Contextualizing the under representation of women in science and engineering: A graphical analysis of trends in Canadian degree attainment statistics

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Abstract

The selective success of women in traditionally male dominated fields is identified as a paradox whose explanation will have implications for the issue of the under representation of women in science and engineering programs. Trends in degree attainment by sex in science and engineering are examined in the context of degree attainment in all traditionally male dominated degree programs in order to generate empirically based hypotheses. Because research designs in use for quantitative data in sociology are much better designed to test hypotheses than to generate new ones, an important aspect of this study is its development of a new analytical strategy. In order to effectively explore the available data, the existing statistics for degree attainment in traditionally male dominated fields for both sexes over the 1962-1989 period are converted to graphical display and analysed visually. The organization of the graphical displays developed is consistent with basic aspects of the comparative, exploratory research strategy advocated by Glaser and Strauss and graphical display techniques of Tufte. Findings show that the largest gains in representation in traditionally male dominated disciplines have been in those where the associated professions or occupations are typically autonomous self-employed professions rather than positions in large organizations. These findings further suggest processes that may be contributing the continued under representation of women in the physical sciences and engineering.

Sommaire

Le succès partiel des femmes dans les domaines d'études traditionnellement dominés par les hommes, est identifié comme un paradoxe dont l'explication aura des conséquences quant à la question de la sous-représentation des femmes dans les programmes de science et de génie. Les tendances de l'obtention des diplômes des hommes et des femmes en science et génie sont étudiées dans le contexte de l'obtention des diplômes dans tous les programmes universitaires traditionnellement dominés par les hommes, a pour objectif d'émettre des hypothèses fondées sur des données empiriques. Parce que les modèles de recherche utilisés en sociologie, pour les données quantitatives, sont plus appropriés pour vérifier des hypothèses que pour en générer des nouvelles, un aspect important de cette étude est le développement d'une nouvelle stratégie analytique. Pour explorer efficacement les données disponibles, les statistiques existantes pour l'obtention des diplômes dans les domaines d'études traditionnellement dominés par les hommes pour les deux sexes, couvrant la période de 1962 à 1989, sont converties en représentation graphique et analysée visuellement. L'organisation des représentations graphiques, telle que développée, est consistante avec les aspects de base des stratégies de recherches comparatives et exploratoires tel que recommandées par Glaser et Strauss et la technique de représentation graphique de Tufte. Les résultats démontrent que le plus grand accroissement du pourcentage des femmes dans les disciplines traditionnellement dominées par les hommes sont celles où les professions ou occupations connexes sont typiquement des professions autonomes et indépendantes au lieu de postes dans des grandes organisations. Ces résultats suggèrent que des processus peuvent contribuer dans la continuelle sous-représentation des femmes dans les sciences physiques et en génie.

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CONTENTS

CHAPTER ONE: INTRODUCTION

" How wonderful that we have met with paradox.
Now we have some hope of making progress."
- Niels Bohr, physicist

Despite the existence of significant political and research interest in the issue[1], and the generation of an extensive literature spanning three decades, we still do not have an adequate explanation for the under-representation of women in science and engineering programs.

The immediate challenge to current explanations offered for this phenomenon are the emerging patterns of participation in these areas. The prevailing explanations for the relatively lower entry of women than men to science and engineering programs, the differential ability and early childhood socialization arguments, cannot adequately explain patterns such as the higher attrition of women than men from science, or the higher attrition of women from science than from engineering. It has actually been assumed by some

[1]Science and technology are at the heart of advanced industrialized societies and are widely seen as the primary source of western progress. Science is also perceived to be a means of determining objective truth. The centrality of science and technology to post-war western societies has meant that the low level of participation of women in science and engineering has been of considerable political and research interest to several groups over the last three decades. In the 1960s, concerns about gender equity for women in professions important to society grew out of the women's movement. As the women's movement encouraged women to enter non-traditional professions, social scientists began to try to explain the differential career paths of men and women. In the late 1980s, expansion of scientific and technical activity was identified as essential if advanced industrialized countries were to remain competitive in an increasingly global economy (NSERC, 1989,1991; National Science Foundation, 1990; Council of Ontario Universities, 1988), exacerbating already existing concern about possible shortages of scientific and engineering labour due to expected increased demands in academia in the 1990s (Fechter 1989; 46; Ministry of State for Science and Technology, 1981a). Trends in degree production in the 1980s did not indicate strong future growth in the number of new graduates, and demographic trends indicated that the university age population would shrink in the 1990s (May, Fechter, 1989; Koshland, 1988). Policy makers saw raising the lower level of participation of women as a domestic solution to expected shortages.

