account for two of the top fastest growing categories of jobs between now and the year 2005. Computers have already transformed a wide range of other professions, such as secretarial work that employ millions of women and it is becoming a key part of almost all industries. The absence of women from university computer sciences programs will close this expanding job market to them and hence, limit their career choices.

Mathematics avoidance is the most frequently adopted explanation for the paucity of women in engineering and computing professions. The relationship of females' mathematics achievement to internal factors such as attitudes and self-confidence, and to external factors such as lack of role models and teachers' and parents' attitudes are also used to explain the under-representation of women in these fields (Cottrell, 1992). Bernstein (1992) advocates that in order to attract women, the focus of the computer sciences curriculum should be changed to applications rather than mathematics. Collis (1991) maintains that making mathematics courses pre-requisite or co-requisite to computer courses in high school, and/or locating the computers in the mathematics department strengthens the masculine stereotyping of computer courses.

Other factors used to explain women's low participation in these fields are the gender biases and stereotyping found in recreational and educational software programs, the fact that boys have more exposure than girls to computers at home, and that boys are more likely to be sent to computer camps (Pearl, Pollack, Riskin, Thomas and Wu, 1990). Lack of female role models is also indicated as a contributing factor to women's low participation in both fields. For example, in 1987/88, only 2% of full-time faculty, and 0.4% of full-time full professors in engineering and applied sciences were women (Industry, Science and Technology Canada, 1991). In 1992/93 in Ontario the picture was not much better; only 5.6% of full-time faculty were women (Council of Ontario Universities, 1996).

A longitudinal study was carried out at the University of Guelph to examine attrition and educational outcomes of undergraduate students and to provide insight into difficulties associated with the recruitment and retention of women in science and engineering disciplines (Gilbert and Pomfret, 1995). In this study, all new first semester students in the fall of 1986 at this university were surveyed and data on their background characteristics, expectations, and aspirations regarding university life were collected. The same students were surveyed again in the fall of 1987, and the winter of 1990 with a focus on their educational experiences and outcomes. Interviews were conducted with students who left the university between 1986 and 1988 (264 leavers) and with women high achievers (average A or B+) who transferred out of the science and engineering to other fields (20 changers) and those who stayed (27 persisters). In these interviews, data on reasons for transferring out of science, attitudes about the science program features, and gender identity were collected. Some of the findings reported by the authors are: (1) The existence of a strong gender difference in the kind of pre-university influences which students report as affecting their program choice, with women rating factors such as home (mother, father, other family members) and high school (teachers and guidance counsellors) influences as well as interest in the subject matter higher than men do. (2) "Males and females enter science with different value orientations to self and to others. Women tend to have a response and care orientation which stresses the connection of self to others while, less clearly, men have more of a rights and justice orientation with greater emphasis on the autonomous self." (p. 29). (3) Among the 1986 cohort of science and engineering students, no gender difference was observed in the percentage of students who left university (30% of men and 30% of women), transferred out of science (12% of women and 13% of men), or persisted in science (58% of women and 57% of men). However, men and women may leave science for different reasons. (4) Reasons for women leaving science programs included concern about the job market for scientists, non-supportive environment, lack of flexibility in science programs, brutal examinations which are part of a weeding out culture, and not offering enough practical and hands-on courses.

A longitudinal, multi-institutional study of undergraduates of science majors was conducted by the Higher Education Research Institute (HERI) at the University of California, Los Angeles to investigate the effect of college years on women's interests in science (Astin and Sax, 1996). Students majoring in science were surveyed as freshmen in 1985 and were surveyed again in 1989. In general, less than half of the students choosing a science major in their first year of university were in the same science major four years later. The highest persistence rates were among engineering men (55.4%) and engineering women (47.4%) and the lowest were among women in the physical sciences (36.4%) and men in mathematics (40.3%). Data collected in these surveys show that about one half of the women who leave their initially selected science major are still in the sciences but in new majors, and the other half switch to humanities, education and the social sciences. Other conclusions reported by Astin and Sax (1996) include: (1) men and women are more likely to pursue careers in science and engineering if one or both parents held such an occupation, and (2) faculty in science are much less likely to employ active learning methods in the classroom than faculty in humanities or the social sciences.

Women engineers and computer scientists report concerns of physical safety particularly for students who need to access laboratories or public computers after hours to complete their assignments. Lack of supportive environments both in the classroom and in the work place is indicated by numerous examples of negative attitudes towards women engineers and computer scientists (Brush, 1991; Canadian Committee on Women in Engineering, 1992; Leveson, 1990; Spertus, 1991).

Some researchers argue that mathematics and science teaching methods discourage women. Rosser (1990) for example, argues that teaching practices that emphasize competitiveness and rapid solving of problems and depicts careers in science as being overly demanding, discourage female students. These factors however, do not explain the disparity in women's enrolment in specialization areas within the engineering field. For example, according to Statistics Canada report "Women in Science and Engineering, 1991", women earned 24% of the bachelor degrees awarded in chemical engineering and only 8% of the bachelor degrees awarded in electrical engineering in 1989.

Lower salaries received by women in scientific and technological jobs are reported as one of the disincentives to women majoring in these fields. However, reports about women's earnings relative to men's are mixed and do not seem to support this view. According to Statistics Canada (1995b), women earn less than men at all levels of educational attainment and in all types of occupations and the earnings gap is smaller in professional than non-professional occupations. That is, lower salaries earned by women are not confined to scientific and technological occupations. The report states that women university graduates employed on full-time full-year basis earned an average of 75% as much as their male colleagues in 1993 (74% for non-university post-secondary certificate and 72% for high school graduates). On the other hand, Wannell and Caron (1994) analyzed data collected in the National Graduate Surveys which cover the 1982, 1986 and 1990 graduating classes of Canadian universities and colleges and arrived at somewhat different conclusions. The authors report that: (1) among the 1990 class, women university graduates who are employed full-time earn an average of 91% of men's earnings two years after graduation, (2) the gender earnings gap has been shrinking for recent graduates, (3) the trend for smaller earnings gap is not evenly spread across industries and occupations. For example, women mathematicians and physical scientists earn 88.5% of men's wages whereas women engineers earn as much as men, (4) the earnings gap is smaller at higher degree levels; women at the doctoral degrees earn, on average, as much as men, (5) the gender earnings gap widens with age, (6) among university graduates employed full-time, women work an average of almost three hours a week less than men. Thus, the hourly wage gap is smaller than the yearly earnings gap, (7) when hours of work are controlled for, together with prior work experience, job tenure, and education and when part-time workers are included in the model, women in the class of 1990 earned higher hourly wages than men, and (8) even after controlling for hours of work, prior experience, education, and the presence of children, the wage gap is still larger for older women vis-a-vis older men within each graduating class. Hughes and Lowe (1993) examined the effects of socio-demographic, educational, work attitude, and labour market characteristics on gender differences in earnings and promotion opportunities of a sample of 1985 university graduates employed full-time one year after graduation. The authors concluded that: (1) gender specific patterns regarding field of study reinforce existing gender segregation in the work force, (2) even after field of study is controlled for, men and women with the same education translate credentials into different kinds of employment futures, and (3) gender differences in initial employment outcomes are attributable to gender segregated occupational structures, professional association membership, and other specific job conditions. Although these authors reported that female graduates employed full-time worked an average of 2.6 hours a week less than men, they did not include this factor in their models.

At the graduate level, Hollenshead, Wenzel, Lazarus and Nair (1994) reported on a survey of University of Michigan bachelor's engineering graduates where many women did not pursue graduate studies because they were drawn by more people-oriented or socially meaningful jobs, were disinterested in academic careers, or could not afford graduate school. Promotion systems in universities are also criticised for forcing women to choose between raising a family and establishing an academic career (Brush, 1991). In a study done at Columbia University, 25 women doctoral students and recent graduates and 7 female faculty members in physics, chemistry, electrical engineering, and computer science departments, were interviewed to determine the receptivity of university cultures to women graduate students and faculty members (Etzkowitz, Kemelger, Neuschatz and Uzzi, 1994). Interviews were also conducted with chairs, administrators, and male faculty members who had been identified as having either particularly good or poor relations with women graduate students. The authors identified these factors as acting against the progress of women in science and engineering: (1) Extra academic factors such as differential socialization of men and women, impaired self-confidence, and family obligations including child care and lack of geographical mobility coupled with the reluctance of academic institutions to hire both husband and wife. (2) Everyday features of academic science such as advising patterns that have the unintended consequence of excluding women. Women reported that men advisors were sometimes unsupportive. Women recalled frequent negative instances in which they were left with doubt about their self-worth. Women also expressed preference for industrial rather than an academic career because industry has more support systems in terms of child care and maternity leave. (3) Subtle and not-so subtle bias that is derived from taken-for-granted male model of doing science.

National statistics on women's participation in university computer science or as computer scientists in the labour force are sparse. Most published statistics of university enrolment do not separate enrolment in computer science programs from enrolment in mathematics and the physical sciences. Labour force statistics combine computer scientists with programmers, analysts, and related occupations in a single category. Patterns and trends of enrolment in both the engineering and the computer sciences have not been investigated. Published reports express concern about women's low participation in these fields, but the dimensions of the problem have not been appraised, particularly in the area of computer sciences. Are enrolment patterns similar in these two disciplines? Do women computer scientists and engineers drop out of the education system at the graduate level? At the same rate as women mathematicians do? Is the gender gap in enrolment in these fields closing with time? At the same rate or at different rates? Does it seem likely that women's lack of mathematical skills or their desire not to study mathematics is the reason for their low enrolment in engineering and computer science programs? If not, what are the plausible reasons for the problem?

The assumptions underlying the above mentioned explanations and/or justifications for the low participation of women in scientific and technological arenas include a belief in the gender neutrality of mathematics and science and in the similarity of women's and men's cognitive abilities to practice them (Kimball, 1995). Intervention strategies based on these notions include encouraging more women to study mathematics and science, to fight discrimination within these fields, and to strive to change the image of women as unable to do mathematics and science.

An alternative view, held by some feminist scholars, is that science as currently defined has a masculine perspective since it was developed and shaped by men, and that science itself is responsible for deterring women away from participating in it. A basic assumption of some feminist work is that women's interpretations of the world and their ways of knowing and working are different from men's. This view suggests that women have preference for cooperative, caring, connected approaches to learning and working, and are less interested than men in competing to finish a task first or in imposing their power over a machine such as the computer (Belenky, Clinchy, Goldberger and Tarule, 1986). On the other hand, Hanna (1994) challenges the notion that women know differently from men and the idea it leads to which is that girls and boys should be taught differently. Some feminist scholars also argue that most of our beliefs and perceptions, including our scientific methodologies, interpretations, and findings have been formulated through masculine eyes and reflect masculine perspectives. As part of this approach to the problem, Fennema (1996) ponders the possibility that mathematics, at least as currently taught, is also intrinsically biased. Intervention strategies adopting these notions face the difficult task of reworking science, mathematics and technology with the intention of designing female-friendly or gender-neutral curricula and pedagogies (Acker and Oatley, 1993).

While examination of the gendered values of science curricula is both necessary and valuable, it does not have to lead to the conclusion that science should be judged as a field that is not suitable for women.

2.6. Economic and Demographic Factors Affecting University Enrolment

Three main theories of the demand for post-secondary education have been developed by educational economists; these are: the consumption theory, the investment theory, and the cohort size theory (Foot and Pervin, 1983). The consumption theory treats education as a consumption good and suggests that its demand is primarily a function of its relative price and the consumer's income. This theory assumes that an individual enrols in an educational program because it yields satisfaction and/or benefit. Two main effects are at work here, the cost of education and the consumer's income. That is, an increase in the cost of education or a decrease in income, other things being unchanged, will result in education being relatively more expensive and the consumer switching to other goods.

The investment theory views education as an investment decision and suggests that individuals will purchase a university education if the expected benefits of such an investment exceed the costs of acquiring it. This model implies that students enrol in higher education to prepare for future work opportunities, that they have access to reliable information about occupation requirements, prospects, and earnings and have the foresight to plan their schooling accordingly (Walters, 1986). Expected benefits include monetary as well as psychic benefits resulting from elevated social status. The costs include direct costs of acquiring education and indirect cost of foregone income while in school.

The cohort size theory focuses attention on demographic and sociological factors and suggests that the comparative size of one's generation determines one's life chances and perceptions of the likelihood of achieving economic aspirations and hence, one's decisions about marriage, family size, and post-secondary education. According to this theory, if younger workers are in relatively short supply, their earnings, employment experiences, and career advancement will be favourably affected. Similarly, an increase in the size of university age cohort reduces the return to a post secondary education and, consequently, discourage them from seeking university education. Moreover, with a relatively large population at university age, there will likely be more university age children per family, which with parental income constant, reduces the probability of any given sibling's enrolment (Foot and Pervin, 1983).

The three theories mentioned above provide complementary explanations of the demand for post-secondary education from an educational economist perspective.

None of the influences suggested by the above theories however, can be equally applicable to men and women. It is often suggested that women's higher education attendance is less motivated by long term investment factors than men's, and that the availability of work opportunities for school-age individuals may have a stronger effect on women's enrolment decisions than on men's. In other words, women's university enrolment increases when they have difficulty finding employment at graduation from high school. With a relatively large university age cohort, it is assumed that families will give financial preference to their sons' education, resulting in fewer women in university programs. Also, the sex segregation of the labour market and the difference between the occupations for which men and women are trained for may cause male and female enrolments to respond differently to the same set of labour market changes (Walters, 1986). Smith (1982) found that women's enrolment decreased as the percentage of never-married among women aged 20-24 years increased.

Based on the notion that students' decisions about post-secondary educational alternatives are mostly investment decisions that are strongly influenced by expected monetary returns, Stager (1989,1994) estimated private and public rates of return on investment in different fields of study in Ontario for males and females for the period 1960 to 1990. The return to educational investment is a measure directly comparable with the yield rate on investment in physical capital. Whereas private returns provide an estimate of returns on educational investment for an individual student, public returns provide an estimate of returns for the whole economy. Rates of return are estimated by comparing expected lifetime net earnings with the costs of post-secondary education, and are primarily used by economists and educational policy makers for exploring the implications of tuition fee policy on enrolment, and for planning government expenditures on higher education. Changes in rates of return have historically accounted for more of the variation in enrolment than have changes in either fees or family income (Freeman, 1986). Stager found that private and public returns differed greatly across programs of study, and were generally higher for women than for men; a finding which may help explain the fast increase in women's participation rates in university education. In 1990, the private rate of return on investment in a bachelor degree in mathematics and physical sciences was 15.1%

for men and 21.2% for women. For all bachelor degree programs, the estimated private rates were 13.8% for males and 17.6% for females. Estimates of total rates of return for the whole economy were 11.5% for males and 14.6% for females for investment in a bachelor degree in mathematics and physical sciences. Stager's estimates indicate that female private and total rates of return to investment in a bachelor degree in mathematics and physical sciences are the second highest rates after commerce among all university programs (1990 data). Private rates of return on investment in a bachelor degree in engineering in 1990 was 19.8% for women and 16% for men. The lowest rate of return for women, 14.8%, is on investment in a bachelor of humanities and fine arts. Based on these estimates and on the notion that enrolment decisions are, at least in part, investment decisions, more women should be pursuing careers in engineering, mathematics, health professions, and commerce than in humanities and biological sciences. It is not obvious whether investment incentives play a minor role in women's decisions about higher education, or that these findings, which could help sway young women to increase their participation in these fields, are not adequately communicated to them.

Denton and Spencer (1992) studied post-secondary enrolment patterns in Ontario during the period 1976 to 1989. In this study, the most important factor in determining university enrolment rates was found to be a variable representing the relative sizes of student-age and parent cohorts. That is, the ratio of population aged 15-24 years to the population aged 40-49 was negatively related to enrolment rate; a 10% fall in the child/parent ratio induced a 9% increase in enrolment of both male and female university students (other things being equal). The smaller families meant more income and assets available per child to finance post-secondary education. The ratio of student aid (grants plus loans) to student costs was also significant; a rise of 10% in the aid ratio resulted in a 3-4% rise in university enrolment. The ratio of average income of a person with university education to one without was found to have a stronger influence on female university enrolment than male university enrolment. The rate of youth unemployment has a negative effect on university enrolment. The authors also reported that attempts to relate masters' enrolment to prior undergraduate enrolment levels and doctoral enrolment to prior masters' enrolment were unproductive, and that consistent "flow through" relationships from undergraduate to masters' to doctoral were not possible to establish.

2.7. Summary

Although women have been pursuing university education in unprecedented numbers, they continue to be under-represented in mathematical, scientific, and technological programs. Moreover, women's representation declines at each higher level of study. Understanding the reasons behind women's career choices is an essential first step toward understanding and appraising the reasons behind their paucity in these fields. The literature provides many psychological, socio-cultural, educational, and economic explanations and/or justifications for an individual's decision to pursue a specific educational endeavour. These explanations give complementary rather than competing interpretations of the shifts in university enrolment. Each approach contributes a number of factors which, put together, yield a comprehensive set of considerations which influence the individual's decision to enrol in a university program. The decision to enrol in any particular program is the outcome of expectancies for positive educational experience and successful performance. Such decision must also reflect intrinsic social values and psychological processes and is constrained by financial limitations and enhanced by the anticipation of high returns. In other words, social, psychological, familial, and economic influences affect the individual's decision to enrol in a specific program. Research findings indicate, however, that the relative importance of these influences is not the same for men and women.

Chapter 3

Women's Enrolment in University Mathematics in Canada

3.1. Introduction

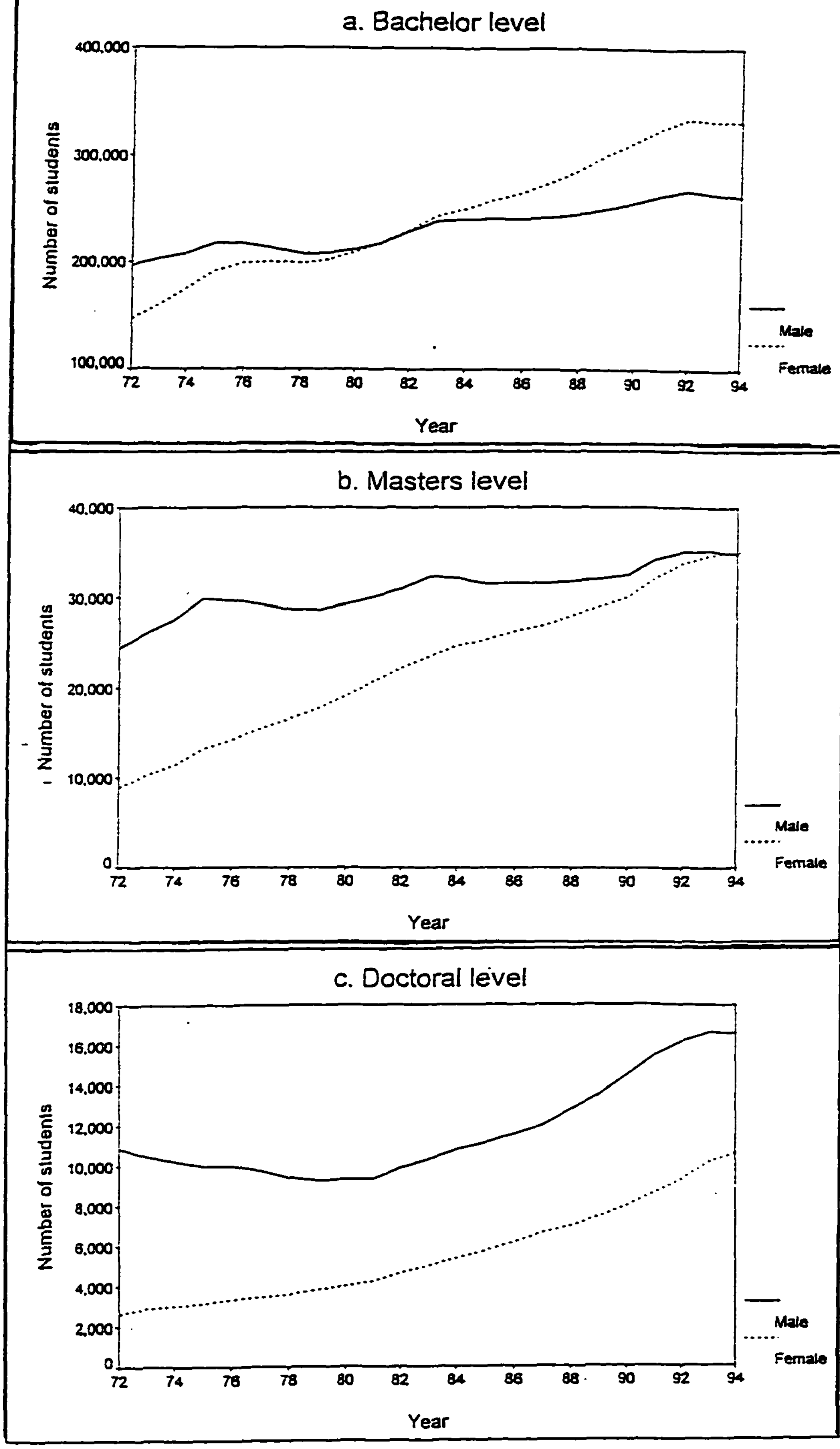
In this chapter, trends of enrolment in all university programs at the bachelor, masters and doctoral levels are analysed and discussed with focus on the change, if any, in women's representation over the period 1972/73 to 1994/95. As mentioned, 1972/73 was the first year in which Statistics Canada collected data on students' gender. Enrolment rates are inspected separately and in conjunction with dependency ratio in an attempt to isolate changes in enrolment trends due to shifts in the demographics of the Canadian population, from those related to changing attitudes towards university education. Trends of enrolment in mathematics programs at the three levels of study are examined with an eye on the progress of women's representation in what has been traditionally considered a male domain. Mathematics programs, as defined by Statistics Canada, include pure and applied mathematics, statistics, and actuarial science programs. Parity indices and adjusted participation rates for men and women university students are inspected in an attempt to disentangle mathematics specific and gender specific changes from the more general trend of increased men's and women's presence on Canadian campuses. A snapshot of mathematics enrolment at the present time is presented. Comparisons are made between (1) women and men, and (2) mathematics and all programs, as part of the investigation of both historical trends and current enrolment. Transition rates are used to study the advancement of women to graduate levels in mathematics programs in relation to men's advancement to graduate levels in mathematics and to women's advancement to graduate levels in all programs.

At the time of writing this thesis, Quebec's enrolment figures for the last year of the study, 94/95, were not available and were therefore, replaced by 93/94 figures to arrive at estimates of Canada's enrolment for 94/95.

3.2. Trends of University Enrolment During the Period 72/73 to 94/95

Numbers of men and women enrolled in all programs in Canadian universities by level of study during the period 1972/73 to 1994/95 are plotted in Figure 3.1. This figure shows that the number of women on Canadian campuses at all three levels of study has been increasing steadily over the study period except for the last two years where their bachelor level enrolment stabilized. The number of men on the other hand, rose steadily during the 80s but decreased at the doctoral level and fluctuated up then down at the bachelor and masters levels during the 70s. In general, the number of women in bachelor and masters programs has been increasing at a faster rate than that of men. At the doctoral level, men's and women's enrolment seems to be increasing at the same rate from 1982 to the present.

Figure 3.1. Total university enrolment by gender, Canada 1972-94



To what extent are these increases due to changes in the demographics of the Canadian population, and to what extent do they reflect shifts in attitudes toward university enrolment? In order to separate trends in university enrolment levels from demographic trends, enrolment at the bachelor level as a percentage of the Canadian population aged 18-24 years is plotted in Figure 3.2. Upon comparing figures 3.2 and 3.1.a, it becomes apparent that changes in enrolment rates over time mirror changes in total enrolment. This indicates that the changes in enrolment do not merely reflect demographic trends, but rather reflect real change in men's and women's enrolment levels in university education. Furthermore, the rise in enrolment rates has more than offset the decline in the university age population which had started in 1984. As a consequence, university enrolment has been increasing. Figure 3.2 reveals a rising trend in female enrolment rate in the early 70s which gave way to a plateau in the late 70s, a sharp increase during the 80s, more notable in the second half than in the first, and a plateau from 92/93 to 94/95. For males, enrolment rates were stable in the early 70s, declined slightly in late 70s, and increased during the 80s.

Figure 3.2 also reveals a gender difference in the tendency to enrol in university education over the study period. This is evident from the fact that the rate of increase in the percentage of women aged 20-24 who opt for university education is consistently higher than that of men's. Men's and women's enrolment rates rise, fall, and level off over identical periods, a fact which suggests that they are possibly reacting to the same set of social and economic factors in the same

Figure 3.2. Enrolment rate by gender, Canada

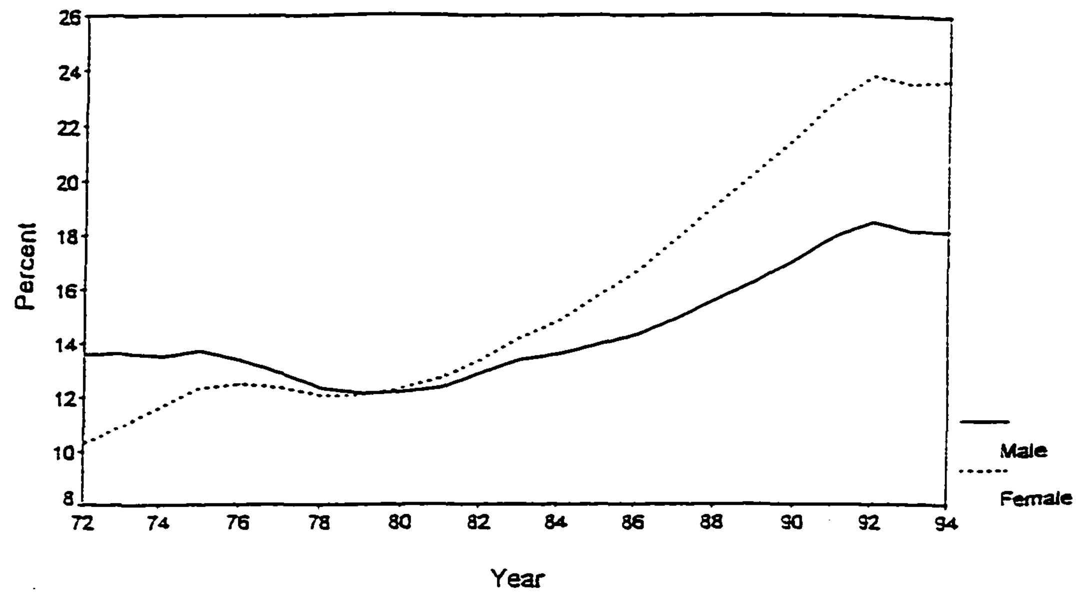
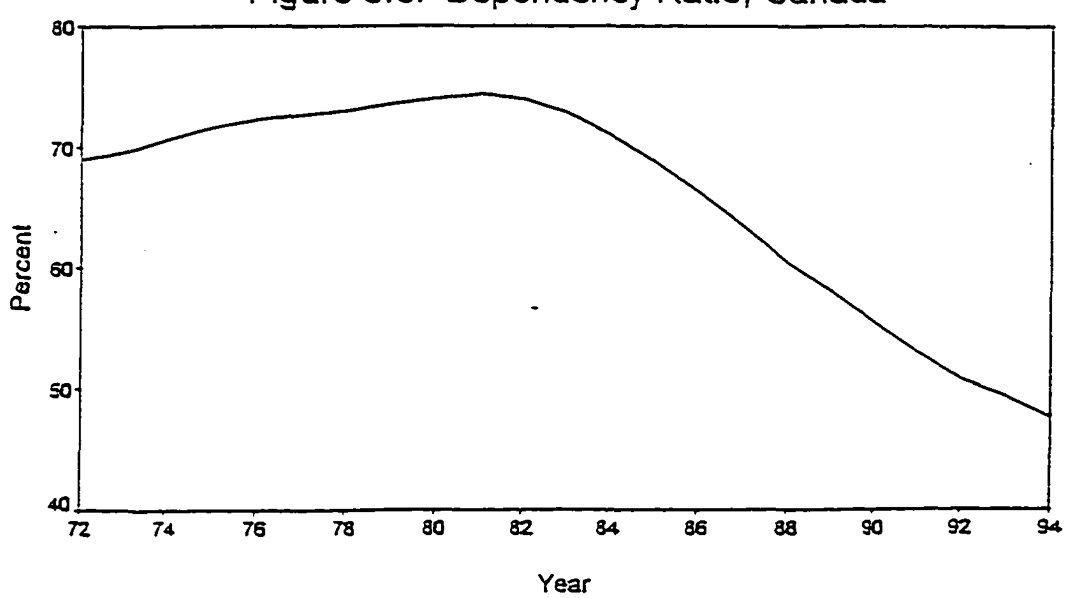


Figure 3.3. Dependency Ratio, Canada



general direction. However, women's enrolment has been more responsive to favourable influences, and more resistant to dampening effects. For example, while men's enrolment rate was receding between 1975 and 1980, women's enrolment rate was levelling off, and while men's enrolment was going up during the 80s, women's enrolment was going up at a faster rate. This may also suggest that additional forces are motivating women to seek university education. Up until 1979, the proportion of men aged 18-24 years who were enrolled in a bachelor degree program was higher than that of women. Since 1980, women's enrolment rate has surpassed men's. In 1994/95, 24% of women aged 18-24 years were enrolled in a bachelor program as opposed to 18% of men at the same age. Enrolment rates for both sexes went through a 10 year period of marked increase from 1982 to 1992 then stabilized. The recent stabilization in enrolment rates coupled with an expected continuation of the decline in the size of the 18-24 year old cohort, have led researchers to expect a shrinkage in university enrolment during the 1990s (George & Pineo, 1992).

Dependency ratio is the ratio of the sizes of the student age cohort to their parents' cohort. This ratio was found by Denton and Spencer (1992) to be the most significant predictor of university bachelor enrolment. The smaller this ratio, the higher the enrolment. Figure 3.3 displays changes in the dependency ratio in Canada over the study period. The dependency ratio rose slowly in the 70s, stabilized for about 2 years, and fell during the 80s, more rapidly in the second half than in the first. Shifts in enrolment rates (shown in Figure 3.2) occur at the time as shifts in dependency ratio (shown in Figure 3.3). Although this observation does not prove that dependency ratio is a determinant of university enrolment as concluded by Denton and Spencer (1992), it is highly suggestive. There is, however, a gender difference in the level of correspondence between enrolment rate and dependency ratio. For example, the slow increase in the dependency ratio during the 70s is reflected in a slow decrease in men's enrolment during the same period. Women's enrolment rate showed resistance to this negative effect. This observation is at odds with the notion that a bigger family size will result in less female enrolment. Also, the fast decline in the dependency ratio during the second half of the 80s was accompanied by faster growth for women than men. This gender difference in the relationship between enrolment rate and dependency ratio does not support the finding reported by Denton and Spencer (1992) that changes in the dependency ratio affect male and female enrolment equally.

Table 3.1 displays data on part-time and full-time enrolment in all programs by gender and level of study in the first and the last year of the study period. The table shows that university enrolment grew from 389,793 in 72/73 to 690,713 in 94/95, a growth of about 77%. Women's share of enrolment in all programs at the bachelor level grew from 42.6% in 72/73 to 55.9% in 94/95 while their share of enrolment at the graduate levels almost doubled. At the present time, 56% of students in bachelor programs are women, enrolment in masters programs is split evenly between men and women, and in doctoral programs, 39% are women. That is, women's enrolment decreases as the level of study increases.

Table 3.1. Enrolment in All Programs by Gender, Level of Study and Registration Status, Canada

	1972/73				1994/95			
	Total	Men	Women		Total	Men	Women	
			number	%			number	%
Bachelor:								
Full-time	255,371	157,273	98,098	38.4	471,799	215,634	256,165	54.3
Part-time	87,574	39,442	48,132	55.0	121,906	46,453	75,453	61.9
Total	342,945	196,715	146,230	42.6	593,705	262,087	331,618	55.9
Masters:								
Full-time	19,093	13,913	5,180	27.1	42,100	22,157	19,943	47.4
Part-time	14,259	10,537	3,722	26.1	27,717	12,606	15,111	54.5
Total	33,352	24,450	8,902	26.7	69,817	34,763	35,054	50.2
Doctoral:								
Full-time	9,887	8,025	1,862	18.8	22,688	14,042	8,646	38.1
Part-time	3,609	2,841	768	21.3	4,503	2,535	1,968	43.7
Total	13,496	10,866	2,630	19.5	27,191	16,577	10,614	39.0
Total	389,793	232,031	157,762	40.5	690,713	313,427	377,286	54.6

Table 3.1 also shows that in 72/73, part-time students accounted for 25% of total enrolment at the bachelor level, 43% at the masters level, and 27% at the doctoral level. In 94/95, these percentages dropped to 21% of total enrolment at the bachelor level, 40% at the masters level, and 17% at the doctorate level. Women's representation is higher among part-time students compared to full-time students. Table 3.2 includes percentages of students in part-time study in all disciplines by gender and level of study. In 94/95, 23% of women in bachelor programs and 19% in doctoral programs studied on a part-time basis, a drop of 10 percentage points from their 72/73 levels. At the masters level, 43% of women

study on a part-time basis; a percentage which hardly changed over the last two decades. For men, the picture is different; their percentage dropped from 43% and 26% in 72/73 to 36% and 15% in 94/95 in masters and doctoral programs, while their percentage in bachelor programs dropped slightly from 20% in 72/73 to 18% in 94/95.

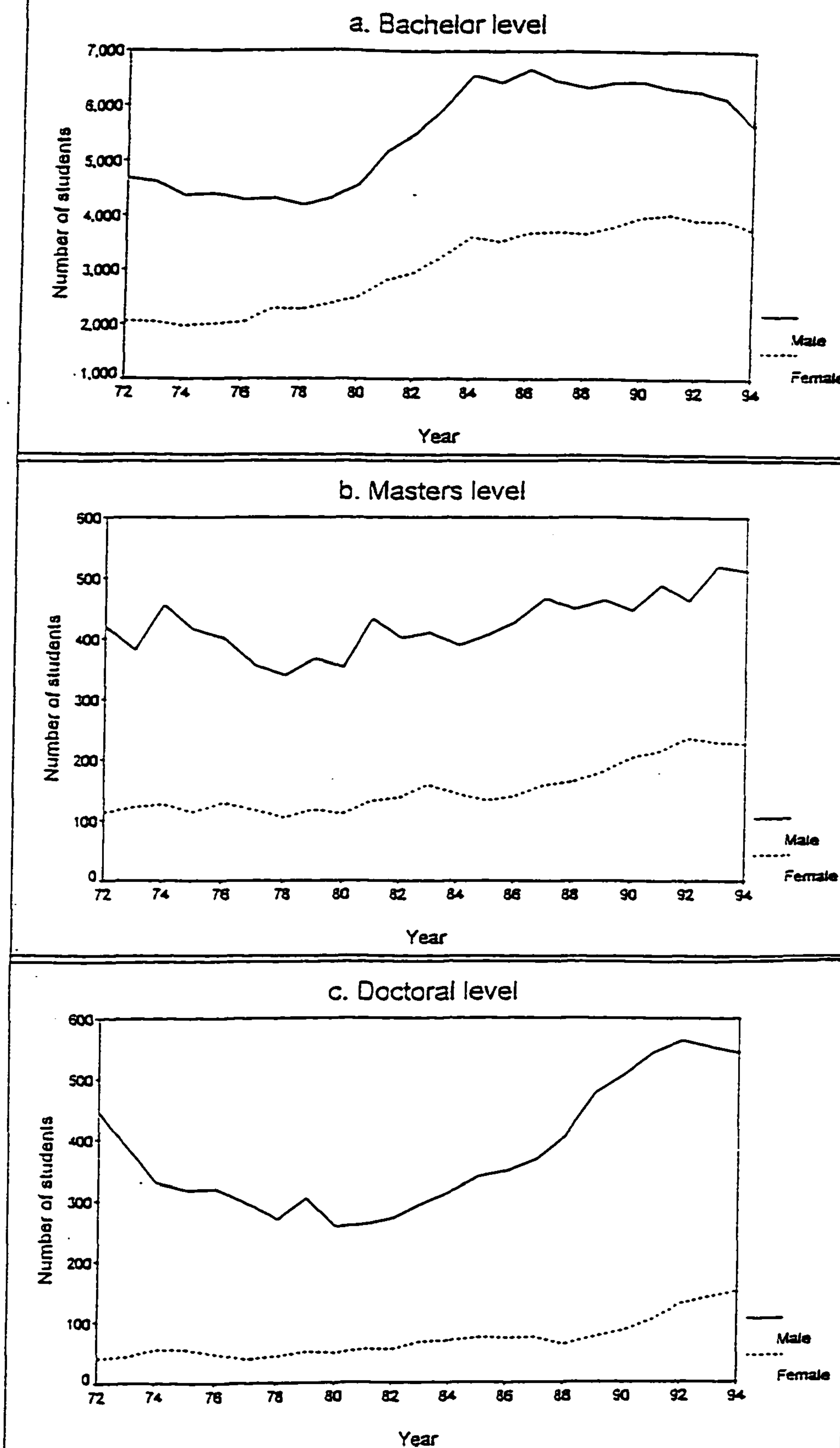
Table 3.2. Percentage of Part-time Students in Mathematics and in All Disciplines by Gender and Level of Study, Canada

Gender	Level of Study	All Disciplines		Mathematics	
		72/73	94/95	72/73	94/95
Women	Bachelor	33%	23%	12%	13%
	Masters	42%	43%	20%	18%
	Doctoral	29%	19%	24%	11%
Men	Bachelor	20%	18%	10%	15%
	Masters	43%	36%	26%	17%
	Doctoral	26%	15%	19%	11%

3.3. Trends of Mathematics Enrolment During the Period 72/73 to 94/95

Figure 3.4 represents numbers of men and women enrolled in mathematics programs in Canadian universities by level of study during the period 72/73 to 94/95. This figure illustrates that at both the bachelor and masters levels, mathematics enrolment for men and women exhibit quite similar trends with varying degrees of fluctuations. In absolute numbers, the gender gaps in mathematics enrolment at these two levels have been almost constant throughout the whole period. At the doctoral level, women's enrolment increased very slightly,

Figure 3.4. Mathematics enrolment by gender, Canada 1972-94



while men's enrolment exhibited a downward trend followed by a slow and then a rapid increase but decreased in 1993 and 1994. As a result, the gender gap in doctoral enrolment decreased and then increased back to its original size in 1972.

Table 3.2 includes proportions of mathematics students in part-time study by gender and level of study. The table shows that the proportions of students of both sexes who are in part-time study are much less in mathematics than in other disciplines. The table also shows that the most noticeable change in the proportion of part-time mathematics enrolment over the study period occurred for women in doctoral programs (a decline from 24% in 72/73 to 11% in 94/95), and for men in masters and doctoral programs (a decline from 26% and 19% in 72/73 to 17% and 11% in 94/95).

Table 3.3 provides data on 1972/73 and 1994/95 enrolment in mathematics programs by gender, level of study and registration status. As seen in this table, the number of students in mathematics programs increased considerably over the study period. Women's share of mathematics enrolment at both the bachelor and the masters levels increased by approximately 10% and at the doctoral level by about 13%. Although absolute numbers displayed in this table indicate improvement in women's representation in mathematics, careful examination of the whole picture will reveal the opposite to be true, i.e. women's representation in mathematics is falling behind their representation in other disciplines.

Table 3.3. Enrolment in Mathematics Programs by Gender, Level of Study and Registration Status, Canada

	1972/73				1994/95			
	Total	Men	Women		Total	Men	Women	
			number	%			number	%
Bachelor:								
Full-time	6,020	4,204	1,816	30.2	8,022	4,762	3,260	40.6
Part-time	710	474	236	33.2	1,358	866	492	36.2
Total	6,730	4,678	2,052	30.5	9,380	5,628	3,752	40.0
Masters:								
Full-time	399	309	90	22.6	607	422	185	30.5
Part-time	134	111	23	17.2	128	88	40	31.3
Total	533	420	113	21.2	735	510	225	30.6
Doctoral:								
Full-time	392	361	31	7.9	617	484	133	21.6
Part-time	95	85	10	10.5	75	58	17	22.7
Total	487	446	41	8.4	692	542	150	21.7
Total	7,750	5,544	2,206	28.5	10,807	6,680	4,127	38.2

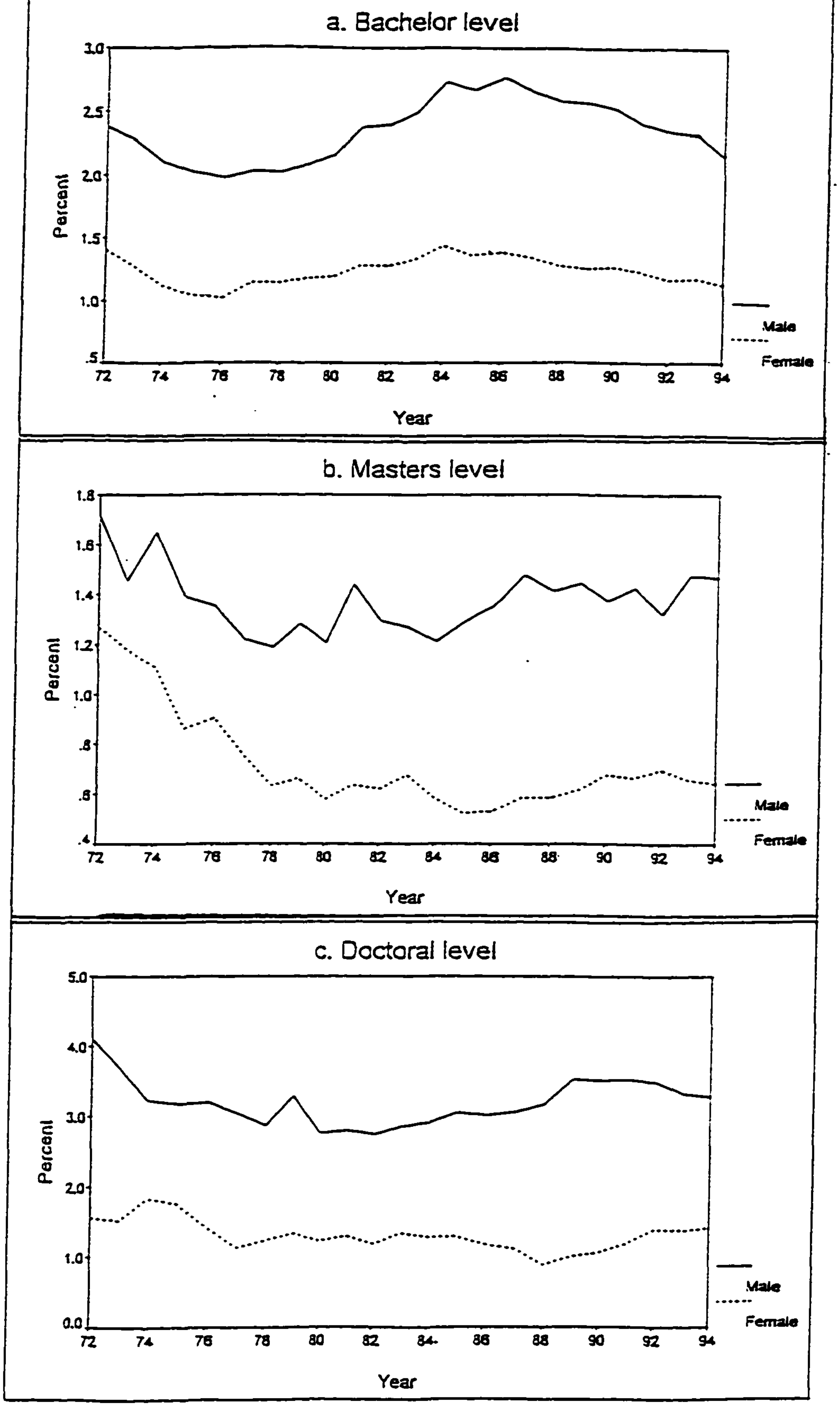
3.3.1. Parity Indices

The period under study was a time of immense social and demographic change in Canada. Women have been swelling the ranks in university programs at all levels. In order to isolate the trend toward women's increased presence in mathematics from the more general trend of their increased presence in university education, parity indices for men and women at each level of study are computed and compared. Parity index as defined by the National Science Foundation (1984) is the number of students in a specified discipline expressed as a percentage of the number of students in all programs.