Within the sociology of science, the continued lower participation of women in many science disciplines has made women in science a strategic research site for proponents of the Mertonian paradigm because their lower participation seems to challenge the validity of the norm of universalism where scientific careers are supposed to be open to all who have talent (Etzkowitz, 1992).

researchers that these explanations do not apply to women who have embarked on a degree in these areas (Nevitte et al., 1988). One of the most commonly posited explanations for the higher attrition of women than men from these degrees is the hypothesis that a 'chilly climate" exists for women in universities, especially in traditionally male-dominated fields (Association of American Colleges, 1982). But this hypothesis alone cannot explain the higher attrition of women from science than from engineering, or the counter intuitive findings of Canadian studies of undergraduate science students. Nevitte et al. (1988) reported but could not explain the finding that average performing women science students were three times more likely than their top-performing female counterparts to be planning graduate studies. Similarly, Gilbert and Pomfret (1991) found that among high achieving women who enter science and engineering disciplines, those who had A grades in high school are more likely to leave science than those with B+ grades, Among those A students who leave, the majority switch to non-science disciplines. An even stronger empirical challenge to the validity of the prevailing explanations in this area is presented when the context is widened from science and engineering to all male dominated fields. Explanations based in traditional assumptions about work and sex roles have been used in the past to explain the lower participation of women in all male-dominated fields, not just in science and engineering. However, while women are still under-represented in science and engineering, they are most definitely no longer under-represented among graduates in other previously male-dominated fields such as medicine, law, and business. Explanations such as the differential childhood socialization and chilly climate hypothesis that have been used to explain women's under-representation in all male-dominated areas cannot effectively explain why women have had success in only some of these areas.

Why have other previously male-dominated fields done better in attracting and retaining women students since the early 1970s than science and engineering?

While the fact that women are no longer under-represented in other traditionally male-dominated areas such as medicine and law is often noted (Berryman, 1985; Widnall, 1988; 1740, Gilbert and Pomfret, 1991; Bar-Haim and Wilkes, 1989; Weston, 1990; Canadian Commitee on Women and Engineering, 1992; Etzkowitz, 1992; Mackay, 1993) the development of this apparent paradox has not resulted in analyses which examine the issue of women's lower participation in science and engineering in the context of their participation in all tradtionally male dominated fields. This study will use this interesting paradox to frame its research site: sites where meaningful comparison can be made are often a prerequisite for fruitful analysis.[2] I argue that it is quite likely that insight that can be gained into the phenomenon of the selective success of women in traditionally male dominated fields will have implications for the issue of women's continued under-representation in science and engineering.

1. Toward the Visual Exploration of Quantitative Data Sets in Sociology

Why has extensive research failed to develop an adequate theory for women in science and engineering? There are two primary issues in women in science; performance differences for men and women in scientific careers, and the lower number of women in science (Long, 1987). Much research has been concentrated on gender differences in performance in science; but the larger question is still about the relatively lower number of women participating. Long argues that the limitations in the literature can be attributed to a set of common methodological flaws. He suggests that improvements in research in this area could be made by widening the scope of sample studies, by sampling from larger populations, specifying more key variables in models and including a time-factor (1987). However, since the more complex sample studies become, the more expensive and time-consuming they become, these kinds of improvements are not often readily feasible .

Part of the inability of research to develop adequate theory also has to do more generally with the methods that are used. Etzkowitz (1992) maintains that a social theory of women in science should account both for women who enter scientific careers and those who

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[2] In examining the participation of women in science and engineering within the context of their participation in all traditionally male dominated fields, this study re-adopts the original contextual framework for this issue (see Rossi, 1965).

are excluded. However, the predominantly used method in this area, the sample study, is not readily applied to broad contexts. Sample studies are more suited to investigation of well-bounded groups; much of the research in this area using them has concentrated on studying gender differences in performance, or attributes of men and women science students.