Mathematics parity indices for men and women during the study period are displayed in Figure 3.5. In general, the figure reveals slight negative mathematics specific changes and gender specific changes in men's favour. At the bachelor level, the parity index curves for men and women show similar, periodic mathematics specific changes over the period studied. Men's and women's parity rise, fall, and level off over the same time periods suggesting that they are reacting to the same set of social and economic factors in the same direction. Both curves show a decrease in mathematics' share of university enrolment between 1972 and 1976, followed by a period of slow increase to 1980. From 1980 to 1986, the curves departed slightly with men's index increasing at a faster rate than women's. Both curves have been on the decrease since 1986 indicating that the likelihood of a bachelor student, of either sex, majoring in mathematics is on the decline.

At the masters level, both men's and women's curves exhibit a somewhat similar downward trend from 1972 to 1978 followed by a period of increase for men up to 1987 then a plateau from 1987 to 1994, while women's curve shows no particular trend during the period 1978 to 1994. In 94/95, only 0.6% of women at the masters level were majoring in mathematics as compared with 1.3% in 72/73. This indicates that the increase in women's participation in masters level mathematics fell short of the general increase in their participation at the masters level in other disciplines. Put another way, women's representation in masters level mathematics programs has not been as responsive to general social and economic changes as their representation in other masters level programs.

Figure 3.5. Mathematics parity index by gender, Canada 1972-94



Mathematics parity for men dropped very slightly from 1.7% in 72/73 to 1.5% in 94/95.

At the doctoral level, men's parity curve encompasses a period of moderate decrease followed by a period of slow increase and a plateau. The most striking feature of women's index curve is the apparent lack of trend over the study period. As a result, the gap between the two curves has been widening. Women's enrolment in mathematics doctoral programs has been fluctuating around 1.3% of all women doctoral enrolment, while the corresponding percentage for men during the last 6 years is 3.5% which is almost two and a half times that of women.

Differences in the shapes of the parity index curves for men and women indicate gender differences in the tendency toward the study of mathematics. The gap between men's and women's curves increased slightly over the study period in bachelor and doctoral programs and increased markedly in masters programs. For example, at the bachelor level, the two curves are almost parallel throughout the whole period except for the hump in men's curve during the 80s where women's enrolment failed to increase as much as men's. During the 70s, women turned away from pursuing masters degrees in mathematics. This results in widening the gender gap in mathematics participation at this level.

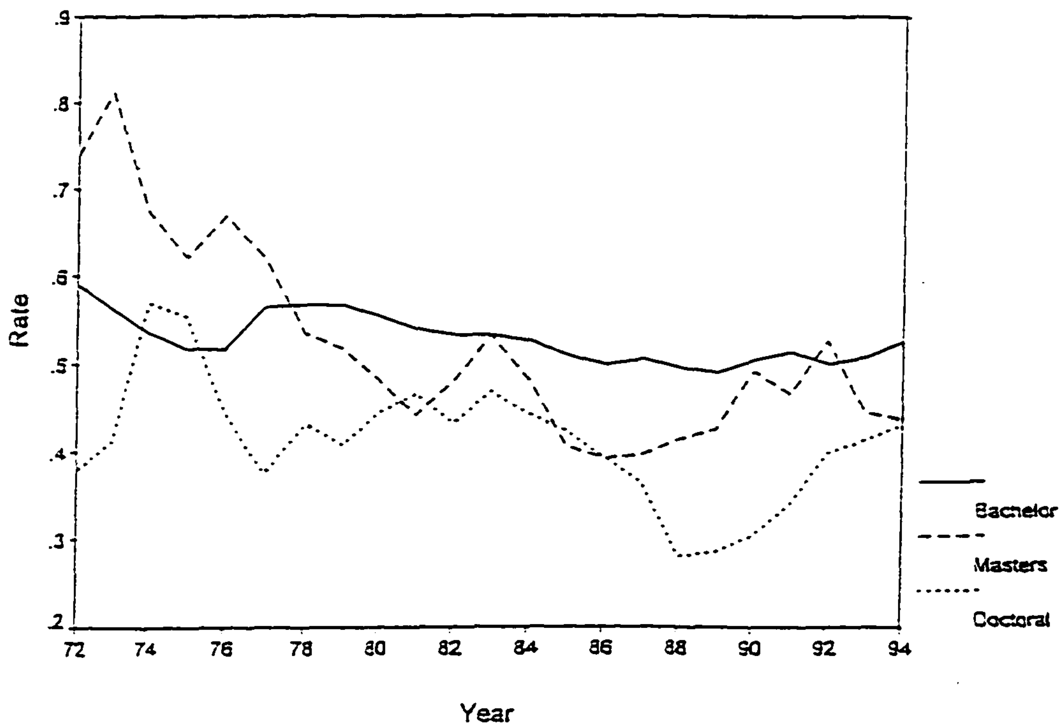
In summary, at the three levels of study, mathematics was losing students of both sexes to other programs during the period 1972 to about 1978, and although it gained some back, participation rates in mathematics never rose back to their 1972 levels. This is particularly true at the masters level.

3.3.2. Adjusted Participation Rate

Adjusted participation rate provides another way of looking at the progress women made in venturing into fields perceived by many as male areas. It measures gender specific changes in women's tendency to major in mathematics relative to men's. It is computed as the ratio of mathematics parity index for women to mathematics parity index for men. That is,

(female enrolment in mathematics/total female enrolment)/(male enrolment in mathematics/total male enrolment).

Figure 3.6. Adjusted participation rate in mathematics by level of study, Canada 1972-94



Adjusted participation rate can also be expressed as the proportion between the sex ratio of mathematics students and that of all students. Based on the assumption that men and women are able to achieve equally in mathematics, the sex ratio in mathematics should be equivalent to that in the student population in all fields. Thus, the difference between adjusted participation rate and one indicates the disparity in the rates at which men and women major in mathematics.

Adjusted participation rates at the three levels of study are displayed in Figure 3.6. The figure shows that the bachelor participation rate exhibits a slight downward trend, from 59% in 72/73 to 53% in 94/95, the masters rate a more noticeable downward trend, from 74% in 72/73 to 44% in 94/95, and the doctoral rate has been fluctuating around the 40% mark. That is, the likelihood of a woman undergraduate majoring in mathematics is about one half that of a man, and the likelihood of a woman in graduate study majoring in mathematics is about two fifths that of a man. Adjusted participation rate at the three levels combined decreased from 58% in 72/73 to 51% in 94/95. In other words, the likelihood of a woman university student majoring in mathematics relative to that of a man dropped from 58% to 51% over the study period.

3.4. Mathematics enrolment at the present time

The data in Tables 3.1 and 3.3 suggest the following points regarding enrolment in mathematics programs at the present time:

1. The proportion of students in both sexes enrolled in mathematics programs is

very low. Of a total of 690,713 students on campus, only 10,807 are studying mathematics, that is less than 1.6%. It is worth noting that the proportion of students of both sexes enrolled in mathematics doctoral programs in 94/95, 2.5%, is higher than their proportions at the bachelor's and master's levels, 1.6% and 1.1% respectively.

2. Mathematics is still predominantly a male field especially at the graduate level with men occupying approximately 7 out of every 10 masters level seats and 8 out of every 10 doctorate seats.

3. Female to male ratio in mathematics is about one half of the female to male ratio in all programs. That is, women are only about half as likely as men to major in mathematics. This likelihood is slightly higher at the bachelor level (53%), and lower at the masters and the doctoral levels (44% and 43% respectively).

3.4.1. Full-time Versus Part-time Enrolment

Part-time enrolment in mathematics in 94/95 accounted for about 14% in bachelor level programs, 17% in masters level programs, and 11% in doctoral level programs. These are about one half of the corresponding percentages in all fields (corresponding percentages in all fields are 21, 40, and 17). In other words, mathematics students of both sexes tend to pursue their studies in full-time capacity, more so than students in other programs. Although women's share of part-time enrolment in all programs at each of the 3 levels is around 7 percentage points higher than their share of full-time enrolment, in mathematics programs the picture is reversed. Women's share of part-time enrolment in mathematics is about 4 points less than their share of full-time enrolment at the bachelor level, and is about the same at the masters and the doctorate levels. In other words, there is little difference in the representation of women in part-time compared to full-time study in mathematics.

3.4.2. Women's Movement Through Levels of Study

Women's share of mathematics enrolment at the three levels of study are 40%, 30.6%, and 21.7%, a drop of about 9 percentage points with each higher level. Women's share of total enrolment decreases by about 6 percentage points from 55.9% to 50.2% as they move up from the bachelor to the master level, and by about 11 percentage points as they move to the doctorate level. In other words, women's drop out rate at the masters level is higher in mathematics than in other disciplines, and the opposite is true at the doctoral level.

In an attempt to disentangle gender specific and mathematics specific differences in enrolment, transition rates from the bachelor to the masters level, and from the masters to the doctoral level for men and women are computed and displayed in Table 3.4. There are three caveats here. Firstly, since transition rates are not based on the same cohort, they should be interpreted with caution. In addition, since a doctorate degree typically takes longer to complete than a masters degree, enrolment in doctoral programs at any point in time could correspond to multiple cohorts of masters students. Secondly, transition rates from bachelor to masters and from masters to doctoral are difficult to interpret because some students advance to doctoral programs without going through masters programs. Thirdly, bachelor degree graduates (not students enrolled) comprise the actual pool of candidates for graduate enrolment. Thus, the comparison of transition rates, as calculated here, implies the assumption that graduation rates in these disciplines are not vastly different.

Table 3.4. Transition Rates, Mathematics and All programs, Canada (Percentages)

	Mathematics		All programs	
	72/73	94/95	72/73	94/95
Women: bachelor->masters	5.5	6.0	6.1	10.6
masters->doctoral	36.3	66.7	29.5	30.3
bachelor->doctoral	2.0	4.0	1.8	3.2
Men: bachelor->masters	9.0	9.1	12.4	13.3
masters->doctoral	106.2	106.3	44.4	47.7
bachelor->doctoral	9.5	9.6	5.5	6.3

Out of all women enrolled in bachelor level programs, approximately 11% advance to the masters level; in mathematics, this ratio is only 6%. In other words, women in mathematics are less likely than women in other disciplines to make the leap to graduate studies. At the doctoral level, however, the picture is reversed. Of all women enrolled in masters level programs, approximately 30% proceed to the doctoral level; in mathematics this ratio is 67%. Put another way, once they are able to go over the hurdle of entry into graduate studies, women in mathematics are more than twice as likely as women in other disciplines to advance to the doctoral level.

Upon examining men's transition rates, it becomes apparent that they exhibit the same pattern as women's transition rates. That is, mathematics students of both sexes are less likely than students in other disciplines to make the leap to graduate studies, but once they make that leap, they are more than twice as likely to proceed to the doctoral level. Table 3.4 also reveals sizable gender differences in transition rates at both levels in favour of men.

It should be noted here that there could be a number of explanations for the high doctoral to masters enrolment proportion. It could be an artifact of the data since these enrolment figures do not belong to the same cohort of students, or it could be a result of doctoral students staying longer in their programs than masters students, or it could reflect a high proportion of honour students advancing directly from bachelor to doctoral programs without having to enrol in a masters program. The gender difference in transition rates however, still requires an explanation. Is it a difference in career intentions? For example, do women take on teaching positions and thus do not need graduate degrees? This does not seem likely in light of the fact that most mathematics teachers in high schools are men.

Comparing transition rates from bachelor to doctoral, we notice that both men and women advance to the doctoral level in mathematics more than in other disciplines, with a gender difference in favour of men, starker in mathematics than in other disciplines. In particular, a female studying for a bachelor degree is half as likely as a male colleague to advance to the doctoral level while in mathematics, a female studying for a bachelor degree is about 40% as likely as a male colleague to proceed to the doctoral level.

Is something unattractive about mathematics graduate programs? Are women graduating from mathematics bachelor programs not well prepared academically to pursue graduate study? Or is this a reflection of the job market demand for different levels of degrees? For example, mathematicians with first degrees can go into teaching (no graduate studies required), or with a doctoral degree into academics; is there then no demand for mathematicians with masters degrees?

3.5. Summary

In summary, examination of university enrolment statistics leads to the following conclusions:

(1) During the last 23 years, women's enrolment in university programs at all three levels increased steadily, and at a much steeper rate than men's enrolment. Since 1982, more women than men have been opting for university education. In 94/95, 24% of women aged 20-24 attended a bachelor program, compared to 18% of men. In recent years, university enrolment rates stabilized at their 1992 peaks. If this trend continues, a decline in university enrolment is to be expected.

(2) Women's share of university enrolment decreases at each higher level. Women

occupy 56% of the bachelor, 50% of the masters, and 39% of the doctoral seats.

(3) More and more students are pursuing their university study on a full time basis. Part-time enrolment in all programs, at all levels declined from 27% in 72/73 to 22% in 94/95. The proportion of part-time students at the masters level is almost twice as high as that at the bachelor or the doctoral level.

(4) Women's representation is higher among part-time students compared to full-time students. During the last two decades, the proportion of women in bachelor and doctoral programs who study on a part-time basis dropped by 10 percentage points (23% and 19% in 94/95), while the proportion in masters programs hardly changed.

Examination of enrolment in mathematics programs leads to the following conclusions:

(1) Although the number of students of both sexes enrolled in mathematics programs increased from 7,750 in 72/73 to 10,807 in 94/95 (an increase of 40%), the proportion of students studying mathematics among students in all programs decreased from 2% to 1.6%. At all three levels of study, mathematics was losing students of both sexes to other programs during the period 1972 to 1978, and although it gained some back, participation rates in mathematics never rose back to their 1972 levels.

(2) Mathematics is still predominantly a male field especially at the graduate level with men occupying approximately 7 out of every 10 masters level seats and 8 out of every 10 doctoral level seats.

(3) While women's share of university enrolment jumped from 40.5% in 72/73 to 54.6% in 94/95 (an increase of 14 percentage points), their share of mathematics enrolment increased from 28.5% to 38.2% (an increase of only 10 percentage points). As a result, the proportion of women studying mathematics to women in all programs decreased from 1.3% to 1.1%.

(4) Mathematics students tend to pursue their study on a full-time basis, more so in mathematics than in other disciplines. There is no gender difference in the proportions of students in part-time study in mathematics.

(5) Most of the increase in women's bachelor enrolment occurred in full-time enrolment. The proportion of women in part-time study in mathematics at the masters level is higher than that at both the bachelor and the doctoral levels.

(6) The likelihood that a female university student will major in mathematics relative to a male student has actually decreased in spite of the reported large increase in mathematics enrolment at the high school level. The likelihood of a woman university student majoring in mathematics in 72/73, was 58% compared to 51% in 94/95. This likelihood is higher in bachelor programs (53%) than in graduate programs (44%). In other words, women university students are only about half as likely as men to major in mathematics.

(7) The proportion of men in mathematics bachelor programs who go on to a doctoral program hardly changed over the study period while the proportion of women in bachelor programs who proceed to a doctoral program doubled. However, a woman in a mathematics bachelor program is still only about 40% as

likely as a man to proceed to a doctoral program.

(8) Road blocks for women in the mathematics education pipeline are located at entry into the field and at entry into masters level programs.

Chapter 4

Women's Enrolment in Engineering and Computer Science in Canada

4.1. Introduction

In this chapter, trends in women's representation in engineering programs and in computer science programs in Canada over the period 72/73 to 94/95 at the three levels of study are investigated. As defined by Statistics Canada, engineering programs include chemical, civil, electrical, mechanical, and other engineering. Parity indices and adjusted participation rates are examined in an attempt to disentangle subject specific and gender specific changes from the more general trend of increased women's presence on Canadian campuses. A snapshot of women's enrolment in engineering and computer science programs at the present time is presented. In each of these two fields, comparisons are made between (1) enrolment of women and men, and (2) enrolment in the specific field and all programs. Transition rates are used to study the advancement of women to graduate levels in engineering and computer science programs in relation to their advancement in all programs and to men's advancement to graduate levels in the specific discipline. Trends in women's enrolment in computer science and engineering programs at each of the three levels of study are contrasted with the trends in their enrolment in mathematics programs. Present levels of women's enrolment in computer science and engineering are contrasted with their enrolment in mathematics. Women's progress through levels of study in the three fields are also compared.

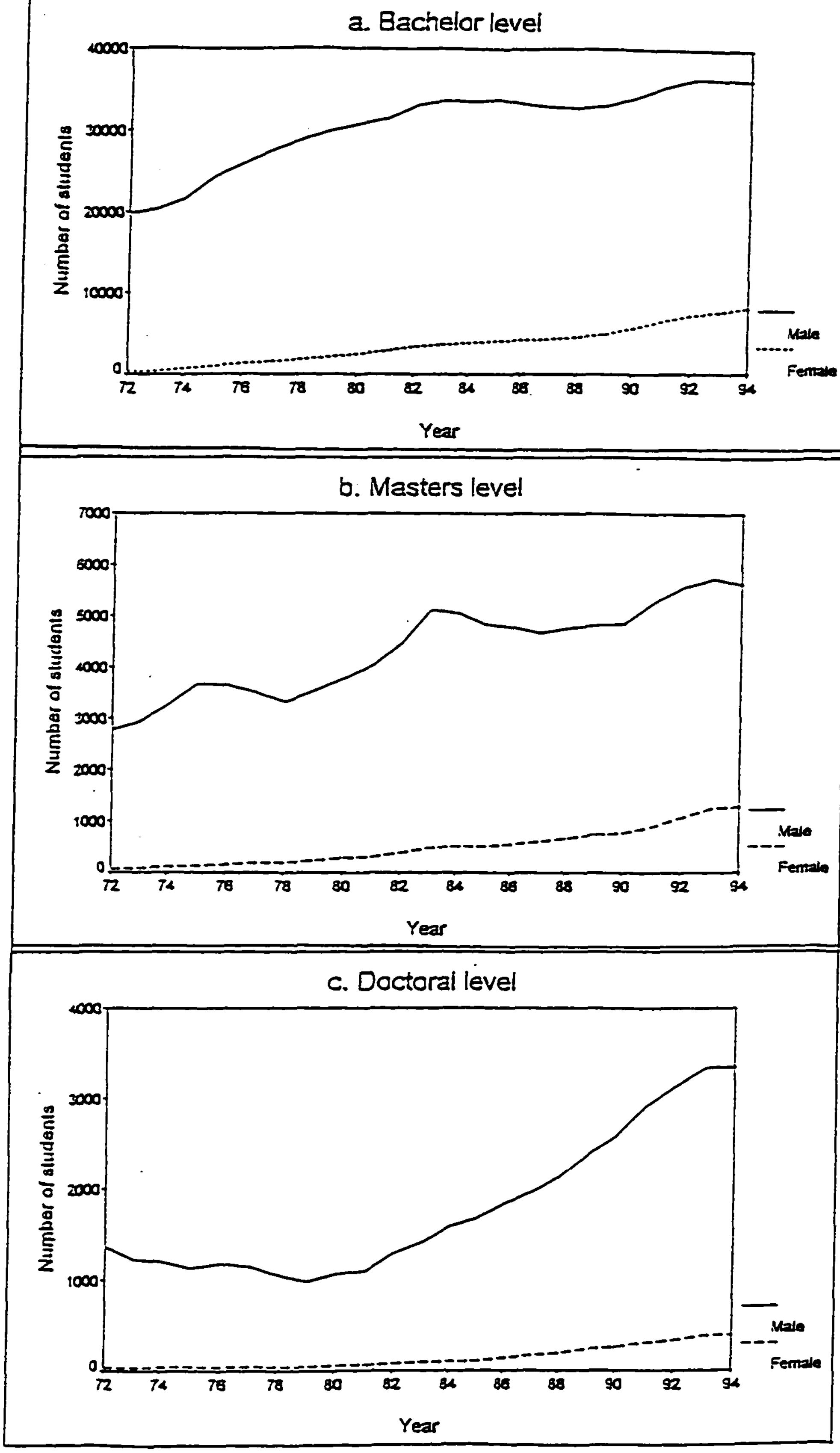
4.2. Engineering

4.2.1. Trends in Women's Enrolment During the Period 72/73 to 94/95

The number of men and the number of women enrolled in engineering programs in Canadian universities during the period 72/73 to 94/95 are plotted in Figure 4.1. This figure illustrates that at all three levels of study, the gender gap in enrolment is wider in 94/95 than in 72/73. In other words, the number of men enrolled in engineering programs has been increasing at a steeper rate than that of women. It is also apparent that in 94/95 enrolment at each of the three levels stabilized or fell slightly from its 93/94 level. In general, women's enrolment at all three levels exhibit less fluctuations than men's enrolment. Trends in men's and women's enrolment were most different at the doctoral level. In particular, number of men studying engineering declined slightly during the seventies, then increased rapidly during the eighties while the number of women showed lack of change during the 70s followed by a slight upward trend during the 80s and 90s. As a result, the gender gap in doctoral enrolment has been on the increase since 1982. In both bachelor and masters enrolment, the gender gap has been slowly and steadily increasing over the study period.

Table 4.1 provides data on 72/73 and 94/95 enrolment in engineering

Figure 4.1. Engineering enrolment by gender, Canada 1972-94



programs by gender, level of study and registration status. As seen in this table, the number of engineering students more than doubled over the study period. The number of women engineering students rose from 441 in 72/73 to 9,805 in 94/95. This corresponds to a 10 fold rise in women's share of engineering enrolment, from 1.8% in 72/73 to 17.9% in 94/95 with the highest increase at the bachelor level, from 1.7% in 72/73 to 18.4% in 94/95, and the lowest increase at the doctoral level from 2.7% in 72/73 to 10.4% in 94/95. It is interesting to note that women's share of masters and doctoral enrolment in 72/73 was higher than their share of bachelor enrolment. This means that as early as 1972, those very

Table 4.1. Enrolment in Engineering Programs by Gender, Level of Study and Registration Status, Canada

	1972/73				1994/95			
	Total	Men	Women		Total	Men	Women	
			number	%			number	%
Bachelor:								
Full-time	19,337	19,015	322	1.7	40,613	32,975	7,638	18.8
Part-time	814	799	15	1.8	3,683	3,180	503	13.7
Total	20,151	19,814	337	1.7	44,296	36,155	8,141	18.4
Masters:								
Full-time	1,772	1,723	49	2.8	5,050	4,061	989	19.6
Part-time	1,077	1,060	17	1.6	1,832	1,546	286	15.6
Total	2,849	2,783	66	2.3	6,882	5,607	1,275	18.5
Doctoral:								
Full-time	1,142	1,110	32	2.8	3,414	3,044	370	10.8
Part-time	256	250	6	2.3	314	295	19	6.1
Total	1,398	1,360	38	2.7	3,728	3,339	389	10.4
Total	24,398	23,957	441	1.8	54,906	45,101	9,805	17.9

few women who majored in engineering tended to persevere in this field and advanced to graduate levels in greater proportions than their men peers. In 94/95, women's portion of bachelor and masters enrolment were about equal at 18.4% and 18.5% respectively and was eight percentage points lower, at 10.4%, of doctoral seats.

It is also apparent from Table 4.1 that most of the increase in women's enrolment happened in full-time enrolment. Furthermore, contrary to the situation in all disciplines where women comprise the majority of part-time enrolment, their share of part-time engineering enrolment is approximately five percentage points lower than their share of full-time enrolment at all three levels of study. Table 4.2 includes proportions of engineering students who were in part-time study in 72/73 and 94/95 by gender. The proportion of part-time bachelor students to all engineering bachelor students increased from 4% in 72/73 to 6% in 94/95 for women and from 4% in 72/73 to 9% in 94/95 for men. Part-time enrolment at the masters and doctoral levels dropped noticeably for both sexes over the study period. In general, proportions of part-time students in engineering are markedly lower than their proportions in all disciplines (Table 3.2). In other words, engineering students of both sexes tend to pursue their studies on a full-time basis, more so in engineering than in other fields.

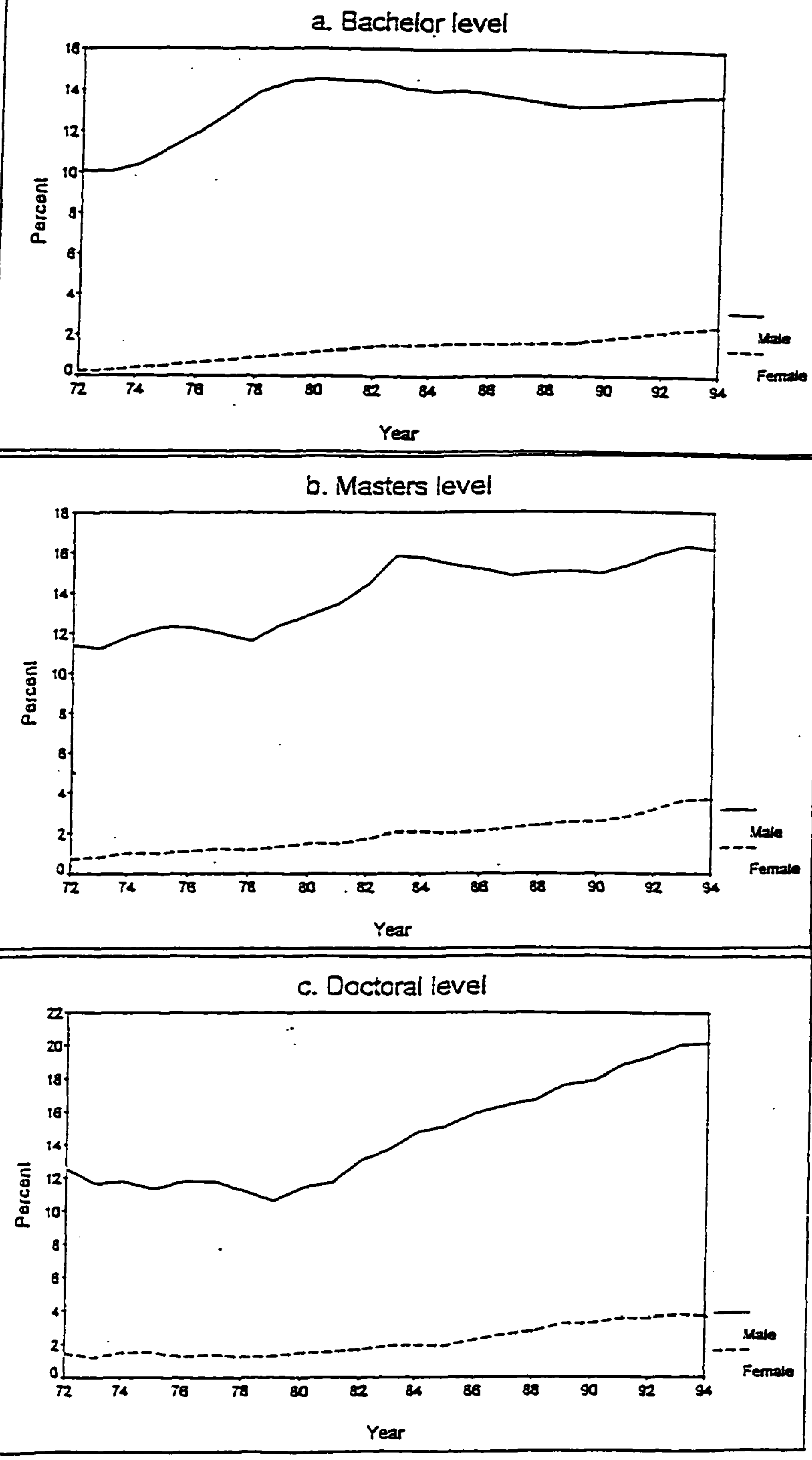
Table 4.2. Percentage of Part-time Students in Engineering by Gender and Level of Study, Canada

Gender	Level of Study	Engineering	
		72/73	94/95
Women	Bachelor	4%	6%
	Masters	26%	22%
	Doctoral	16%	5%
Men	Bachelor	4%	9%
	Masters	38%	28%
	Doctoral	18%	9%

4.2.1.1. Parity Indices

Engineering parity indices, i.e. proportion of students in engineering to students in all disciplines, during the study period are displayed in Figure 4.2. In general, the figure reveals positive engineering specific changes for both sexes at all three levels of study indicating that the likelihood of a university student of either sex majoring in engineering increased over the duration of the study. In addition, the fact that the parity indices for men and women exhibit different shapes reveal definite gender specificity. In particular, at all three levels of study, engineering share of university female students increased slightly and steadily during the whole period, while engineering share of male students had its ups, downs and plateaus with an overall upward trend steeper than that of women. Dissimilarities in the shapes of the parity curves for men and women together with the failure of women's parity indices to increase as much as men's suggest that

Figure 4.2. Engineering parity index by gender, Canada 1972-94



men's and women's engineering enrolments were reacting to dissimilar set of influences.

At the bachelor level, engineering share of male students increased sharply between 1974 and 1979, decreased slowly during the 80s and increased very slightly in the 90s. The proportion of engineering bachelor male students to all bachelor students rose from 10.1% in 72/73 to an all time high of 14.5% in 1980 and reached 13.8% in 94/95, while the proportion for female students rose steadily from 0.2% in 72/73 to a mere 2.5% in 94/95.

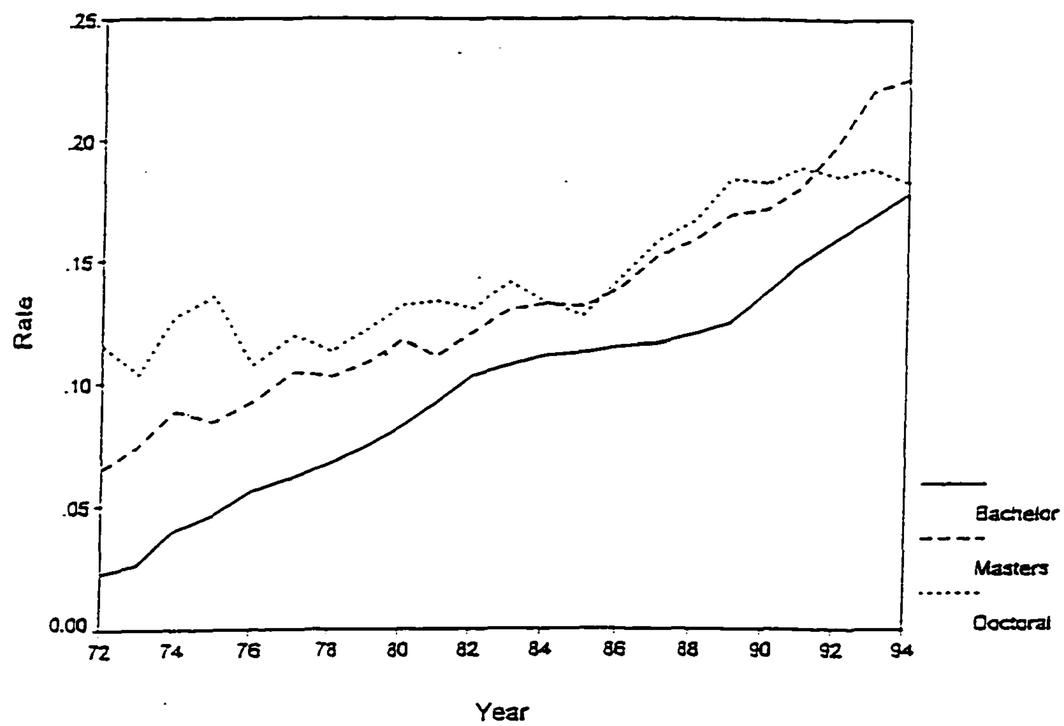
At the masters level, engineering share of male students was 11.4% in 72/73. It fluctuated over the study period and reached 16.1% in 94/95. Engineering share of female masters students rose from 0.7% in 72/73 to 3.6% in 94/95.

At the doctoral level, both men's and women's parity curves show lack of apparent trend during the 70s followed by steady moderate increase during the 80s and the 90s with men's index rising much faster than women's resulting in widening the gap between the two curves. Men's share of doctoral enrolment rose from 12.5% to 20.1% over the study period while women's share rose from 1.4% to 3.7%.

4.2.1.2. Adjusted Participation Rates

Adjusted participation rate measures the female to male ratio in engineering enrolment compared to the female to male ratio in all fields. It is a useful measure in comparing women's representation in engineering programs to their representation in all university programs. The larger the difference between this rate and one, the larger the disparity between women's representation in this field and their representation in all fields. Adjusted participation rates in engineering at the three levels of study are displayed in Figure 4.3. The most striking feature of this figure is the upward trends at the bachelor and masters levels which cover the whole study period. The figure shows that the bachelor participation rate grew from 2% in 72/73 to 18% in 94/95 and the masters rate grew from 7% to 23% while the doctoral rate grew from 12% to 18%. Adjusted participation rate at the

Figure 4.3. Adjusted participation rate in engineering by level of study, Canada 1972-94



doctoral level shows the most fluctuations, less overall increase and a plateau since 1989 to the present. Adjusted participation rate at the three levels combined rose from 2.7% to 18.1% over the study period. In other words, although the likelihood of a woman university student majoring in engineering relative to that of a man increased about 7 fold over the study period, a woman university student is still only 18% as likely as a man university student to major in engineering.

4.2.2. Engineering Enrolment at the Present Time

Eight percent of students of both sexes on Canadian campuses study engineering. This percentage is higher at the graduate levels than at the bachelor level. In particular, 10% of masters students and 14% of doctoral students study engineering while only 7% of bachelor students do. This means that a greater proportion of engineering students remain in the education pipeline compared to students in other fields.

Engineering is a predominantly male field. As shown in Table 4.1, women make up 17.9% of all engineering students; 18.4% at the bachelor level, 18.5% at the masters level, and 10.4% at the doctoral level. In spite of the ten fold rise in women's share of engineering enrolment, the female to male ratio in engineering is still less than one fifth of the female to male ratio in all fields of study. Put another way, the likelihood that a woman university student will major in engineering is less than one fifth that of a man.

4.2.2.1. Full-time Versus Part-time Enrolment

Part-time enrolment in 94/95 accounted for about 8%, 27%, and 8% in bachelor, masters, and doctoral programs respectively. These percentages are much lower than the corresponding 21%, 40%, and 17% in all fields. In other words, more students of both sexes pursue their studies in full-time capacity in engineering than in other fields.

Women's share of part-time enrolment in engineering is about 5 percentage points lower than their share of full-time enrolment at all three levels of study (Table 4.1). This is contrary to the situation in all fields where women's share of part-time enrolment is about 7 percentage points higher than their share in full-time enrolment (Table 3.1). Table 4.2 shows that the proportions of women in engineering who study on a part-time basis are consistently lower than that of men. This is also contrary to the situation in all fields where proportions of women studying on part-time basis are higher than those of men (Table 3.2). In 94/95, 6% of women in engineering bachelor programs and 5% in doctoral programs studied on a part-time basis. Nine percent of men in engineering bachelor and doctoral programs study on a part-time basis. The proportion of part-time students at the masters level is much higher: 22% of women and 28% of men.

4.2.2.2. Women's Movement Through Levels of Study

As shown in Table 4.1, women's share of engineering enrolment at the bachelor and masters levels are very similar, i.e. 18.4% and 18.5%, while their share at the doctoral level is 10.4%. This indicates that although graduate engineering programs do not lose women at entry into the masters level, they lose them at entry to the doctoral level. Table 4.3 provides another way of looking at the flow of students through levels of study by displaying the proportions of men and women engineering students moving up to higher levels of study. The table shows that in 94/95 about 16% of bachelor students of both sexes advance to a masters program, but twice as many men as women masters students advance to a doctoral program. That is, a woman engineer is just as likely as a man to move up to a masters program but is only half as likely to move up to a doctoral program. Surprisingly, in 72/73, the proportions of women engineers advancing to graduate programs were higher than those of men. While men's transition rates grew over the study period, women's rates declined substantially, especially at entry to the doctoral level. Specifically, the proportion of women doctoral to bachelor students declined from 11.3% to 4.8% while the corresponding proportion for men grew from 6.9% to 9.2% over the study period.

When comparing the proportions of students advancing to graduate levels in engineering with those in all fields (Tables 3.4 and 4.3), it becomes apparent that higher proportions of engineering students of both sexes seek graduate degrees than do students in other fields. Although fewer women than men enter the field of engineering, once women are able to go over the hurdle of entry into the field, they are more likely than women in other fields to advance to graduate studies. However, the number of men in doctoral programs as a proportion of those in bachelor programs is still twice as high as that of women, both in engineering and in all fields.

Table 4.3. Transition Rates by Gender, Engineering, Canada

	Engineering	
	72/73	94/95
Women: bachelor->masters	19.6%	15.7%
masters->doctoral	57.6%	30.5%
bachelor->doctoral	11.3%	4.8%
Men: bachelor->masters	14.0%	15.5%
masters->doctoral	48.9%	59.6%
bachelor->doctoral	6.9%	9.2%

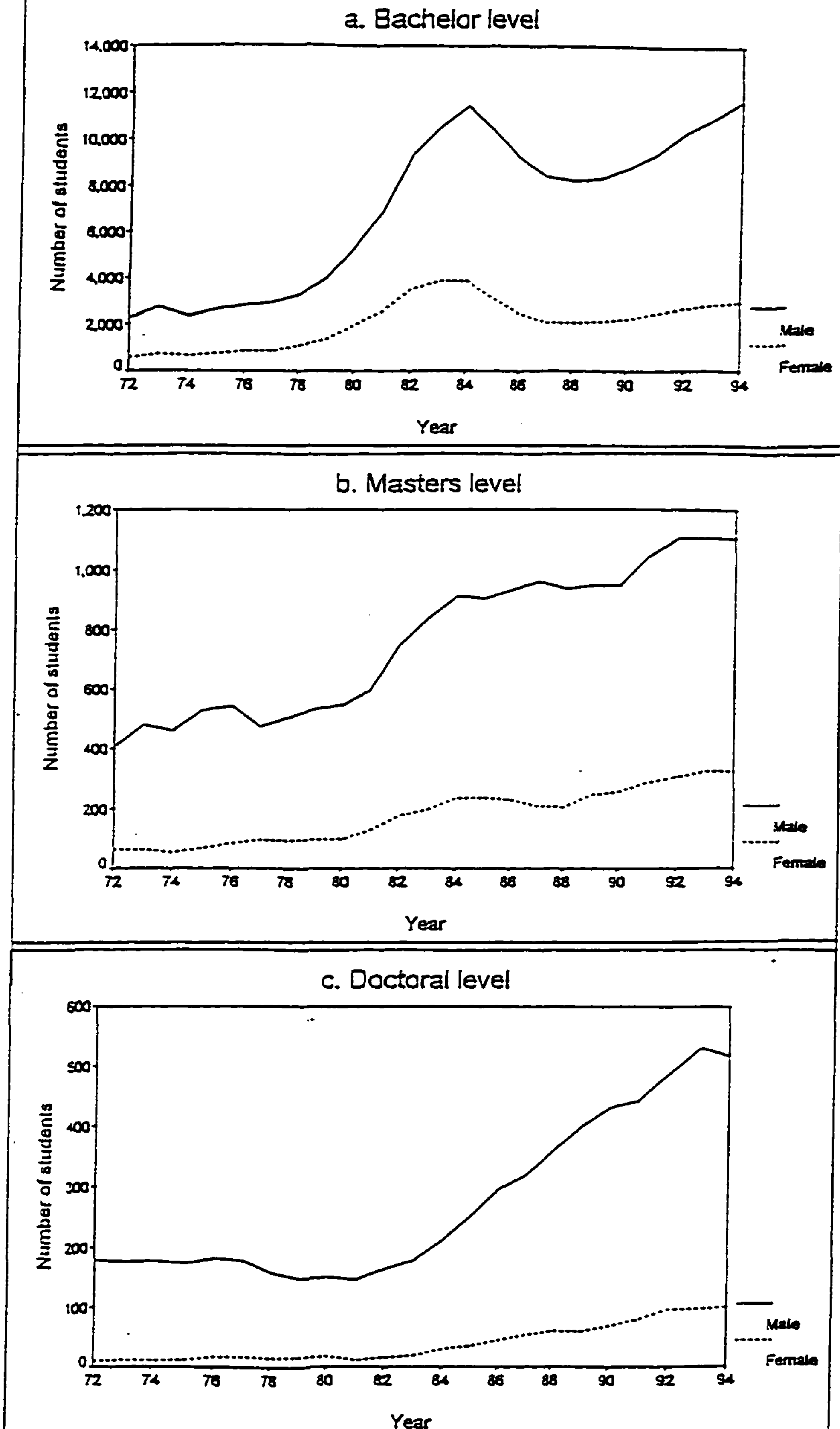
4.3. Computer Science

4.3.1. Trends in Women's Enrolment During the Period 72/73 to 94/95

Numbers of men and women enrolled in computer science programs in Canadian universities by level of study during the period 72/73 to 94/95 are displayed in Figure 4.4. A noticeable characteristic of this figure is the expansion in the gender gap in enrolment at all levels of study which started in 1980 in bachelor enrolment and in 1982 in graduate programs. This expansion is the result of a faster rise in men's enrolment compared to women's enrolment, the latter showing modest increases over the study period.