One of the means available do a feasible comparative analysis in the wider context of all male dominated fields is to explore the existing statistics for degree attainment; comparable time-series degree attainment data for the last two decades are available for most traditionally male dominated disciplines in Statistics Canada publications. This study will systematically explore degree attainment for men and women over a period when substantial change in women's representation has occurred (1962-1989) in all fields where women have been traditionally under-represented: natural sciences, engineering, social sciences and the professions. The purpose of this comparison study is to frame the differential participation by sex in science and engineering in the context of recent historical trends in participation by sex in traditionally male dominated degree programs in order to generate empirically based hypotheses.[3] Perhaps because existing official statistics are often unexplored by sociologists, these data have been used only to monitor the status of women's under-representation rather than as a resource for detailed contextual analysis. Because most research designs for quantitative data in sociology are designed to test existing hypotheses rather than to generate new ones, an important aspect of this study is its development of a new analytical strategy, designed specifically to facilitate the comparison of trends in aggregate degree attainment for men and women in traditionally male dominated fields over the last three decades. The strategy developed is essentially a systematic qualitative method for exploring a quantitative data set.

In order to effectively explore this quantitative database to generate empirically based hypotheses, the entire database of existing statistics on degree attainment in traditionally male dominated fields for both sexes over the 1962-1989 period is converted to graphical

[3]Hypotheses which are both suggested by, and consistent with the complex picture of existing data patterns revealed by the exploratory study.

display. This transformation of the data allows the best access possible to empirical patterns and cues in the data because it capitalizes upon one of the most highly developed human information processing capacities - the ability to recognize, classify and remember visual patterns (Lewandowsky and Spence, 1990). The general organization of the graphical displays used in this analysis (developed in detail in the methods section) is consistent with basic aspects of the comparative, exploratory research strategy suggested by Glaser and Strauss (1967) and graphical display techniques of Tufte (1983,1990). Initial exploration and interpretation of the primary graphical displays will direct construction of secondary data displays. The hypotheses generated in this study are necessarily suggestive, rather than conclusive and will be investigated further in my Ph.D. thesis work.

A brief review of the current explanations for the under-representation of women in science and engineering programs is given in Chapter 2. Chapter 3 provides the background for the exploratory analytical strategy developed in this study, and Chapter 4 outlines that strategy. The analysis and findings are presented in Chapter 5. Since a new strategy involving the use of graphs has been developed for this study, in this chapter I take the reader through the analytical process in order to demonstrate it. Since exploratory studies unearth findings and suggestions that do not necessarily address the issue of concern directly but should be recorded, all of the main findings of this study and the suggestions generated by them are summarized in Chapter 6. I then discuss those that have implications for the issue of the under-representation of women in science and engineering in Chapter 7.

CHAPTER TWO: CURRENT EXPLANATIONS FOR THE UNDER-REPRESENTATION OF WOMEN IN SCIENCE AND ENGINEERING PROGRAMS

1. Sex Differences in Ability

It is the lower level of preparation and achievement in mathematics that is thought by many researchers to be the primary direct cause for the lower participation of females in science and engineering programs (Berryman, 1983). The search for an explanation for women's lower level of mathematical preparation launched a surprisingly intensive research program into the possibility that sex differences in mathematical and spatial abilities existed. Eleanor Maccoby and Carol Jacklin (1974) reviewed more than 1,400 studies of sex differences, concluding that four differences were well established : superior verbal ability in girls, and, higher visual-spatial ability, mathematical skills and more aggression in boys and they concluded by supporting the view that there was a genetic basis for these differences. Scientists in other areas assumed that Maccoby and Jacklin had established the existence of genetic differences in ability and began to investigate possible biological mechanisms (Brush, 1991).

It is no longer considered justifiable by many to argue that genetically based sex differences in abilities needed for science and engineering are sufficient to explain observed differences in participation (Fausto-Sterling, 1985; Zuckerman, 1991). According to Hornig (1987), despite hundreds of studies investigating possible sex differences in mathematical ability, no unequivocal evidence for these differences has been found. Differences among members of the same sex have been found to be far greater than average differences between the sexes (Gelman et al., 1981). Considerable increases in women's participation in quantitative-based degrees in the last few decades have themselves undermined support for the view that any sufficient genetic differences exist.

With increasing participation of women in science and engineering education and the lack of conclusive findings on sex differences in cognitive ability, research has gradually shifted away from an emphasis on abilities (Hornig, 1987). However, the publicity of this research itself is seen by some as having a negative impact on women's participation through its creation of a social mythology about women's inabilities to do math, science and engineering (Vetter,1992), since studies indicating that these differences are not empirically supported were much less publicized (Brush,1991). The sheer size and intensity of the research effort and its wide coverage in the popular press also may have helped to completely dissociate the research on women's under-representation in science and engineering from its original context in the 1960s, women's position in the traditionally male dominated professions, since the existence of sex differences in mathematical and spatial abilities did not represent a plausible explanation for women's under-representation in other much less quantitative non-traditional fields such as law, medicine and dentistry.