Men's bachelor enrolment demonstrates a curious trend, namely, a very steep climb between 1979 and 1984 followed by a decline which lasted for about

Figure 4.4. Computer science enrolment by gender, Canada 1972-94



three years, a plateau and a slower climb from 1989 to the present. Women's bachelor enrolment follows the same general trend exhibited by men's enrolment but with less dramatic shifts. The decrease in bachelor enrolment between 1985 and 1988 is not reflected in graduate enrolment.

Both men's and women's masters enrolment show intervals of increase and intervals of stability over the same time periods throughout the duration of the study but the increases in women's enrolment are always lower than the increases in men's. Men's and women's doctoral enrolment remained unchanged during the 1970s then started to depart with men's enrolment rising rapidly to 93/94 then declining in 94/95 and women's enrolment rising very slowly.

The numbers of students enrolled in computer science programs in 72/73 and 94/95 broken down by gender, level of study and registration status are presented in Table 4.4. This table shows that women's portion of computer science enrolment hardly changed over the last 23 years. In 94/95, women occupied 20.2% of all computer science places compared with 18.6% in 72/73. At the bachelor level women's portion was 20.2% in both years. At the masters level, women's enrolment rose from 13.6% in 72/73 to 22.6% in 94/95 whereas at the doctoral level, it rose from 5.3% to 16.2% during the same period. Most of the increase in women's bachelor enrolment took place in part-time enrolment. Women's portions of part-time bachelor and doctoral enrolment are higher than their portions in full-time enrolment.

Table 4.4. Enrolment in Computer Sciences Programs by Gender, Level of Study and Registration Status, Canada

	1972/73				1994/95			
	Total	Men	Women		Total	Men	Women	
			number	%			number	%
Bachelor:								
Full-time	2,630	2,081	549	20.9	11,263	9,085	2,178	19.3
Part-time	225	196	29	12.9	3,376	2,600	776	23.0
Total	2,855	2,277	578	20.2	14,639	11,685	2,954	20.2
Masters:								
Full-time	343	295	48	14.0	980	755	225	23.0
Part-time	127	111	16	12.6	447	349	98	21.9
Total	470	406	64	13.6	1,427	1,104	323	22.6
Doctoral:								
Full-time	147	137	10	6.8	526	443	83	15.8
Part-time	42	42	0	0	90	73	17	18.9
Total	189	179	10	5.3	616	516	100	16.2
Total	3,514	2,862	652	18.6	16,682	13,305	3,377	20.2

Table 4.5 includes proportions of computer science students who were in part-time study by gender and level of study in the years 72/73 and 94/95. The table reveals a large jump in the proportion of men and women in computer science programs who study on part-time basis at all levels except for men in doctoral programs whose proportion decreased from 23% in 72/73 to 14% in 94/95. In 72/73, proportions of women in part-time study were lower than those of men. In 94/95, this was reversed.

Table 4.5. Percentage of Part-time Students in Computer Science by Gender and Level of Study, Canada

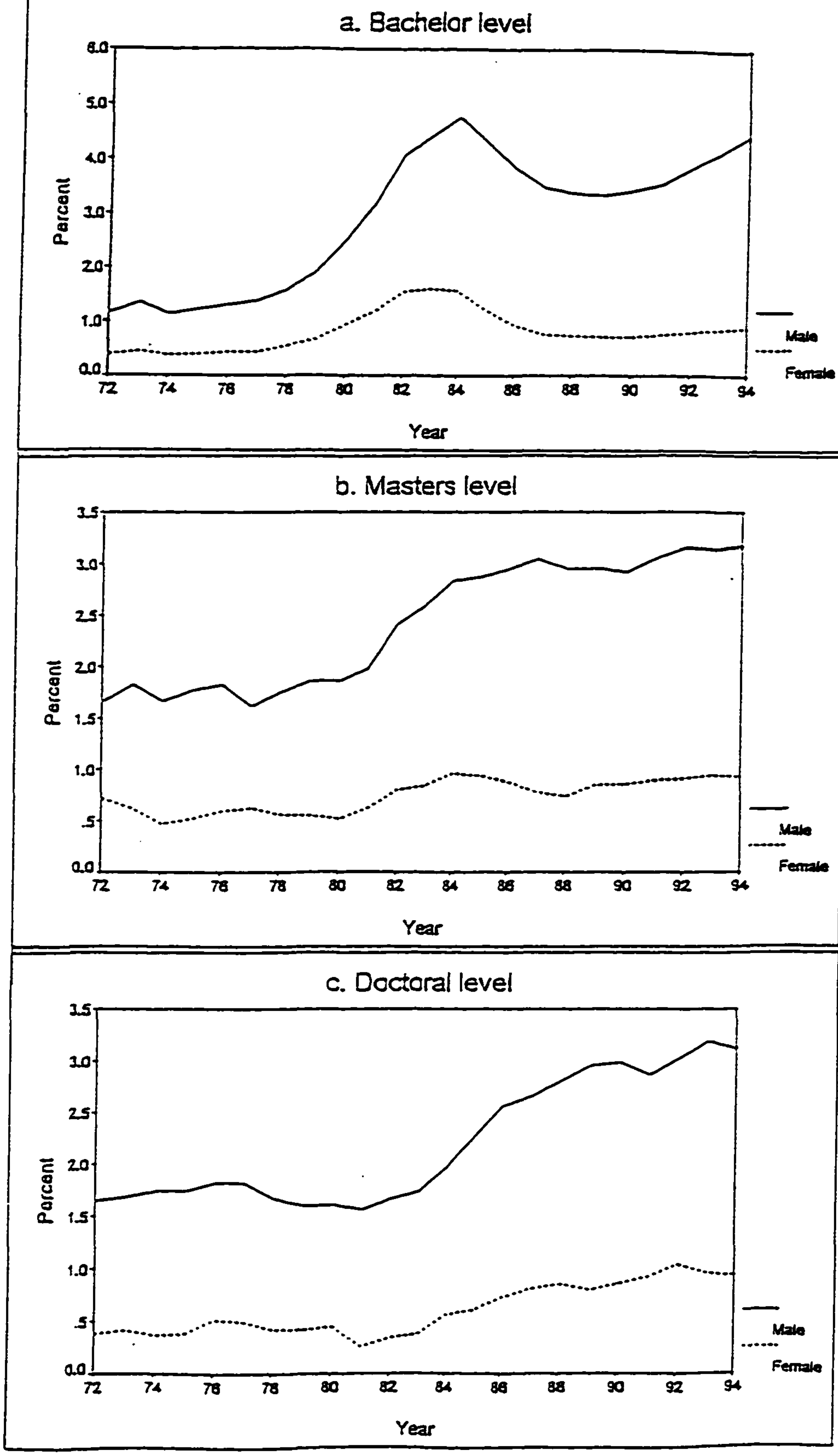
Gender	Level of Study	Computer science	
		72/73	94/95
Women	Bachelor	5%	26%
	Masters	25%	30%
	Doctoral	0%	17%
Men	Bachelor	9%	22%
	Masters	27%	32%
	Doctoral	23%	14%

4.3.1.1. Parity Indices

In 94/95, 2.4% of students in Canadian universities majored in computer science compared with 0.9% in 72/73. Almost all of the increase in computer science bachelor and masters enrolment took place in the late 70s and early 80s. In doctoral programs, most of the increase took place in the second half of the 80s. This increase, however, was not the same for men and women. Men's and women's enrolment in computer science programs as a proportion of their total university enrolment are plotted in Figure 4.5. In general, the curves demonstrate the same features demonstrated in Figure 4.4 by number of students enrolled. This means that the changes in computer science enrolment were field specific. Bachelor parity curves peaked in 1984, decreased sharply between 1984 and 1988, plateaud in the late 80s, and increased moderately in the 90s.

The gender gap in computer science enrolment at the bachelor level expanded markedly in the 80s and 90s. While 1.2% of men and 0.4% of women

Figure 4.5. Computer sc. parity index by gender, Canada 1972-94

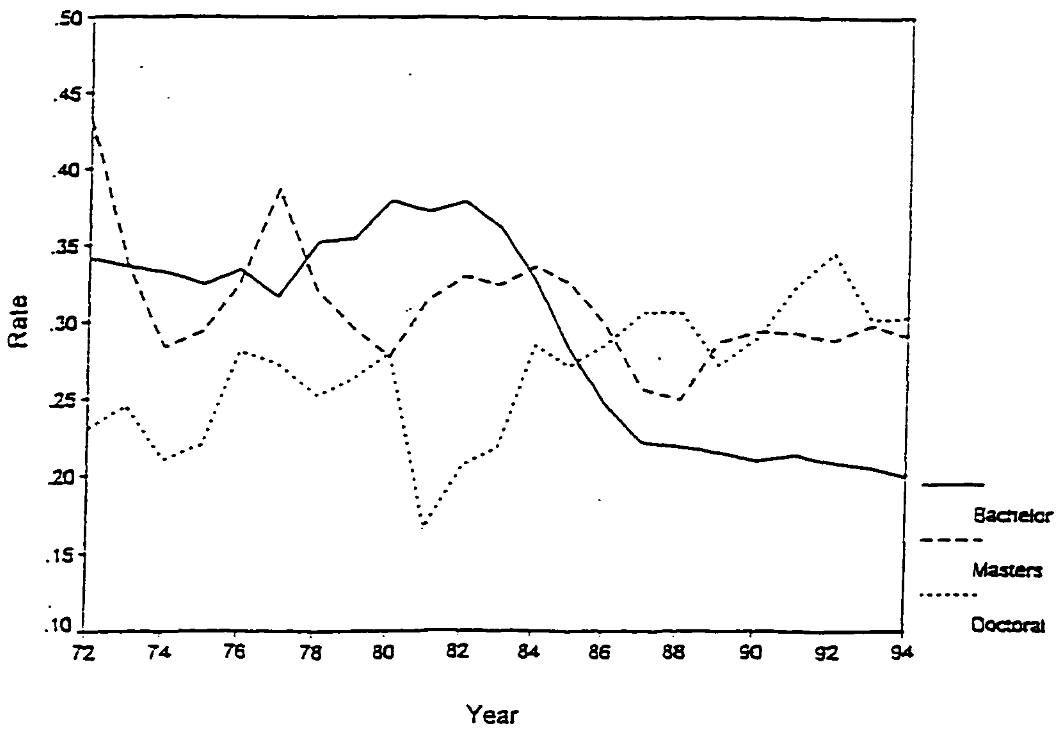


university students majored in this field in 72/73, the corresponding percentages in 94/95 were 4.2 and 0.9. This corresponds to a 2.25 fold increase for women and 3.5 fold increase for men. The gender gap in enrolment in graduate programs also expanded but to a lesser extent than it did in bachelor programs. For example, proportions of men and women masters students studying computer science in 72/73 were 1.7% and 0.7%; in 94/95, they were 3.2% and 0.9%. Proportions of men and women doctoral students studying computer science increased from 1.6% and 0.4% in 72/73 to 3.1% and 0.9%, respectively, in 94/95. This corresponds to about two fold increase for men and 1.5 fold increase for women in graduate programs. It is thus evident that at all three levels of study, changes in women's parity index echo changes in men's parity index in direction albeit less dramatic in magnitude. This suggests that gender specific factors might be causing women's enrolment to be less responsive than men's to economic and social factors which influence enrolment in this discipline.

4.3.1.2. Adjusted Participation Rates

Figure 4.6 shows the changes in adjusted participation rates for women in the field of computer science over the duration of the study. This figure reveals a decline in women's representation in this field especially at the bachelor level. The likelihood of a woman bachelor student majoring in this field compared to that of a man declined from 34% in 72/73 to 20% in 94/95. In other words, the likelihood of a woman university student majoring in computer science as compared to that of a man dropped from 34% in 72/73 to 20% in 94/95. Put another way, in 94/95, female to male ratio in this field as compared to the same ratio in all fields was about one half its value in 72/73. Almost all of this decline took place between 1982 and 1987 following a period of healthy improvement for women in the late 70s where their level of participation relative to men's was increasing. Adjusted participation rate at the masters level fluctuated between 72/73 and 1990 with an overall downward trend from 42% to 28% and stabilized in the 90s. Adjusted participation rate at the doctoral level also fluctuated over the duration of the study but with a slight overall upward trend from 24% in 72/73 to 29% in 94/95.

Figure 4.6. Adjusted participation rate in computer science by level of study, Canada 1972-94



4.3.2. Computer Science Enrolment at the Present Time

Of all students on Canadian campuses, only 2.4% study computer science. This percentage is about the same at all three levels of study. Less than 1% of women in university major in computer science. Women make up 20% of computer science bachelor enrolment, 23% of masters enrolment, and 16% of doctoral enrolment (Table 4.4). The female to male ratio in bachelor computer science programs is about one fifth of the female to male ratio in all fields; that is, the likelihood of a woman university student majoring in computer science is about one fifth that of a man.

4.3.2.1. Full-time Versus Part-time Enrolment

Part-time enrolment in 94/95 accounted for about 23%, 31%, and 15% in bachelor, masters, and doctoral programs respectively. These proportions are comparable to the 21%, 40%, and 17% seen in all fields. Upon comparing the data in tables 4.5 and 3.2 the following points are revealed: (1) the proportion of women in bachelor programs who study on a part-time basis is slightly higher than that observed in all fields (26% in computer science versus 23% in all fields), (2) in computer science masters programs, the proportion of part-time women students is 30% which is much lower than the 43% in all fields, and (3) in doctoral programs, the proportion of women who study on a part-time basis is slightly lower than that seen in all fields (17% versus 19%). In addition, Table 4.4 shows that the representation of women in part-time enrolment at the bachelor and doctoral levels is higher than their representation in full-time enrolment.

4.3.2.2. Women's Movement Through Levels of Study

Table 4.4 shows that the percentage of women at the masters level (22.6%) is higher than that at the bachelor level (20.2%). This suggests that the proportion of women bachelor students who move up to a masters program is higher than that of men. Women's share of doctoral enrolment, however, is only 16.2% indicating that although women do not drop out of the education pipeline at entry to the masters programs, they drop out at entry to the doctoral programs.

Table 4.6 presents men's and women's enrolment in masters and doctoral programs as proportions of their enrolment in bachelor and masters programs in 72/73 and 94/95. The table shows that the proportion of women in the masters programs to those at the bachelor level hardly changed over the last 23 years while the proportion of doctoral to masters enrolment almost doubled. As a consequence, the proportion of doctoral to bachelor enrolment doubled from 1.7% to 3.4%. On the other hand, the proportion of men's masters to bachelor enrolment dropped from 17.8% to 9.4% while their doctoral to masters proportion increased slightly. As a consequence, the proportion of men's doctoral to bachelor enrolment dropped from 7.9% to 4.4%. Women's doctoral to bachelor enrolment (3.4%) is not very different from men's (4.4%).

Table 4.6. Transition Rates by Gender, Computer Science, Canada

	Computer Science	
	72/73	94/95
Women: bachelor->masters	11.1%	10.9%
masters->doctoral	15.6%	31.0%
bachelor->doctoral	1.7%	3.4%
Men: bachelor->masters	17.8%	9.4%
masters->doctoral	44.1%	46.7%
bachelor->doctoral	7.9%	4.4%

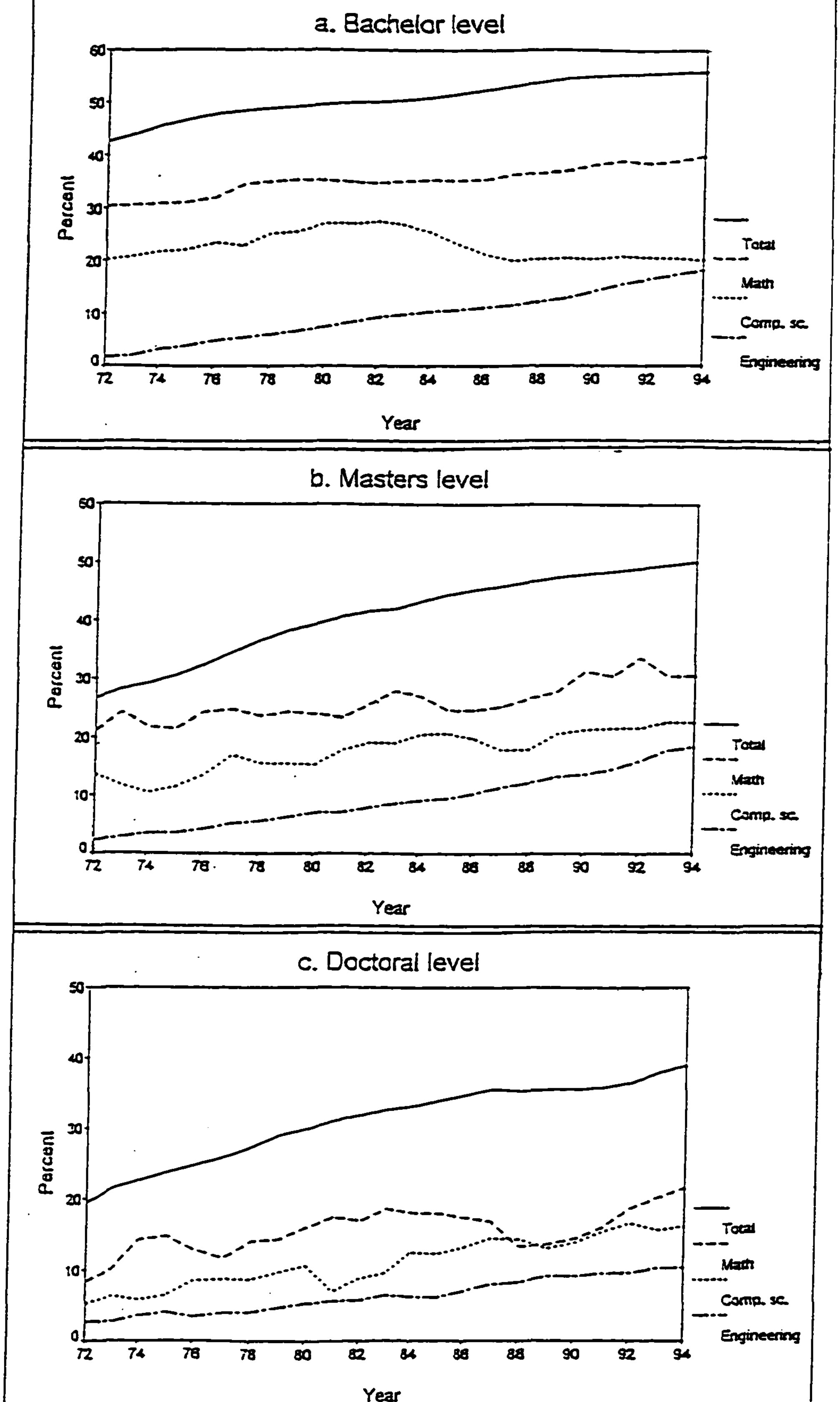
4.4. Comparisons Between Women's Enrolment in Engineering, Computer Science and Mathematics

4.4.1. Enrolment Trends During the Period 72/73 to 94/95

During the period under study, the proportion of university students of both sexes majoring in mathematics declined from 2% to 1.6%, whereas the proportion majoring in engineering increased from 6.3% to 7.9% and the proportion majoring in computer science increased from 0.9% to 2.4%. In other words, while the field of mathematics was losing students to other disciplines, the fields of engineering and computer science were attracting more students.

Time trends of women's share of university enrolment in all programs and in each of the three fields are depicted in Figure 4.7. The most striking feature of this figure is the trend exhibited by the proportion of women in computer science bachelor programs where it increased steadily between 1972 and 1982, then

Figure 4.7. Percentage of female enrolment, Canada 1972-94



decreased and remained almost stationary from 1987 to the present. In other words, women made good progress during the first 10 years considered in this study then turned away from this field in the late eighties and the nineties. This is unlike the trend of women's share of enrolment in engineering bachelor programs where it was steadily increasing throughout the whole period. Women's share of mathematics bachelor enrolment also increased steadily throughout the whole period but the increase is less steep than that seen in engineering. At both masters and doctoral levels, women's participation in all three fields showed some general upward trends which clearly fell below the expansion in their participation in graduate programs in other fields. In general, among the three fields under study, the representation of women is highest in mathematics followed by computer science and lowest in engineering. However, the difference between women's representation in computer science and their representation in engineering bachelor enrolment has been decreasing as a result of the increase in the numbers of women going into engineering programs.

Table 4.7 displays the gain in women's share of university enrolment at the three levels of study in all programs and in each of the three disciplines in the twenty three years under study. A number of observations arise from the data in this table:

(1) Among the three fields viewed as non-traditional for women, mathematics has always been the least male dominated one.

Table 4.7. Women's Share of Enrolment by Program and Level of Study, Canada

Discipline and Level	1972/73	1994/95	Gain in %
Mathematics :	28.5%	38.2%	9.7%
Bachelor	30.5%	40.0%	9.5%
Masters	21.8%	30.6%	9.4%
Doctoral	8.4%	21.7%	13.3%
Engineering:	1.8%	17.9%	16.1%
Bachelor	1.7%	18.4%	16.7%
Masters	2.3%	18.5%	16.2%
Doctoral	2.7%	10.4%	7.7%
Computer Science:	18.6%	20.2%	1.6%
Bachelor	20.2%	20.2%	0%
Masters	13.6%	22.6%	9.0%
Doctoral	5.3%	16.2%	10.9%
All Programs:	40.5%	54.6%	14.1%
Bachelor	42.6%	55.9%	13.3%
Masters	26.7%	50.2%	23.5%
Doctoral	19.5%	39.0%	19.5%

(2) With the exception of engineering bachelor programs, the gain in women's share of university enrolment in the three disciplines at all levels fell short of their overall gain in other programs. Put another way, the proportion of women in engineering bachelor programs has been increasing at a higher rate than their proportion in total university enrolment. This is in contrast to the situation in mathematics, computer science, and engineering graduate enrolment.

(3) The field of computer science has seen a dismal increase in the representation of women. This is particularly true at the undergraduate level where the proportion

of women in 94/95 was exactly the same as it was in 72/73.

Review of Figures 3.4, 3.5, 4.1, 4.2, 4.4, and 4.5 reveals the following points:

(1) In all 3 fields, number of students enrolled and parity at the masters level show the most fluctuations over time. This attests to the fact that the masters degree enrolment is difficult to evaluate since it is sometimes awarded as an indicator of progress toward a doctoral degree. Also, some honour students advance to the doctoral level directly after attainment of a bachelor degree.

(2) In all 3 fields, there is a marked expansion in the gender gap in enrolment in doctoral programs from 1981 to 93/94 as a result of a faster rise in men's enrolment. This expansion is more dramatic in engineering and computer science than in mathematics. This was not the case for enrolment in all disciplines where the gender gap in doctoral enrolment remained almost unchanged from 1981 onwards. In other words, while women's doctoral enrolment in all programs was rising at the same rate as men's enrolment, in mathematics, engineering and computer science it was rising at a much slower rate than men's.

(3) Except for computer bachelor programs, enrolment in all three disciplines in 1994/95 either dropped or remained unchanged from their level in 93/94.

Comparison of adjusted participation rates in the three disciplines (Figure 3.6, 4.3, and 4.6) indicates that women's representation in engineering relative to their representation in all programs has been steadily increasing over the past two decades which is in contrast to the downward trend exhibited by women's adjusted participation in computer science, especially at the bachelor and masters levels, and the almost static state of the mathematics participation rates.

4.4.2. Enrolment at the Present Time

Eight percent of university students study engineering whereas only 1.6% study mathematics and 2.4% study computer science. Women are still under-represented in all three fields but to different degrees. Data in table 4.7 show that women's participation in mathematics (38.2%) is more than twice as high as their participation in engineering (17.9) and almost twice as high as their participation in computer science (20.2%). The disparity in women's representation in these fields persists at the graduate level where they make up 21.7%, 10.4%, and 16.2% of doctoral enrolment in mathematics, engineering, and computer science, respectively. These proportions are much less than their 39% share of doctoral enrolment in all fields.

In 1994/95, women's adjusted participation rate at all three levels combined was 21% in computer science and 18% in engineering. That is, a female university student is about one fifth as likely as a male student to major in computer science and less than one fifth as likely as a male student to major in engineering. These are much lower odds than seen in mathematics where a female student is half as likely as a male student to major in mathematics.

4.4.2.1. Full-time Versus Part-time Enrolment

Examination of enrolment by registration status (Tables 3.2, 4.2 and 4.5) shows that among the three disciplines under study, bachelor and doctoral engineering programs have the lowest proportions of part-time student of both sexes (less than 10%). Computer science on the other hand, has the highest proportions of part-time students of both sexes. Among the three levels of study, masters programs in all three disciplines have the highest proportions of part-time students (27% in engineering, 32% in computer science, and 17% in mathematics). While most of the increase in women's enrolment in mathematics and engineering over the study period occurred in full-time study, most of the increase in their enrolment in computer science occurred in part-time study; this is especially true in bachelor and doctoral programs. One might wonder whether women in part-time study are those working in low-level technical jobs in the computer industry.

Table 4.8. Women's Share of Part-time and Full-time Enrolment by Discipline, Canada, 1994/95

Discipline	Full-time	Part-time	Total
Mathematics	38.7%	35.2%	38.2%
Engineering	18.3%	13.9%	17.9%
Computer science	19.5%	22.8%	20.2%
All disciplines	53.1%	60.0%	54.6%

Table 4.8 displays women's shares of part-time and full-time enrolment in

all programs and in mathematics, engineering and computer science. This table indicates that women in mathematics and engineering are better represented in full-time enrolment. This is in contrast to the situation in computer science and in total university enrolment.

Table 4.9. Percentages of Men and Women in Part-time Study by Discipline, Canada, 1994/95

Discipline	Women	Men
Mathematics	13.3%	15.1%
Engineering	8.2%	11.1%
Computer science	26.4%	22.7%
All disciplines	24.5%	19.7%

Table 4.9 displays data on enrolment by registration status viewed from a different angle. This table displays proportions of men and women university students who study on a part-time basis. As can be seen from these proportions, more than a quarter of women in computer science study on a part-time basis. This is much higher than their proportion in engineering (8.2%) and mathematics (13.3%).

4.4.2.2. Women's Movement Through Levels of Study

When comparing transition rates presented in tables 3.4, 4.3 and 4.6, the following points emerge:

(1) Doctoral female enrolment as a proportion of their bachelor enrolment in all

three fields are higher than that in all programs; 4.0% in mathematics, 4.8% in engineering, and 3.4% in computer science compared with 3.2% in all programs, indicating that once they get over the hurdle of entry into mathematical and scientific fields, women are more likely to advance to the doctoral level than in other fields.

(2) The gender difference in the above proportion is much larger in mathematics and engineering than in computer science. That is, proportions of doctoral to bachelor enrolment for men in mathematics and engineering are twice as high as those for women, while the difference in computer science is only 1% in favour of men.

(3) Assuming that the proportion of students advancing to doctoral study directly after bachelor attainment is similar across all three fields, one can conclude that the pattern of women's advancement through levels of study varies across the three disciplines. While women's share of mathematics enrolment drops by about 9 percentage points at each higher level of study, women's share of engineering enrolment is the same at the bachelor and the masters levels, and their share of computer science enrolment actually increases at the masters level. At the doctoral level, women's share of engineering enrolment drops by about 8 percentage points and their share of computer science enrolment drops by about 6 percentage points. The hurdle for women's advancement to graduate studies in mathematics seem to lie at the entry to the masters level while in engineering and computer science, it lies at the entry to the doctoral level.

4.5. Summary

Improvement in women's representation in mathematics, engineering, and computer sciences fell short of the improvement in their representation in other fields. Among the three fields under study, women's representation shows the most improvement in engineering, less so in mathematics and no improvement in computer science. However, the improvement is not sufficient as women are still far from achieving parity in these fields; this is most pronounced in computer science and engineering.

The field of engineering has been gaining students of both sexes from other disciplines. However, the likelihood that a woman university student will major in engineering is still less than one fifth that of a man. On the other hand, representation of women in the field of computer science as compared to their representation in university education has been declining while there has been little change in mathematics.

Women occupy 20% of all computer science seats and 18% of all engineering seats in Canadian universities. These are markedly lower than the 38% in mathematics. But despite their lower representation in engineering and computer science programs, women in the latter two fields do not seem to drop out from the education pipeline at the masters level at the same rate as women in mathematics do. The proportions of women advancing to graduate studies in all three fields are higher than those in all programs. This denotes that women who do get into these male dominated fields seem to stick with them. The gender gap in the likelihood of advancing to the doctoral level is much wider in mathematics and engineering than in computer science and other fields.

In mathematics and engineering, women's representation is higher in full-time compared to part-time enrolment, at each of the three levels of study. This is in contrast to women's representation in computer science and in all programs.

In conclusion, comparisons of enrolment in mathematics, engineering, and computer science programs reveal many differences among these disciplines in women's level and trend of enrolment in part-time and full time study, in the size of the gender gap in enrolment, and in the rate at which women progress to graduate study.

Chapter 5

Discussion and Recommendations

5.1. Introduction

University enrolment data analysed in chapters 3 and 4 show that women have been swelling the ranks of university programs at all levels and in all disciplines, yet they continue to be under-represented in mathematics, engineering, and computer science. The extent of women's under-representation and the pattern of enrolment over time are not uniform across these fields. Women seem to have always been better represented in mathematics than in computer science or engineering. Though women's representation in engineering has been improving, in computer science it has been deteriorating and in mathematics, it has been slightly declining. Moreover, although women in these three disciplines advance to graduate study at higher rates than women in other disciplines, their percentage decreases at each higher level of study. The rates at which women advance to graduate study as well as the gender difference in the likelihood of advancing to graduate study are also not uniform across the three disciplines. Proportionately twice as many men as women in mathematics and engineering bachelor programs advance to the doctoral level, but the gender difference in computer science is not as large (3.4% of women vs 4.4% of men).

Obstacles to women's full participation in mathematical and scientific fields are still very much at work. Such obstacles may discourage women from pursuing careers in these fields or keep them at a disadvantage if they do. The first step toward the elimination of these obstacles is to recognize them. Many such obstacles have been identified in the literature. The first part of this chapter contains a discussion of these obstacles and an assessment of their validity in light of the data presented in chapters 3 and 4. To that end, some additional data and research findings are introduced. Emphasis is placed on findings from Canadian studies and only when Canadian data are unavailable, data from American studies are used for illustration. The second part of this chapter contains specific recommendations and suggestions for policies to ensure equitable treatment of women in the study of mathematics, science and technology.

5.2. Discussion

5.2.1. The High School Years

High school mathematics courses have been declared a 'critical filter' for screening women out of mathematics and science university programs, and have long been blamed for the paucity of women in the scientific and technological work force (Wiggan et al., 1983). Many interventions and remedial measures have been adopted to encourage young women to take mathematics courses. A welcome rise in the number of women taking advanced level mathematics and science courses has been observed and documented. Table 5.1 presents numbers of students enrolled in high school OAC (Ontario Academic Credits leading to university) mathematics and science courses in Ontario in 1994 by gender. As shown in the table, women account for 46.2% of students enrolled in OAC mathematics courses. Upon comparing this percentage to the percentages of women enrolled in mathematics, computer science, and engineering bachelor programs in Ontario, i.e. 40%, 21% and 19%, one can conclude that many more women are well prepared in mathematics than choose to enter math-related university programs. Put another way, the under-representation of women in these fields, at least at the present time, is not due to women's lack of prerequisite mathematics courses.

Table 5.1. Enrolment in High School OAC Science and Mathematics Courses, Ontario, 1994

	Total	Men	Women	% Women
Mathematics	108,982	58,678	50,304	46.2
Biology	33,724	13,430	20,294	60.2
Chemistry	34,068	17,407	16,661	48.9
Physics	24,357	14,981	9,376	38.5

* Source: Nyhof-Young (1997).

Mathematics avoidance has also been proclaimed as a reason for women's reluctance to study scientific and mathematics related disciplines (Cottrell, 1992). Data presented in chapters 3 and 4, however, do not support this assertion; women's share of mathematics enrolment at the bachelor level is about twice as high as their share of engineering and computer science enrolment. If women choose not to enrol in engineering or computer science, it seems they do so not because they want to avoid mathematics.

Gender imbalance in high school science enrolment and proficiency have also been reported (Vetter, 1996). Table 5.1 shows however, that women graduating from high school are also well qualified in science. The percentages of women in OAC science courses ranges between 38.5% in physics to 60.2% in biology. Although high school female students choose to study biology and chemistry in much larger numbers than they do physics, these figures indicate that there are many more women qualified to pursue studies in science than actually do so.

Table 5.1 also shows that gender imbalance in enrolment is not uniform across subject matter specializations within science. Few studies address this issue at the high school level. Several studies report that gender differences in areas of interest within the sciences are observed as early as kindergarten and elementary school (Lawton and Bordens, 1995). Relevance to everyday life is also found to be very important to girls. Sjoberg (1990) reported that girls show interest in subjects only when placed in a context related to daily life or society. Does the presentation of science and technology in elementary and high school turn girls off these subjects? Regardless, the first step on the road to gender segregation of higher education, and hence the work force, seems to occur during the high school years. This is reflected in the twenty two percentage points difference between women's enrolment in OAC biology and their enrolment in OAC physics courses. Gender imbalance in enrolment at the high school level in Canada should be investigated, and its causes examined. This is important since courses taken in high school determine the range of career choices available to high school graduates.

5.2.2. Entry Into University

Academic competence. If many women high school graduates have taken mathematics and science courses, why do they continue to avoid study of mathematics, engineering and computer sciences? One might wonder whether women's grades in high school mathematics and science courses are lower than men's. Evidence from many US based studies indicate that men outperform women in standardized tests but women outperform men in classroom tests (e.g. Kimball, 1989), and that the differences, when they are present, are small and nonsignificant (Linn and Hyde, 1989). Although Canadian data on high school achievement levels by gender are scarce, particularly at the provincial and national levels, data on undergraduate scholarship awards (Council of Ontario Universities, 1995) seriously challenge the notion of superior male achievement. These scholarships are awarded solely on the basis of academic excellence, and as seen in Table 5.2 and Figure 5.1, women have consistently been awarded more admission and in-course scholarships from Ontario Universities than men. However, the report does not include a breakdown by discipline; it is, thus, unknown what subjects these men and women excelled in.

Table 5.2. Distribution of Undergraduate Scholarships by Gender, Ontario, 1994/95

Type of award	Number of awards	Total funds
Admission:		
Total	8,301	$8,803,275
Men	3,381	$3,718,922
Women	4,920	$5,084,353
In-course:		
Total	10,067	$9,254,810
Men	4,697	$4,328,884
Women	5,370	$4,925,926

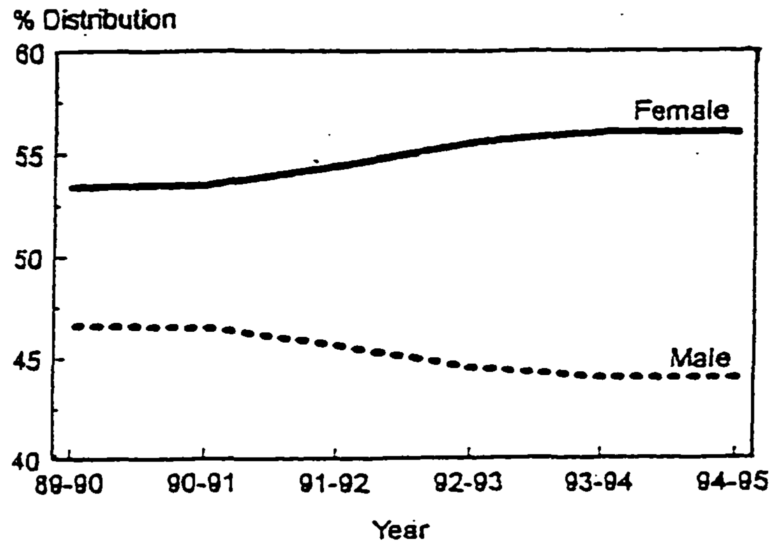
* Source: Council of Ontario Universities (1995).

Canada scholarship awards are awarded to top Canadian students entering their first year in a natural science or engineering program and renewed on the basis of their academic performance (Industry, Science and Technology Canada, 1992). These awards were contrived to encourage more students to study science and engineering. According to the program's 1991/92 report, 32% of that year's scholars studied engineering, 26% biological sciences, 18% general sciences, 9% physical sciences, 8% mathematics, 5% computer sciences, and 1% agriculture. Table 5.3 reveals a clear gender difference in discipline choice of these scholars with women maintaining majorities in agriculture, biological sciences, general sciences, and mathematics; and men dominating computer sciences, engineering and the physical sciences. The report also stated that women scholarship winners continue to follow mainly biological and health science career paths (44.2%) while engineering attracted only 24.5%, mathematics attracted 5.7% and computer sciences only 3%. Thus, the second step on the road to the gender segregation

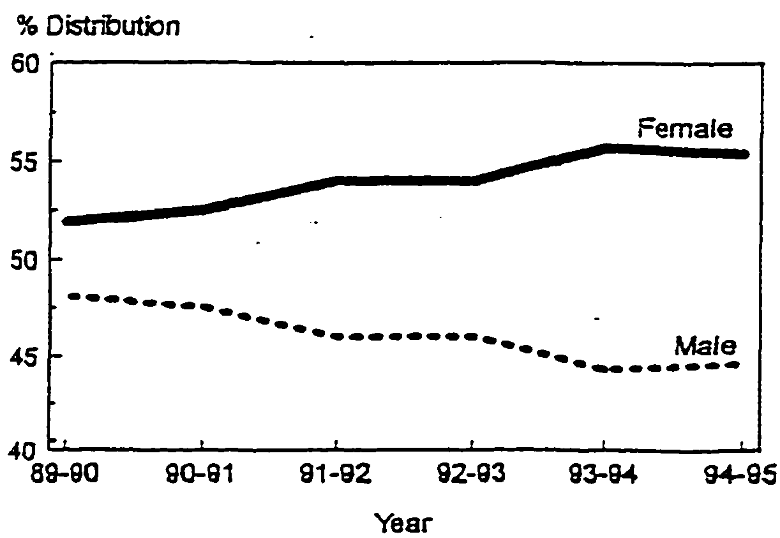
Figure 5.1. Undergraduate Scholarships at Ontario Universities

Percent distribution by gender, 1989/90 to 1994/95

Total Number of Awards



Total Funds



* Source: Council of Ontario Universities (1995).

of education occurs at entry to post-secondary institutions.

Table 5.3. Discipline Choice of Canadian Scholars by Gender, 1991/92

Discipline	% Women	% Men
Agriculture	67	33
Biological sciences	63	37
General sciences	63	37
Mathematics	56	44
Physical sciences	44	56
Engineering	40	60
Computer sciences	33	67
Total	52	48

* Source: Industry, Science and Technology Canada (1992).

Socialization. Why do academically capable women choose to study biological and health sciences and shy away from engineering and computer science? The decision to select a profession is greatly influenced by the profession's image in the minds of high school graduates. A woman's lack of enthusiasm for a certain profession is probably caused by an undesirable image of that profession, an image she is reluctant to identify with. It is suggested that the participation of women in engineering is much lower than their participation in medical and biological sciences because medicine, although governed by male norms, defines itself as a helping or service profession, an image that appeals to women while engineers define themselves very differently and that the large increase in women's enrolment in medical and biological sciences in recent years may hold a key to promoting similar improvements in other fields (Hollenshead, Wenzel, Lazarus and Nair, 1996).

The premise of this thesis is that there is no inherent physical or intellectual limitation to full participation of women in mathematics, science and technology. There is strong evidence, however, that society believes in rigid pre-defined sex roles and encourages boys and girls to fit in this paradigm. Many studies demonstrate that gender differences in mathematics and science achievement are insignificant (Lynn and Hyde, 1989), and many more show the differences to be in favour of women (Kimball, 1989). Yet, it appears that society, including parents and teachers, continue to hold inaccurate beliefs about the relative talents and abilities of boys and girls. Myths such as 'women can not do math' or 'women do math differently from men' still linger and affect the lives and careers of women in spite of lack of real evidence to support them and in spite of research findings indicating otherwise (Gray, 1996). In qualitative studies based on interviews with undergraduate students, women more than men rated family members and high school teachers as having significant influence on their career choice (Gilbert and Pomfret, 1995; Manis et al., 1989). Thus, parents and teachers who believe in gender role stereotyping may directly or indirectly discourage women from joining a traditionally male field. Also, parents who see science and computers as more important for boys may offer their daughters fewer opportunities for science and computing activities than boys. Research findings indicate that although parents' hopes for their daughters' and sons' educational achievement are similar, the jobs they expect them to do around the house and their career expectations are sex differentiated (Alloway, 1995). Evidence of gender role identification is observed in children at a very young age. Alloway (1995) reported that kindergarten children expressed opinions that boys could not be secretaries or kindergarten teachers, and that girls could not be park rangers or fire fighters. Oppler, Stocking, Goldstein and Ported (1993) studied the patterns of career interests in high ability seventh grade boys and girls in North Carolina. The students were asked to rate 59 occupations for liking/disliking. 'Research scientist' and 'medical doctors' were popular for boys and girls, but boys rated quantitative scientific occupations such as 'chemist', 'biologist' and 'engineer' more highly than did girls. In contrast, girls rated creative artistic careers more highly than boys. Assimilation with the culturally defined gender roles can limit the range of viable career options for women such that activities classified as part of the other gender's role are rejected, often unconsciously (Eccles, 1994). Socialization seems to be the real filter impeding women's full participation in the mathematical, scientific, and technological arenas.

Research findings indicate that teachers at all levels share society's beliefs about the abilities of men and women with regard to science and mathematics and their attitudes reflect society's convictions regarding sex-role stereotyping. Elementary school teachers, almost all women, tend to be inadequately trained in science and therefore, lack confidence in their abilities to teach science effectively

(Weiss, 1993), and university professors in mathematics and science are almost all men. Boys are reported to have more opportunities than girls to use scientific equipment, to perform experiments, and to take science-related field trips (NEAP, 1976-77). Sadker and Sadker (1994) reported that boys are more likely than girls to initiate classroom interaction with teachers, to respond to teachers' questions, and to receive feedback for their responses. It is not clear, however, if boys behave this way only in mathematics and science classes or in all classes. Nonetheless, the notion that women and science do not mix is emphasized at every stage of their lives and especially throughout their educational journey.

Psychological factors. Psychological research indicates that in spite of their demonstrated abilities, women display low self confidence in themselves as learners of mathematics, computers, and science, and express low opinions about their competence in these subjects (Leder, 1992). It is also reported that women attribute their success to extrinsic factors (luck or good teachers) and their failure to intrinsic factors (lack of ability), an attitude which can yield a belief in a low likelihood of a future success (Leder, 1992). Socialization of women against mathematics, science and technology explains why this phenomenon has such a damaging impact on women's self confidence and participation in these socially defined male fields while it does not affect their self confidence and participation in socially accepted female fields.