Why did investigation of the possibility of sex differences in ability to do science attract so much research attention? In hindsight, it certainly seems obvious that the realm of plausible explanations for this phenomenon was much larger. Some argue that this research emphasis was rooted in two of the fundamental ideologies in Western society - belief in the meritocracy and a view of science as a value free enterprise which reveals objective truths. Schiebinger outlines this argument :

> Fee, Lewontin, Rose and Kamin... examine how the rise of a belief in the meritocracy inaugurated and maintained the complimentary belief that social inequalities resulted not from systematic discrimination but from intrinsic inabilities within certain groups. If women have not made outstanding contributions to the sciences, so the logic goes, perhaps women are naturally incapable of doing science. As Fee and Sayers argue, it became the task of science to define the natural abilities (and inabilities) of identifiable social groups - women and blacks among others (1987:328).

The idea of a value free science has been challenged by some feminist scholars. These feminists argue that this belief has obscured the fact that scientific discourse has been a male discourse, since it is predominantly males who have had the opportunity to participate in it. They contend that methods and practices of science are imbued with masculine values, and that because science has been structured by these power relations and this gender bias, it cannot be seen as being neutral (Keller, 1985; Harding, 1986).

2. **Early Childhood Socialization**

A less controversial explanation for girls' lower preparation in math and science sees the phenomenon as a product of early childhood socialization (Rossi, 1965; Fischer, 1982; Berryman, 1985; Gaskell, 1985; Bar-Haim and Wilkes, 1989). Early childhood socialization, not only by parents and teachers, but also by the media - teaches children roles, attitudes and behaviours thought to be appropriate for each sex (Ehrhart and Sandler, 1987).

The early socialization model explains the under-representation of women in science and engineering as a result of sex differentiated socialization processes that surround young girls with values and normative expectations which cue them towards traditionally female roles and away from traditionally male roles such as occupations in science and engineering (Nevitte et al., 1988). It stresses the primacy of gender role learning and the subsequent mismatch between traditional female roles and professional achievement in explaining the lower numbers of women in science and engineering.

> No one forces girls out of the study of math and science, yet a process of self-selection occurs as a result of the differing career aspirations of boys and girls, as well as differing expectations of their parents, peers, and teachers (Schiebinger, 1987:321)

Socialization is seen as producing not only the persistent pattern of greater female than male self-selection away from scientific and technical roles, but lower enrolment in elective sequences of science and math courses which are prerequisite for entry to science and engineering programs at university (Berryman, 1985).

The classic model of socialization views the effects of early childhood socialization as relatively stable in later life (Jacobs, 1987). Several authors disagree with this view, arguing that the perception of opportunity is also important in establishing motivation. Lilli Hornig (1987) supports the argument developed by Kaufman and Richardson (1982), whose critical review of the women's achievement literature led them to suggest that motivation can change with changing opportunities. She maintains that this "more fluid interpretation of motivation" can better explain the increases in participation of women in science and engineering degrees in recent years.

Differential ability and socialization arguments were both offered as explanations for the lower entry of women into science and engineering programs in universities. It has been assumed by some researchers that these arguments did not apply to women who embarked on a degree in science or engineering (Nevitte et al., 1988; Bar-haim and Wilkes, 1988). This gave rise to a number of studies attempting to delineate the characteristics of women who choose to enter these fields. Because of the interest of policy makers in recruiting more women, it became important to know which women chose these fields and what characteristics were predictors of these non-traditional choices. The assumption was that women choosing science had been under different influences than the majority of their peers, and that this had given them different motivations. Studies either compared women in their undergraduate years of science to women in traditional fields (e.g. Peng and Jaffe, 1979) to men in science (Ware et al., 1985) or to both (Gilbert and Pomfret, 1991) .

Peng and Jaffe found that women who choose science and engineering majors were more likely to have higher academic ability, more preparation in science and math in high school, and to be more work-oriented than women in traditional fields. Gilbert and Pomfret found that women entering undergraduate science and engineering, particularly the high achievers, were more likely than their male counterparts to indicate encouragement from teachers, good grades in high school, the expectation of good grades in university, and a desire to be self-sufficient as important influences in their choice of major.

Ware et al. (1985) also found that the men and women who choose science differ to some extent in the factors that shape their choices. While for both men and women, enjoying a science course in their freshman year was a significant predictor of choosing a science major, they differ on other significant factors which influence their choice. For men, other significant factors were having high grades in freshman year science courses, and being certain about their choice of major in the summer prior to attending college. For women, the other significant factors were having highly educated parents, achieving outstanding (rather than just high) mathematic scores on the SAT test, having a strong desire for control, prestige and influence, and, a desire for positive interaction with others. In other words, as the authors suggested, women's choice of a science major tended to be shaped by family background, an aptitude for mathematics, and a need for power.