Interest. Interest is frequently mentioned by students of both sexes, more so by women than men, as one of the main reasons for their choice of subject specialization. In a longitudinal study of Wellesley undergraduates, Rayman and Brett (1993) found that the most important reason for not majoring in science was the students' greater interest in other subjects. In another study done at the University of Michigan (Manis, Thomas, Sloat and Davis, 1989), "personal enjoyment and interest," received the highest rating in a list of factors regarded as important by students of both sexes in their choice of specialization subject. Furthermore, women in scientific majors were more likely than men to identify this factor as the most important one. Why are women less interested in science careers than men? What are the factors that shape a person's interest in a subject or a career option? General factors such as socially constructed gender roles and students' out of school activities as well as specific factors such as curriculum, classroom and instructional factors in elementary and high schools must affect the formation of the students' interests and performance in mathematics, science and technology (Hidi and Baird, 1988).

In addition to the factors listed above, women's experiences in traditionally male fields, which are influenced by the institutional factors discussed in the following sections, in turn, will affect the profession's image in the minds of young women contemplating a career in these fields.

Factors affecting women's educational and career choices are inter-correlated in complex ways. It is unclear for example, how many of the gender patterns in education are due to individual preference and how many to social pressures to stay out of or move into various fields. Also unknown is how many influence these pressures have in shaping individual preferences.

5.2.3. The Undergraduate Years

The third step on the road of gender segregation of higher education takes place during the undergraduate years. Women who do get over the hurdle of entry into male dominated fields very quickly segregate themselves into specific majors through specialization, or they transfer to other fields, or drop out. For example, women studying engineering are known to be more attracted to chemical engineering and less to electrical and mechanical engineering. According to a report on women in science and engineering (Industry, Science, and Technology Canada, 1991) women constituted 24% of bachelor degree recipients in chemical engineering in 1989, but only 8% of bachelor degree recipients in each of mechanical and electrical engineering. Since these are all engineering professions, it is unclear whether this phenomenon is an outcome of the profession's image or an outcome of discipline specific factors, and/or personal preferences and interests.

While the process of selecting a university major is greatly influenced by the profession's image in the minds of high school graduates, by their individual interests in the subject matter, and by encouragement from family members and teachers, the decision to persist through graduation is greatly influenced by day-to-day experiences in the field. The satisfaction, retention, and success of women in their educational endeavours are influenced by institutional policies and practices. It is thus imperative to ensure that such policies and practices provide safe and equitable learning environments to women (Gilbert and Pomfret, 1995).

Data on retention rates in any field are difficult to find, and it is not usually clear whether students who drop out transfer to other majors in or out of the science and mathematics fields. In addition, studies on retention and drop out rates are normally restricted to one institution where factors specific to that institution may have a considerable influence on retention in some programs, a fact that can make the conclusions difficult to generalize. Data on retention and dropout rates in Canadian universities are particularly scarce and almost non-existent at the national and provincial levels. It is, thus, difficult to estimate the dimensions of this problem in Canada.

Vetter (1996) estimated about two thirds of the women who enter college with plans to major in engineering or physical science complete those plans. Astin and Sax (1996) reported an even lower retention rate of 47.4% for women in engineering. In a study done at the University of Guelph (Gilbert and Pomfret, 1995), out of a cohort of 471 women entering natural science and engineering programs in 1986, 273 were still in science and engineering four years later, that is a 58% retention rate. Although the retention rate for men of the same cohort was almost identical, 57%, the difficulties men and women experience in science programs, hence their reasons for leaving, were not similar. Factors that excluded other women from science and technology programs continue to disadvantage academic careers of women in these programs.

Curriculum. It is clearly evident from the data presented in chapters 3 and

4 that women's participation in the three disciplines under study varies a great deal. Thus, discipline specific factors such as curricula, topics, pedagogy, methods of instruction, context, applications, and presentation must influence women's participation in these fields in various degrees. In the University of Guelph longitudinal study mentioned in the previous section, women in science and engineering expressed dissatisfaction with the lack of flexibility in science programs, the fact that these programs do not have enough practical and hands on courses, and with the competitive nature and the 'weeding out' culture in science programs (Gilbert and Pomfret, 1995).

In the same study, of students entering science and engineering programs with an "A" high school average, only 31% of women maintained an "A" average in the first semester, compared to 53% of men. Four years later, this difference had become negligible with 29% of that year's women and 30% of that year's men maintaining an "A" average. The same pattern emerges from an examination of renewal rates of Canada Scholarships from first to second year. Only 46% of the 1988 women scholars renewed their scholarships as compared to 65% of men scholars. Approximately the same rates were observed in 1989. Most of the non-renewals (88%) occurred because the scholars did not maintain a sufficiently high academic standing in their first year of undergraduate study (Gilbert and Pomfret, 1995). The authors conclude that women face more academic and/or social difficulties in their first year of university than men do. Do women enter science and engineering programs with different expectations and purposes than men? If this is the case, then it seems that university education in these disciplines corresponds more to men's expectations and purposes than to women's. This could be due, at least in part, to the absence of women's input into the curricula, research, and study programs because of their near absence in faculty positions.

Climate. Qualitative research based on interviews with women in male-dominated fields suggests that these fields are inhospitable to women (Pearl et al., 1990). Being in a minority in a class or a lab makes female students visible, subjecting them to stereotyping and other perceptual distortions, and adding to the pressure they experience as students. Also, being a minority makes women feel isolated and out of place. Such feelings are alleviated when the proportion of women in the program increases. A variety of 'critical mass' theories estimate this proportion to be between 15% and 30% of students and faculty (Industry, Science and Technology Canada, 1991). Women in engineering and computer science also report concerns of physical safety when they need to access labs or public computers after hours (Brush, 1991).

Role Models. The presence of female faculty in universities can serve as evidence that a successful career in mathematics, science or technology is not only possible, but a viable option for women. Unfortunately, it is evident from the data in chapters 3 and 4, that the proportions of women in mathematics, engineering and computer science shrink from the bachelor to the masters to the doctoral level. Also the percentage of women faculty is still lower. According to the 1996 report on the status of women in Ontario universities, the percentage of women full-time faculty in engineering and applied science in 92/93 was 5.6% and in mathematics and the physical sciences 7.9%; these percentages are about half the percentages of women in doctoral programs in these two fields. Women undergraduates and graduates are exposed to few female faculty in these disciplines, a fact that reemphasizes society's pre-defined sex roles, adds to women's feelings of isolation and hence may discourage them from persisting in their programs. Moreover, the paucity of women in faculty positions deprives the field of women's input in shaping the curriculum, topics, and methods of instruction.

Access to Financial Aid. The 1989/90 Annual Report of Canada Student Loans Program states "women continued to outnumber men as recipients of Canada student loans. Loan authorization for women increased from 52% of total authorizations in 1985/86 to 56% in 1989/90." (p. 2). The distribution of loans by discipline however, is not known.

5.2.4. The Graduate Years

Data presented in chapters 3 and 4 suggest that although the likelihood that a woman advances to the doctoral level is higher in mathematical and scientific fields than in other fields, almost twice as many men as women do. With few women attaining doctorate degrees, the problem of not having enough women faculty and, hence, role models will be difficult to solve. Although some longitudinal studies in the US show that women doctoral students in science and engineering are less likely to complete their degrees and take longer to do so than their male peers (e. g. Hollenshead, Wenzel, Lazarus and Nair, 1996), Gonzalez (1996) found the opposite to be true in Canada. Gonzalez (1996) studied graduation rates and times to completion in doctoral programs in Canadian universities for the student cohorts of 1983 and 1984, and concluded that graduation rates in engineering were slightly higher for women than men (79.4% vs 68.9%) and in mathematics and the physical sciences, the rate was also higher for women (76.5% vs 72.1%). Gonzalez also found no gender difference in the mean time to completion of doctoral degrees in mathematics and physical sciences (4.7 years) and a slight difference in favour of men in engineering (5 years vs 4.6 years). In other words, once they pursue doctoral study, women seem to persist until graduation. The challenge to educators thus, is to encourage more women to undertake graduate studies and to make undergraduate studies more appealing so that women continue in these fields.

Data presented in chapters 3 and 4 suggest that while the hurdle impeding women's advancement through levels of study in mathematics seems to lie at entry to the masters level programs, in computer science and engineering it lies at entry to doctoral level programs. These fields should be examined for discipline specific factors which might help identify possible road blocks for women at these junctions.

Academic Competence. One might wonder whether women university graduates are as well qualified as men to pursue postgraduate education. The answer to this question might come from a US national study of the high school graduating class of 1972 where women were found to have continued education at the same rate as men, earned more scholarships than men, completed bachelor's degrees in shorter times than men, and earned better grades, even on a course by course basis. Women earned consistently higher grade point averages than men in the same class in every field, and the differences favouring women were greatest in the traditionally male fields of engineering, science, and business (Vetter, 1996).

Academic Advising and Mentoring. There have been reports of inadequate mentoring of female students by male faculty, and that such interactions have a negative impact on women's confidence. For example, women graduate students in science and engineering report feeling overlooked, unsupported, and not taken seriously by male advisors (Astin and Sax, 1996). Schroeder and Mynatt (1993) studied a sample of 151 women who had attended graduate school for at least one full academic year at one of three Midwestern universities. The subjects came from a variety of departments including art, biology, chemistry, engineering, English, geology, home economics, nursing, pathology, physics, psychology, social work, and sociology. Women students were surveyed to obtain information about their interactions with their major professors and asked to rate the professors' mentoring qualities, recognition of student's competence, concern for student's welfare, frequency of contact and quality of interaction. The authors found a significant effect of gender of main professor in favour of women professors, in concern for student welfare and quality of interactions.

Child Care and Family Obligations. In the University of Michigan study mentioned earlier, Manis et al. (1989) found that more women than men intended to proceed to graduate study (71% vs 66%) but more men than women expressed the intention to begin immediately. The authors concluded that at the postgraduate level, attrition of women from the sciences is not due to lack of interest but due to greater concern for other aspects of life. Although research findings indicate that marriage and children do not have negative effects on women's careers, students majoring in science express concern over the perceived difficulty of balancing career and family responsibilities (Seymour and Hewitt, 1994). Although one can assume that women in other disciplines are also concerned with other aspects of life and conclude that this factor is not specific to the sciences, the challenge of combining career preparation and family obligations is probably more difficult for science students because they are expected to spend a significant amount of time in laboratory work. Concern for child care may also have a significant influence on women's career choices after graduation. For example, doctoral students and recent graduates expressed preference for an industrial rather than an academic career because industry has more support systems for child care and maternity leave (Etzkowitz, Kemelgor, Nueschatz and Uzzi, 1994).

Other factors affecting retention of women in undergraduate science and technology programs - e.g. non supportive climate, curricula, and lack of role models - also deter women from going into graduate study. For example, Gilbert et al. (1983) studied the responses of 80 female and 77 male doctoral students in a psychology department in a large southwestern university to a mailed questionnaire, and found that female graduate students who identified female professors as role models viewed themselves as more confident, career oriented and instrumental than did female students who identified male professors as role models. Also, according to preliminary findings from an ongoing study at the University of Michigan (Pipeline project, 1994), women engineering seniors with above average grades endorsed the following reasons for not undertaking or hesitating to undertake graduate studies: 40% want to pursue more people oriented jobs, 25% are not interested in academic careers, 24% feel they don't need a graduate degree to get a good job, 24% believe they cannot afford graduate education, and 22% want to do more socially meaningful work.

5.2.5. The Work Experience

Reports on the degree of women's satisfaction in the work place undoubtedly play a role in shaping the profession's image in the minds of young women seeking a career in the same profession. Feelings of isolation, chilly climates, being excluded from 'the old boys club', the glass ceiling blocking them from advancing to leadership positions, overt and covert discrimination are repeatedly mentioned by women working in male dominated occupations (Brush, 1991; Spertus, 1991). A survey of 730 female members of the Association of Professional Engineers in Ontario conveys a somewhat less gloomy picture (Association of Professional Engineers of Ontario, 1990). The survey was carried out in 1989 by the Women in Engineering Advisory Committee to identify the concerns of women in engineering. Women engineers indicated that they are happy in their jobs and in their chosen profession and that their pay is comparable to that of their male peers. They also indicated, however, that their professional development lags behind, and that family commitments and maternity leave may penalize them professionally. Most of the respondents expressed concern over the inadequate promotion of engineering among young women in high schools and universities. Respondents also believed that lack of role models is a deterrent for young women interested in engineering. Two thirds of the respondents agreed that being a sole woman in an engineering team creates additional stresses. One half of the women surveyed thought that the image of engineering discourages women from pursuing a career in this field. Also, about half of them agreed that the "old boys" network is a benefit unfortunately not available to female engineers.

The lower salaries of women in scientific and technological jobs are reported as one of the disincentives to women majoring in these fields. According to Statistics Canada's published reports (Statistics Canada, 1995b), however, lower salary is a general phenomenon for women, one that is not confined to scientific and technological occupations. In addition, the data collected in the Canadian National Graduate Surveys indicated that the earning gap declines at higher degree levels and that, two years after graduation, women engineers in particular, earn as much as men. Although differential pay, and the statement it makes, should not be condoned by a society striving to achieve equity, lower salary expectations might discourage women from pursuing higher education in general rather than pose a barrier to women contemplating careers in specific fields.

Women in academia face additional difficulties due to the incompatibility of the typical 'tenure track' career requirements and family responsibilities (Pearl et al., 1990). Women who are married to men in academia suffer from lack of geographical mobility, coupled with the reluctance of educational institutions to hire both husband and wife (Etzkowitz et al., 1994). The 1996 report on the status of women in Ontario universities states that the average salary for full-time women faculty in 1992/93 ranged between 78% and 99% of the salary for a man depending on the rank, with the difference being smaller at lower ranks (Council of Ontario Universities, 1996).

5.2.6. The Computer Science Dilemma

The gender gap in computer science enrolment is particularly puzzling. Computer technology is a new field with no long history of sexism to overcome, and the expansion in this field occurred in the early seventies, almost at the same time as the birth of the feminist movement. At the beginning, the field was open to women but quickly became male dominated. Data presented in chapter 4 indicate that while women constituted 28% of bachelor degree enrolment in 1984, in 1987 they constituted only 20%. And although computer science programs suffered a decline in enrolment of both sexes during this period, men's enrolment quickly bounced back, while women's enrolment never returned to the 1984 level. This trend is particularly alarming for at least two reasons. First, it raises the distressing possibility that this field functions in a way that discourages women from joining it. Second, the absence of women from university computer science programs will close an expanding job market to them and hence, limit their career choices.

The computer gender gap begins early, with boys and girls believing that boys are better at computers than girls because they play more computer games. Hence, boys have more confidence in their computer knowledge. Collis and Ollila (1986) found that children as young as 3 to 6 years old already associate computers with boys rather than with girls. Among the grade 8 and grade 12 students interviewed by Collis (1985), sex differences in attitudes toward computers were strongly established by grade 8, with boys being more positive and showing more interest and pleasure in using computers.

Gender differences in access to computers has also been observed and documented. For example, Collis (1991), states that "Despite the (large) number of computers in schools, there is consistent evidence that females make less use of the technology than do males. This is particularly so with regard to participation in computer science courses at the secondary level." (p.147). Mckelvey (1984) noted in a study done in several Ontario schools that boys outnumbered girls 10 to 1 in using computers during extracurricular time.

Reasons for the low participation of women in computer science classes include the gender bias and stereotyping found in the vast majority of computer games which are aimed at the male market, women's lack of self confidence in their abilities even when their grades are higher than their male peers, women's perception of a computer scientist as a white male working in solitude and not being socially attractive, women's low self-esteem, often due to lack of role models or little family support, and their perceived lack of relevance of computers to their daily lives and interests (McGrath, 1996). McGrath (1996) also observed gender differences in teaching computers and suggested employing more women teachers of computer science to attract students with different range of learning styles. Collis (1991) proposed the development of a variety of computer applications that can be used in other high school subjects such as language arts, science, social studies, and art classes, thus, providing interesting and relevant computer experiences for a larger group of students.

5.3. Recommendations

Gender inequity has no single cause and there is no single obstacle whose removal would prevent it from occurring. Differing gender roles are present in virtually all societies and are conveyed to children through toys, story books, media information, parents' and teachers' attitudes, and by the very structure of the society they live in. If we are to achieve gender equity, the society at large needs to work at changing the gendered contexts in which we live, and encourage boys and girls to refuse restrictive gender identities. Policies aimed at promoting gender equity in the work place, such as equal pay and opportunity for promotion, should be implemented. Also, procedures and practices aimed at providing support to caregivers such as parental leave, child care and flexible time should be explored and utilized. Within the education system, changes are needed at several levels: in the classroom (through more inclusive teaching strategies), in the school (curriculum revisions, career counselling for students), and in the education system (more effective teacher education, building a more open education system). These are some specific recommendations:

1. Curriculum, course content, and teaching methods which allow students to explore science and technology as they relate to a broad social and environmental context should be encouraged. Every profession's ultimate aim is to advance standards of living and improve quality of life. Perhaps these human dimensions ought to be brought out and stressed.

2. Teachers at all levels should employ a variety of teaching styles, thus making the scientific enterprise more robust by using the full range of human potential. For example, if teaching practices that encourage competition and portray science careers as exceedingly demanding alienate some students, be they male or female, they should be avoided.

3. Professionals in male dominated fields should take a hard look at policies and practices in their fields in order to ensure that a fair and equal treatment be provided to all current and potential participants.

4. Elementary school teachers need better preparation in mathematics and science.

5. Elementary and high school teachers and university professors need better preparation in gender issues with the objective of raising their awareness of gender

matters.

6. Statistics showing that women can and actually do excel in mathematics and science, e.g percentages of women winning academic awards, should be publicised. Also, women who invest in engineering, mathematics and the physical sciences education have higher rates on return on their investment than women who invest in education in humanities. Based on these findings, if women's enrolment decisions are, at least in part, investment decisions, the dissemination of this information may in fact sway more women to enrol in these programs.

7. Effort should be directed at encouraging more women to enrol in the still male-dominated fields in order to provide the critical mass necessary to promoting women's social comfort and combat feelings of isolation.

8. Women from outside academia, for example from industry or government agencies, should be invited to mentor graduate students in scientific and technological programs.

9. It is important to facilitate multiple entry points to the education system rather than consider it a linear pipeline with one entry point. This would make education more accessible to students who take time off to raise families in subjects where students are expected to spend a significant length of time in laboratories.

10. Training programs should be developed for professionals who have to take time off to raise children so they are able to continue with their careers after an interruption.

11. With regard to computer science, gender neutral recreational and educational

software should be developed and promoted. In addition, a wide spectrum of computer applications should be developed and used in other high school classes. Also, technology education in schools needs to be restructured to ensure equal representation and active participation of girls.

5.4. Directions For Future Research

1. A full understanding of the problem of under-participation of women in mathematical and scientific fields requires more than an examination of statistics and demographics. There is a need for Canadian based research describing women's experiences in educational institutions at all levels. What are the reasons behind career choices made by high school graduates? How do women shape their expectations about what is possible for them with respect to fields of study and future careers? Why do women drop out after completing their bachelor degrees in mathematics and after completing their masters degrees in computer science and engineering?

2. Science encompasses a range of distinct subjects, each containing a variety of topics. As was illustrated in chapters 3 and 4, the extent of the gender imbalance and its trend over time is not uniform across the three fields under study. These disciplines also vary in their curricula and the types of occupations they lead to. There is a need for discipline specific studies, within the sciences, to find out about discipline-specific barriers which may act as deterrents to women in these disciplines.

3. While we know from the findings presented in chapter 4 that some gains in women's participation in engineering have been made, it is not known how much this gain is due to intervention efforts in recruiting women nor which interventions are most effective. In general, intervention efforts aimed at encouraging women to pursue non-traditional careers have not been properly evaluated. The effectiveness of these efforts need to be evaluated and the evaluation results be adequately disseminated.

4. The interaction of race, ethnicity, social class, and gender and the effect such interaction has on levels and patterns of participation in various educational disciplines should be studied with the objective of achieving educational equity for all individuals.

5. There is a need for studies on the development of academic interest with age and personal and environmental factors influencing this development at each stage of life. How do parents and early childhood educators influence children's academic interests? Methods to elicit situational interest and to utilize it in motivating students of all ages should be explored and implemented.

6. There is a need for studies of gender equity policies and their implementations in scientific and technological fields.

7. There is a need for Canadian studies on retention and dropout rates in the scientific and technological programs at the national and provincial levels.

8. Levels and trends of women's participation in other disciplines in and outside the science grouping should be examined and contrasted them with those in

mathematics, engineering and computer science.

9. Comparison of women's participation levels in mathematical and scientific fields across geographical regions within the Canadian borders may help identify institutional or policy barriers hindering women's progress in these fields.

5.5. Conclusion

Efforts to ensure equity for women in scientific and technological disciplines must precede, or at least accompany, efforts to persuade them to pursue these studies. To achieve gender equity in these disciplines, factors discouraging women from full participation in them should be removed. For the aim of understanding and appraising the factors contributing to the under-representation of women in these fields in Canadian universities, this study offers a factual characterisation of women's enrolment levels in mathematics, engineering, and computer science and the change in these levels over the period 1972 to 1995.

There is no single reason for the under-representation of women in mathematics, science, and technology. Researchers in this field have identified a variety of sociological, psychological, institutional and economic factors which interact in complex ways to deter women from pursuing careers in these areas. This study shows that many more differences in levels and patterns of women's enrolment exist among scientific and technological disciplines than can be explained by the more general factors discussed in the literature. This author proposes that discipline specific factors, such as curriculum, course content, instruction methods and context, interact with those general factors and modify their effects on women's participation in these disciplines. Professionals in male dominated educational disciplines should take responsibility for examining their specific programs with the objective of providing an equitable learning environment for women and men alike.

References

Acker, S. & Oatley, K. (1993). Gender issues in education for science and technology: Current situation and prospects for change. *Canadian Journal of Education*, 18(3), 255-272.

Alloway, N. (1995). *Foundation stones. The construction of gender in early childhood*. Carlton, Vic.: Curriculum Corporation.

Association of Professional Engineers in Ontario (APEO) (1990). *Making up the difference: Ontario women in engineering.* Prepared by Women in Engineering Advisory Committee.

Astin, H. & Sax, L. (1996). Developing scientific talent in undergraduate women. In C. Davis, A. B. Ginorio, C. S. Hollenshead, B. B. Lazarus, P. M. Rayman & Associates (Eds.), *The Equity Equation* (pp. 96-121). San Francisco: Jossey-Bass.

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.

Bernstein, D. (1992). A new introduction to computer science. In D. Martin & E. Murchie-Beyma (Eds.), *In search of gender free paradigms for computer sciences education*. International Society for Technology in Education.

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

Canadian Committee on Women in Engineering. (1992). *More than just numbers*. Ottawa: Canadian Committee on Women in Engineering.

Canadian Teachers' Federation (1992). *The better idea book, a resource book on gender, culture, science, and schools.* Ottawa: Canadian Teachers' Federation.

Chipman, S., Krantz, D. H. & Silver, R. (1992). Mathematics anxiety and science careers among able college women. *Psychological Science*, 3, 292-295.

Chipman, S., Krantz, D. H. & Silver, R. (1993). Mathematics anxiety/confidence and other determinants of college major selection. Paper presented at the International Committee on Mathematics Instruction Study Conference on Gender and Mathematics Education. Hoor, Sweden, 7-12 October, 1993.

Chipman, S.F. & Thomas, V.G. (1985). Women's participation in mathematics: Outlining the problem. In S. F. Chipman, L. Brush & D. Wilson (Eds.), *Women and mathematics: Balancing the equation* (pp. 1-24). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chipman, S.F. & Wilson, D.M. (1985). Understanding mathematics course enrolment and mathematics achievement: A synthesis of the research. In S. F. Chipman, L. Brush & D. Wilson (Eds.), *Women and mathematics: Balancing the equation* (pp. 275-328). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chipman, S. (1996). Female participation in the study of mathematics: The US situation. In G. Hanna (Ed.), *Towards gender equity in mathematics education, an ICMI study* (pp. 285-296). Dordrecht: Kluwer Academic Publishers.

Clark, M. (1996). Education in New Zealand. In G. Hanna (Ed.), *Towards gender equity in mathematics education, an ICMI study* (pp. 257-270). Dordrecht: Kluwer Academic Publishers.

Collis, B. (1985). Sex differences in secondary school students' attitudes toward computers. *The Computing Teacher,* 12(7), 33-36.

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.

Collis, B. & Ollila, L. (1986). Gender stereotypes about reading, writing, and computer use in pre school, kindergarten, and grade 1 boys and girls. Paper presented at the Annual Meeting of the Canadian Society for Studies in Education, Winnipeg, Manitoba.

Committee W on the Status of Women in the Academic Profession (1996). Women in science. *Academe* (May-June).

Cottrell, J. (1992). I'm a stranger here myself: A consideration of women in computing. In *Learning from the past, stepping into the future* (pp. 71-76). The proceedings of the 1992 ACM SIGUCCS User Services Conference, Nov

8-11, 1992, Cleveland, OH. New York: The Association for Computing and Machinery.

Council of Ontario Universities (1994). *Women's role in economic recovery.* Toronto: Council of Ontario Universities.

Council of Ontario Universities (1995). *Undergraduate scholarships at Ontario universities.* Prepared by the External Relations Division. Toronto: Council of Ontario Universities.

Council of Ontario Universities (1996). *1985/86 to 1994/95 Status of women in provincially assisted Ontario universities and related institutions.* Prepared by the Committee on the Status of Women. Toronto: Council of Ontario Universities.

Denton, F. & Spencer, B. (1992). *Modelling and analysis of postsecondary institutional enrolment patterns in Ontario.* Hamilton, Ontario: McMaster University.

Department of Secretary of State Canada (1991). *Canada student loans program. Annual Report for the year 1989/90.* Ottawa: Department of Secretaty of State Canada.

Dewey, J. (1913). *Interest and effort in education.* Boston: Houghton Mifflin.

Eccles, J. (1994). Understanding women's educational and occupational choices: Applying the Eccles model of achievement-related choices. *Psychology of Women Quarterly,* 18, 585-609.

Etzkowitz, H., Kemelgor, C., Neuschatz, M. & Uzzi, B. (1994). Barriers to women in academic science and engineering. In W. Pearson Jr. and I. Fechter (Eds.), *Who will do science? Educating the next generation.* Baltimore: John Hopkins University Press.

Feingold, A. (1988). Cognitive gender differences are disappearing. *American Psychologist*, 23, 95-103.

Fennema, E. (1977). Influences of selective cognitive, affective, and educational variables on sex-related differences in mathematics learning and studying. In *Women and Mathematics: Research Perspective for Change*. Washington, D.C.: The National Institute of Education.

Fennema, E. (1985). Explaining sex-related differences in mathematics: Theoretical models. *Educational Studies in Mathematics*, 16, 303-320.

Fennema, E. (1996). Mathematics, gender, and research. In G. Hanna (Ed.), *Towards gender equity in mathematics education, an ICMI study* (pp. 9-26). Dordrecht: Kluwer Academic Publishers.

Fennema, E. & Leder, G. (1990). *Mathematics and gender.* Teachers College, Columbia University New York and London. Teachers College Press.

Foot, D. & Pervin, B. (1983). The determinants of postsecondary enrolment rates in Ontario. *The Canadian Journal of Higher Education*, 13, 1-22.

Freeman, R. (1986). Demand for education. In O. Ashenfelter & R. Layard (Eds.), *Handbook of Labour Economics, Vol 1.* Amsterdam: Elsevier.

Gaffney, J. & Gill, J. (1996). Gender and mathematics in the context of Australian education. In G. Hanna (Ed.), *Towards gender equity in mathematics education, an ICMI study* (pp. 237-256). Dordrecht: Kluwer Academic Publishers.

Gardner, P. L. (1996). Students' interest in science and technology: Gender, age and other factors. International Invitational Conference on Interest and Gender: Issues of Development and Change in Learning. Munich, Germany, 9-13 June 1996.

George, P. & Pineo, P. (1992). *A study of the factors affecting the demand for post-secondary education.* Hamilton, Ontario: McMaster University.

Gilbert, L., Gallessich, J. & Evans, S. (1983). Sex of faculty role model and students' self-perceptions of competency. *Sex Roles,* 9, 597-607.

Gilbert, S. & Pomfret, A. (1995). *Gender tracking in university programs.* Occasional paper number 4. Ottawa: Industry, Science and Technology Canada.

Glaze, A. (1979). *Factors which influence career choice and future orientations of females: Implications for career education.* Unpublished doctoral dissertation, Toronto: O.I.S.E.

Gonzalez, A. (1996). *Graduation rates and times to completion for doctoral programs in Canadian universities.* Unpublished doctoral dissertation. University of Toronto, Graduate Department of Education.

Gray, M. (1995). Recruiting and retaining graduate students in the mathematical sciences and improving their chances for subsequent success. In B. Grevholm & G. Hanna (Eds.), *Gender and mathematics education*, an ICMI study in Stiftsgarden Akersberg, Hoor, Sweden 1993. Lund: Lund University Press.

Gray, M. (1996). Gender and mathematics: Mythology and misogyny. In G. Hanna (Ed.), *Towards gender equity in mathematics education, an ICMI study* (pp. 27-38). Dordrecht: Kluwer Academic Publishers.

Grevholm, B. (1995). Gender and mathematics education in Sweden. In B. Grevholm & G. Hanna (Eds.), *Gender and mathematics education*, an ICMI study in Stiftsgarden Akersberg, Hoor, Sweden 1993. Lund: Lund University Press.

Hanna, G. (1993). Retaining women in mathematics and science. In *SANN, JA! Norges forskningsråd, avd.* NAVF. Oslo: Sekretariatet for Kvinneforskning.

Hanna, G. (1994). Should girls and boys be taught differently? In R. Biehler, R. W. Scholz, R. Sträßer & B. Winkelmann (Eds.), *Didactics of mathematics as a scientific discipline* (pp. 303-314). Dordrecht: Kluwer Academic Publishers.

Hanna, G., Kundiger, E. & Larouche, C. (1990). Mathematical achievements of grade 12 girls in fifteen countries. In L. Burton (Ed.), *Gender and mathematics: An international perspective* (pp. 78-98). New York: Cassell.

Harding, J. & Sutoris, M. (1987). An object-relations account of the differential of boys and girls in science and technology. In A. Kelly (Ed.), *Science for girls?* Milton Keynes: Open University Press.

Hedman, B. (1988). Women's participation in the planning, administration, and management of higher education. Paper prepared for the European symposium on "The Role of Women in Higher Education, in Research, and in the Planning and Administration of Education" in Bucharest, Romania; 17-19 Oct., 1988.

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research*, 60, 549-571.

Hidi, S. & Baird, W. (1988). Strategies for increasing text-based interest and students' recall of expository texts. *Reading Research Quarterly*, 23, 465-483.

Hollenshead, C., Wenzel, S., Lazarus, B. & Nair, I. (1996). The graduate experience in the sciences and engineering: Rethinking a gendered institution. In C. Davis, A. B. Ginorio, C. S. Hollenshead, B. B. Lazarus, P. M. Rayman & Associates (Eds.), *The equity equation* (pp. 29-56). San Francisco: Jossey-Bass.

Hughes, K. & Lowe, G. (1993). Unequal returns: Gender differences in initial employment among university graduates. *The Canadian Journal of Higher Education*, 23(1), 37-55.

Human Resources Development Canada (1993). *Profile of post-secondary education in Canada, 1993 Edition*. Ottawa: Human Resources Development Canada.

Hyde, J.S., Fennema, E. & Lamon, S. J. (1990). Gender differences in mathematics performance: a meta-analysis. *Psychological Bulletin*, 107, 139-155.

Hyde, J.S., Fennema, E., Ryan, M., Frost, L. A. & Hopp, C. (1990). Gender comparisons of mathematics attitudes and affect: a meta-analysis. *Psychology of Women Quarterly*, 14, 299-324.

Industry, Science and Technology Canada (1991). *Women in sciences and engineering, Volume I: Universities*. Ottawa: Industry, Science and Technology Canada.

Industry, Science and Technology Canada (1992). *Canada scholarships program: Annual Report Card 1991-92.* Ottawa: Industry, Science and Technology Canada.

Kimball, M. M. (1989). A new perspective on women's mathematics achievement. *Psychological Bulletin*, 105, 198-214.

Kimball, M. M. (1995). *Feminist visions of gender similarities and differences.* New York: Harrington Park Press.

Lantz, A. E. & Smith, G. P. (1981). Factors influencing the choice of non-required mathematics courses. *Journal of Educational Psychology*, 73, 825-837.

Larter, S. & Fitzgerald, J. (1979). *Students' attitude to work and unemployment: part III, the open-ended and true-false questions*. Toronto: The Board of Education for the City of Toronto.

Lawton, C.A. & Bordens, K.S. (1995). Gender differences in science interests: an analysis of science fair projects. Paper presented at the 61st Biennial Meeting of the Society for Research in Child Development, Indianapolis, IN, 30 March-2 April 1995. ERIC Document ED 384430.

Leder, G. C. (1982). Mathematics achievement and fear of success. *Journal for Research in Mathematics Education*, 13, 124-135.

Leder, G. C. (1986). Mathematics: stereotyped as a male domain? *Psychological Reports*, 59, 955-958.

Leder, G. C. (1992). Mathematics and gender, changing perspectives. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning.* New York: Macmillan Publishing Company.

Leveson, N. (1990). Educational pipeline issues for women. *Computing Research News*, Oct 1990 and January 1991.

Linn, M. & Hyde, J. (1989). Gender, mathematics and science. *Educational Researcher*, 18(8), 17-27.

Luchins, E. H. (1979). Sex differences in mathematics: How not to deal with them. *American Mathematical Monthly*, 86, 161-168.

Maccoby, E. & Jacklin, C. (1974). *The psychology of sex differences*. Palo Alto: Stanford University Press.

Manis, J.D., Thomas, N.G., Sloat, B.F. & Davis, C.-S. (1989). *An analysis of factors affecting choice of majors in science, mathematics, and engineering at the University of Michigan.* Adult Development Research Program: Research Report No. 23. Ann Arbor, MI: The University of Michigan Centre for the Education of Women. ERIC Document ED 356954.

Marsh, H. W. (1989). Sex differences in the development of verbal and mathematics constructs: The high school and beyond study. *American Educational Research Journal*, 26(2), 191-225.

McGrath, D. (1996). Addressing gender equity in computer science. *Journal of Computer Science Education,* 10(2), 13-22.

McKelvey, G. (1984, January 25). Cited in: *Education Daily*, 17, 17:6.

Meece, J., Eccles, J., Futterman, R., Goff, S. & Kaczala, C. (1982). Sex differences in mathematics achievement: Towards a model of academic choice. *Psychological Bulletin*, 91, 324-348.

Ministers Responsible for the Status of Women (1987). *Toward a labour force strategy: A framework for training for women - Progress Reports*, Annual Conference of First Ministers, Toronto.

National Institute of Education (1977). *Grants for research on education and work*. Washington, D.C.: National Institute of Education.

National Science Foundation (1984). *Women and minority in science and engineering*. Washington, D.C.: U.S. Government Printing Office.

National Science Foundation (1988). *Report on women and minorities in science and engineering*. Washington, D.C.: National Science Foundation.

Niederdrenk-Felgner, C. (1996). Gender and mathematics education: A German view. In G. Hanna (Ed.), *Towards gender equity in mathematics education, an ICMI study* (pp. 179-196). Dordrecht: Kluwer Academic Publishers.

Nyhof-Young, J. (1997). *Action research in gender issues in science education: towards an understanding of group work with science teachers.* Unpublished doctoral dissertation. University of Toronto, Graduate Department of Education.

Oppler, S.H., Stocking, V.B., Goldstein, D., & Porter, L.C. (1993). Career interests of academically talented seventh graders. Paper presented at the annual meeting of the American Educational Research Association, Atlanta GA, 12-16 April. ERIC Document ED 374033.

Pearl, A., Pollack, M., Riskin, E., Thomas, B., Wolf, E. & Wu, A. (1990). Becoming a computer scientist: a report by the ACM committee on the status of women in computing science. *Communications of the ACM*, 33, 47-58.

Pedro, J.D., Wolleat, P., Fennema, E. & Becker, A.D. (1981). Election of high school mathematics by females and males: Attributions and attitudes. *American Educational Research Journal*, 18, 207-218.

Pipeline project. (1994). [Preliminary findings on cohort i from "Education and career plans of women in engineering" survey, University of Michigan Center for the Education of Women]. Unpublished data.

Purser, P. & Wily, H. (1990). Where have the mathematicians gone in New

Zealand? In L. Burton (Ed.), *Gender and mathematics: An international perspective*. London: Cassell.

Rayman, P. & Brett, B. (1993). *Pathways for women in the sciences.* Wellesley, Mass.: Wellesley College Center for Research on Women.

Sadker, M. & Sadker, D. (1994). *Failing at fairness: How America's schools cheat girls.* New York: Charles Scribner's Sons.

Sayer, L. (1980). *An evaluation of career awareness in grade nine girls.* Unpublished doctoral dissertation, Toronto: O.I.S.E.

Schiefele, U. (1991). Interest, learning, and motivation. *Educational Psychologist,* 26, 299-323.

Schofield, H. & Parnaby, M. (1986). *Sex differences in the preference for humanities or science courses: A retrospective study of tertiary students.* Research Working Paper 85.6, Centre for the Study of Higher Education, University of Melbourne.

Schroeder, D. & Mynatt, C. (1993). Female graduate students' perceptions of their interactions with male and female major professors. *Journal of Higher Education,* 64(5), 555-572.

Science Council of Canada (1982). *Who turns the wheel?* Proceedings of a workshop on Science Education of Women in Canada (1981). Prepared by Janet Ferguson. Ottawa: Science Council of Canada.

Scott, J. (1982). Is there a problem? Enrolment and achievement patterns among high school science in Canada. In Janet Ferguson (Ed.), *Who turns the wheel?* Proceedings of a workshop on Science Education of Women in Canada (1981). Ottawa: Science Council of Canada.

Sells, L. (1973). High school mathematics as the critical filter in the job market. Berkeley: University of California. ERIC Reproduction Service No. ED 080 351.

Seymour, E. & Hewitt, N. (1991). *Talking about leaving: Factors contributing to high attrition rates among science, mathematics and engineering undergraduate majors.* Final report to the Alfred P. Sloan Foundation, University of Colorado, Boulder.

Sjoberg, S. (1990). *Gender equality in science classroom*. Perth, Western

Australia: Curtin University of Technology Key Centre for School Science and Mathematics.

Smart, T. (1996). Gender and mathematics in England and Wales. In G. Hanna (Ed.), *Towards gender equity in mathematics education, an ICMI study* (pp. 215-236). Dordrecht: Kluwer Academic Publishers.

Smith, H. L. (1982). *Determinants of higher education enrolment in the United States: 1946-1980.* Doctoral dissertation, Department of Sociology, University of Michigan.

Spertus, E. (1991). *Why are there so few female computer scientists?* Cambridge, MA: MIT Artificial Intelligence Laboratory Technical Report.

Stager, D. (1989). *Focus on fees.* Toronto: Council of Ontario Universities.

Stager, D. (1994). *Returns to investment in ontario university education 1960-1990, and implications for tuition fee policy.* Toronto: Council of Ontario Universities.

Statistics Canada (1994a). *Revised intercensal population and family estimates, 1971-1991.* Catalogue no. 91-537 Occasional.

Statistics Canada (1994b). *Annual demographic statistics, 1993.* Catalogue no. 91-213.

Statistics Canada (1995a). *Annual demographic statistics, 1994.* Catalogue no. 91-213.

Statistics Canada (1995b). *Women in Canada, A statistical report. Third Edition.* Ottawa. Ottawa: Statistics Canada.

Statistics Canada (1996). *Annual demographic statistics, 1995.* Catalogue no. 91-213.

Status of Women Canada Manitoba Women's Directorate (1989). *Participation of girls and women in mathematics, science, and technology.* Winnipeg: The Directorate.

Stipek, D. J. & Gralinski, J. H. (1991). Gender differences in children's achievement-related beliefs and emotional responses to success and failure in mathematics. *Journal of Educational Psychology,* 83, 361-371.

Taber, K.S. (1991). Gender differences in science preferences on starting secondary school. *Research in Science and Technological Education*, 9(2), 245-252.

U.S. Department of Education. *National longitudinal survey of high school seniors of 1972* (NLS-72). Washington, DC: Author.

University Funding Council (1993). *University statistics 1992-93: Vol 1 students and staff.* London: Universities Statistical Record.

Walden, R. & Walkerdine, V. (1985). *Girls and mathematics: From primary to secondary schooling* (Bedford Way Papers, No.24). London: Institute of Education, London University.

Walters, P. (1986). Sex and institutional differences in labour market effects on the expansion of higher education, 1952 to 1980. *Sociology of Education*, 59, 199-211.

Wainer, H. & Steinberg, L.S. (1992). Sex differences in performance on the mathematics section of the Scholastic Aptitude Test: A bidirectional validity study. *Harvard Educational Review*, 62, 323-336.

Wiggan, L., Kryger, M., Gamery, R., Morris, M., Clifford, B. & Getty, B. (1983). *Mathematics: The invisible filter.* Toronto: Toronto Board of Education.

Wannell, T. & Caron, N. (1994). *The gender earnings gap among recent postsecondary graduates, 1984-92.* Business and Labour Market Analysis. Statistics Canada. 11F009E No. 68.

Weiss, I. (1993). *Science and mathematics education briefing book* (Vol 4). Chapel Hill, NC: Horizon Research.

Wise, L.L. (1985). Project TALENT: Mathematics course participation in the 1960's and its career consequences. In S.F. Chipman, L.R. Brush & D.M. Wilson (Eds.), *Women and mathematics: Balancing the equation* (pp. 25-58). Hillsdale N.J.: Lawrence Erlbaum Associates.

Vetter, B. (1996). Myths and realities of women's progress in the sciences, mathematics, and engineering. In C. Davis, A. B. Ginorio, C. S. Hollenshead, B. B. Lazarus, P. M. Rayman & Associates (Eds.), *The Equity equation* (pp. 29-56). San Francisco: Jossey-Bass.

York University (1988). *Strategies, intervention techniques to retain women in* *mathematics and science studies*. North York, Ontario: York University.

Zappert, L.T. & Stansbury, K. (1984). *In the pipeline: A comparative analysis of men and women in graduate programs in science, engineering, and medicine at Stanford University*. Palo Alto, CA: Stanford University Press.

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