3. Participation of Women in Science and Engineering Programs

By the mid 1980s, an important shift had occurred in the type of research being done on this issue. Scientists had failed to establish the existence of sufficient sex differences in ability. At the same time, concern was mounting about possible shortages in scientific and engineering labour by the end of the century. A drop was predicted in the supply of college-age white males, the dominant participants in science and engineering (U.S. Congress, Office of Technology Assessment, 1985; Finkbeiner, 1987; Widnall, 1988), at the same time as renewed emphasis was being given to the key role expanded scientific and technological activity would play in advanced industrialized countries if they were to maintain their competitive advantage in an emerging global economy. As the numbers of women in science and engineering in universities increased noticeably, policy makers began to carefully monitor their participation, the most immediate alternative supply of scientific and engineering labour should shortages occur. In Canada, many studies and reports on women's participation in science and engineering programs have been prepared by government departments (e.g. Industry Science and Technology Canada, 1990), the National Science and Engineering Research Council (e.g. NSERC, 1988, 1991) university bodies (Council of Ontario Universities, 1988; Canadian Committee on Women and Engineering, 1992) or funded in part by government departments (e.g. Gilbert and Pomfret, 1991) in the last decade. In the U.S., this activity was judged so important it was required by law. The Science and Technology Equal Opportunities Act of 1980 mandated a series of biennial reports monitoring the participation of women and minorities in science and engineering (National Science Foundation, 1988, 1990).

4. Higher Attrition of Women and Possible Reasons

The issue of women's under-representation in science and engineering programs is more complex than one of supply to the university level programs. Not only do fewer women begin careers, but there is more attrition of women than men from the science and engineering "pipeline" (Widnall, 1988; Finkbeiner, 1987). Bar-Haim and Wilkes describe this well-documented process:

> ...proportionately more women than men drop out of science majors in college,...women who do persevere in science fare less well in gaining positions and the other rewards of success. Women tend to concentrate in small non-research institutions where they are professionally isolated and remote from the scientific "means of production". A disproportionately high rate of women scientists gravitate into teaching and administrative positions while significant numbers leave their careers altogether. This is in stark contrast to the low withdrawal rate among men in science and the very low withdrawal rate among women physicians, who also operate in a male dominated profession (1989;372).

If differential ability and socialization arguments do not apply to women who have entered science and engineering, what is the explanation for higher attrition of women from these programs? Roberta Hall and Bernice Sandler, in a pivotal 1982 paper, argued that a 'chilly climate' exists for women in universities, especially in traditionally male dominated fields. The authors argued that "women's educational experiences may differ considerably from those of men, even when they attend the same institutions, share the same classrooms, and work with the same graduate advisors" (Association of American Colleges, 1982). They suggested that both overt sexism and small differential behaviours, especially of faculty members, which indicate lower expectations for women than for men students or which cause women to feel that their academic and career ambitions are not as important as those of males, may play a major role in limiting women students' eventual career development (2,4,6).

There is strong evidence to suggest that the experiences of women in universities is having a negative impact on their overall level of participation as well as their ability to participate. Studies have found that women science students suffered a loss of self-esteem in their undergraduate years, while that of males increased slightly (Arnold, 1987, cited in Widnall,1988) and that women undergraduates feel less confident about their preparation for graduate school than males attending the same institutions, even when men and women are matched on grades and plans for graduate study (Zappert and Stansbury, 1984, cited in Widnall, 1988). It has also been found that many women experience a considerable decline in their academic and career aspirations over the course of their academic years (Astin, 1977; Arnold, 1987, cited in Widnall, 1988).

Universities serve as both educators of scientists and engineers as well as "gate-keepers" to the professions (Hornig, 1984;32). A perceived cold or hostile climate in university will be especially discouraging to women who are trying to pursue interests and develop abilities that do not reflect current cultural norms. It is suggested that in this environment more women are less likely to receive the informal encouragement and support provided by closer association with faculty, which has been identified as vital to the development of professional identity, and as a result may feel more doubtful about their academic ability and professional promise (Association of American Colleges, 1982). Similarly, this kind of environment may also more directly threaten women's ability to participate fully in science. Barbara Reskin has argued that women scientists are often excluded from the collegial ties and informal communication networks crucial to the development of scientific ideas (1978).

Bar-Haim and Wilkes (1989) have developed another hypothesis which could contribute to the chilly climate many women may experience during their university years. They argue that the dissatisfaction, isolation, field switching and attrition among women in science is part of a larger conflict of cognitive styles in the sciences, rather than a basic conflict between men and women. These researchers argue that the antagonism and lack of understanding many women experience is the result of a clash of cognitive styles, resulting from the interaction of women's cognitive make-up and prevailing cultural sex-role stereotypes. They hypothesize that women who are 'problem-solvers' and cognitively most suited to the physical sciences will be most likely to enter those sciences which are more acceptable for women - the biological or social sciences - where they will be intellectually mismatched with most males in the field. Conversely, women who are 'problem-identifiers' are the most likely to challenge existing stereotypes and enter the physical sciences but whose cognitive make-up will conflict with the majority of problem-solving men in those fields.

Another suggested possible reason for women's lower participation in engineering is that talented women may be avoiding the profession because their values differ from those of men in the field. If these women come to engineering from a different intellectual and cultural climate than do men - they may avoid it because they can not see any evidence of their broader, more humanistic perspective (Florman 1984; 52). Gilbert and Pomfret (1991) found that many high achieving women students who enter university programs in the sciences or engineering do experience difficulty dealing with the value orientations of these programs. They suggested that differences between women's value orientations and the "justice and rights" orientation of science programs may be directly affecting retention of these women due to pressures caused by a 'lack of fit', and that through a production of lower marks, these differences may also indirectly affect the retention of women in science and engineering programs (26,38).

Florman, challenging the prevailing explanations for women's lower participation in engineering, also suggests that another possible reason that talented young women may be avoiding engineering is that other professions are more direct routes to political power and social prestige (1984; 52). Similarly, Stephen Brush (1991) suggests that women may be avoiding science and engineering because other fields, newly available to them are more attractive, citing the persistent inequality of opportunity for women in the science and engineering labour force - greater unemployment, lower salaries, slower career advancement than for men[1] - as the probable cause (416).

Many observers within the engineering profession now place the blame for the lower

[1] See Vetter (1987)

participation of women on the profession itself. The 1992 report of the Canadian Committee on Women and Engineering concluded that women have difficulty adjusting to the pervasive male culture both in university and in the workplace:

> Once in the workplace, women engineers encounter attitudes and activities that are systematically biased against women. Many face discrimination in hiring, promotion, job assignments and salary, and experience sexual harassment in their workplaces. Many have to cope with the isolation of being the only female engineer in a company or on a job site (1-3).

Internal critics fault the profession's leaders for the lack of improvement in the climate for women (McKay, 1992). Patrick Quinn, a Toronto based engineer has publicly criticised the behavior of those at the top of the profession, maintaining that there is a definite lack of a sense of urgency, indignation or anger about the environment in the profession for women (Qtd. in McKay,1992;44). Norman Ball, Northern Telecom professor of Engineering And its Impact on Society at the University of Waterloo:

> 'It's not that the engineering deans or the guys at the CCPE [Canadian Council of Professional Engineers] or the provincial associations sanction antisocial behavior. It's just that they do damn little to stop it. There's a tremendous leadership vacuum in engineering - and a tremendous conservatism. They are unwilling or incapable of looking at the world in a social context and loath to criticize their fellows.'(Qtd. in McKay, 1992;42).

As an example of this inertia, he cites the continuation of the traditional orientation week activities on university campuses:

> 'Engineering schools have among the highest admission standards in the country. But what do we do? In the first week of school, we take these bright young people and make them behave like buffoons.... Engineering students work very hard to lose the respect of the public.'(41)

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As was outlined in the introduction, prevailing explanations for the lower representation of women in science and engineering are not sufficient to explain the patterns of participation of women in these areas, nor can they adequately account for the selective success of women in the traditionally male dominated professions. In this study, degree attainment for all traditionally male dominated fields are examined in order to generate hypotheses as to processes that may be contributing to the under representation of women in science and engineering. A new exploratory strategy which uses graphs as analytical devices was developed: the degree attainment database was converted to graphical display and analyzed using primarily visual means. In the next chapter, literature which provides the background for the exploratory strategy developed in this study is briefly reviewed.

CHAPTER THREE: BACKGROUND FOR DEVELOPMENT OF AN EXPLORATORY GRAPHICAL ANALYSIS STRATEGY

The past two decades have seen a vigorous development of methods for graphical data analysis by prominent statisticians who lead a movement away from formal statistical techniques to informal, primarily visual, data analysis. These statisticians argue that the concentration on mathematical statistical techniques aimed toward hypothesis testing, or designed under a logic of proof, has de-emphasised the need for descriptive methods whose aims are exploratory rather than confirmatory (Wainer and Thissen, 1981: 192). A whole literature has developed to elaborate and advance the use of these exploratory techniques, which are primarily graphical, flexible and robust, and of general applicability (Tukey, 1977; Mosteller and Tukey, 1977; Hartwig and Dearing, 1979; Wainer and Thissen, 1981; Hoaglin et al. , 1983; Chambers et al., 1983; Tufte, 1983, 1990; Lewandowsky and Spence, 1990).

My own interest in graphical analysis began with a descriptive study done as an undergraduate term paper where I used several graphs to depict trend data for degree attainment in science. Although I plotted these graphs to display the data and not to analyse it, I was very intrigued by the discovery that the visual patterns in the data suggested to me hypotheses about processes which might be occurring. I came away from that study with a strong interest in the potential value of graphical methods for exploring large quantitative datasets in sociology.

The interest in the use of graphs for data analysis is concomitant with the increasing availability of computer hardware and software for generating graphics. Although large-scale use of plots in data analysis was difficult when they had to be drawn by hand, relatively inexpensive computer technology has made exploratory research strategies for quantitative data which use graphs feasible.

The use of graphical displays for data analysis allows processing of data by the visual-perceptual system, a human cognitve strength ; visualising numbers therefore bypasses a cognitive limitation - the direct analysis of tables of numbers (Krohn, 1991:181). Chambers et al. suggest that no single statistical tool is as powerful as a well-constructed graph

(1983:1). They argue that in many situations a set of data, even a large set, can be adequately analysed through graphical methods alone due to the ability of a graph to allow our visual-perceptual system to interact with the structure of the data (1983: vii; Tufte, 1983:9). Graphs are effective because they exploit our strongest natural perceptual, cognitive and memorial capacities (Kosslyn, 1985, 1989). An enormous amount of quantitative data can be succinctly conveyed by graphs, and our perceptual cognitive system is both capable of comparing and summarising this information, as well as extracting salient features and focusing on details (Chambers, 1983:1), often with relatively great speed. Through graphical displays we can often gain otherwise unattainable insight into the structure of a data set. The analyst is able to explore data thoroughly, to find patterns and relationships, to confirm or disconfirm the expected and discover new phenomena (Chambers, 1983:1).

The seminal work published in this area was Tukey's Exploratory Data Analysis in 1977. The use of graphs for exploratory data analysis (EDA) as outlined by Tukey however represents only part of the potential scope for the use of graphs in data analysis. In EDA, graphical methods for data analysis consists essentially of graphing quantitative information to help the analyst understand the structure of a dataset or the performance or properties of statistical models fit to the data (Tukey, 1977; Hartwig and Dearing, 1979; Cleveland and McGill, 1987). Hartwig and Dearing outline the course of exploratory data analysis as a step by step visual approach to understanding first the structure of each variable in the data set then each pair of variables (bivariate relationships), and the groups of variables (multivariate relationships). The structure of each variable (distribution and variability) is explored using such techniques as the stem-and-leaf display (Tukey, 1977). After each variable has been carefully examined, techniques such as scatter plots and residual plots are employed to investigate relationships between variables (linear, non-linear). Following this, multivariate models can be built. Because the analyst has learned as much as possible about the structure of the data set and the relationships between variables before constructing the models, these models are less likely to be misspecified or to be built on the basis of false assumptions[1].

As Wainer and Thissen (1981) have suggested, however, the real potential power of graphical data analysis is to aid in the construction of theory. The ability of graphics to aid in generating theory goes beyond their use in exploration of the data set so that better models can be constructed,as in EDA. Tukey's own statements allude to the much broader potential of graphs for generating theory. Visualisation of data in the graphical form, as Tukey himself has suggested, allows consideration "not only (of) the multiple hypotheses we hold, but (of) the many we have not yet thought of, regard as unlikely, or think impossible" (1974: cited in Wainer and Thissen, 1981:193). The hypotheses suggested could well involve processes that cannot easily be modelled using variables and a stochastic error term. Indeed, during the past decade, statistical "causal modelling" methodologies, universally employed in social science research have become the focus of increasing controversy. Prominent statisticians have voiced strong criticism of these methodologies; since a variety of models seem to fit the data equally well, there is growing concern that the kind of data usually available to social scientists do not support the kinds of conclusions routinely drawn, that analysis of statistical correlations may not be that useful identifying causal relationships in the social world (see Freedman,1990; Liebersen, 1985).

Marini and Singer (1988) argue that the initial ideas for causal relationships are usually triggered by empirical cues and inductive reasoning, through evidence that is often observational rather than experimental, and, accumulated across multiple studies in multiple settings. Through the access to the processing capacity of the perceptual-cognitive system given by the visualisation of data in graphical form, we can often get a comprehensive picture of a set of quantitative data as well as an immersion in its detail not otherwise possible. The iterative movement from the overview to the detail exploits the synthetic pattern finding and analytic powers of human visual cognition first described by the Gestalt psychologists (W.

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[1] **False assumptions about the normality of distributions or linearity of relationships between variables will confound causal influences at later stages (Hartwig and Dearing, 1979).**

Kohler, F. Kafka, M.Wertheimer). Graphical displays can therefore facilitate inductive reasoning from quantitative data. Although the empirically-based construction of theoretical ideas is an analytical strategy that has been advocated primarily by qualitative, not quantitative sociological methodologists in the past, I advocate that the use of visual portrayals of quantitative data makes possible empirical construction of theory from quantitative data in sociology.

This broader use of graphs for data analysis was elaborated by Krohn (1991), who examined the use of statistical graphics by scientists working in ecology. Natural scientists routinely use statistical graphs in their work; measurements (data) collected are often "graphed" in order to "see" the data and determine whether patterns can be found. Krohn maintains that graphs are such powerful analytical tools because they represent an" interactive site" where visualised empirical evidence is "brought against conceptually led imagination" (1991:198). In a graph, measurements transformed into numbers are then re-visualised, allowing the perceptual-cognitive system to find patterns and relationships that can in turn interact with our conceptual framework (Krohn, 1991). Krohn argues that the visualisation of numbers is so "suggestive" in comparison with the direct examination of lists of numbers in data sets that, given a conceptual framework and the discovery of patterns via the data, the scientist can formulate ideas about processes. This is probably especially true if time-series data are used, as in his case, and in this study.

Another significant aspect of the use of graphical analysis, which could be one of the most revolutionary for sociological research, is that use of graphs increases the opportunity for participation by others in the analysis and interpretation of the data of any given researcher. The quick access to the data being analysed through use of graphical displays increases the possibility for meaningful contribution by others during the analysis and interpretation phases of the research as well as after publication (if graphs used as analytical devices are carried into published results).

Within sociology, Glaser and Strauss advocated the use of quantitative data for the generation of theory in 1967. They maintained, as the statisticians leading the movement towards exploratory data analysis did later, that the close association of quantitative data with confirmatory studies had left its possibilities for generating theory vastly underdeveloped. Although Glaser and Strauss did not discuss the use of graphs to analyse quantitative data, they argued that existing data, often severely limited for purposes of descriptive and verification studies due to the problems of accuracy of the data, are uniquely suited to exploitation for the generation of grounded theory (1967: 189). They argued that the problem of accuracy in the data is not as important if the data are being used to generate, rather than verify, a hypothesis. According to Glaser and Strauss, what is important are the general categories and properties and the general relations between them that emerge from the data. They argue that in verification studies, cross-tabulations of quantitative variables continually and inadvertently lead to discoveries of new social patterns and new hypotheses which are often ignored as not being the purpose of the research. As one of the possible strategies for generating empirically based ideas, they advocate secondary analysis of existing data using cross-tabulations and a variation of Lazarfelds' elaboration technique. It is my conviction that the analysis of large datasets using statistical graphics, a strategy whose utility is amply proven in other subjects, can enhance the theoretical yield of a general exploratory approach for quantitative data in sociological research.

Similarly, the exploration of official statistics by sociologists has been strongly advocated by British sociologist Martin Bulmer (1984). Like Glaser and Strauss, he maintains that the arguments often voiced against using official statistics in sociological research, such as awareness of error and doubts about validity and reliability, need not necessarily lead to rejecting their use for exploratory research purposes. Bulmer argues that these data show significant regularities (trends, patterns, etc.) which warrant further investigation and that instead of ignoring them, it may in fact be the professional responsibility of the sociologist to examine and interpret these regularities. In any case, he argues that the wealth of data available to us in official statistics should be actively exploited for exploratory research purposes and should not continue to be ignored on the basis of arguments that make them flawed for confirmatory analysis. In the present study, while there may be some inaccuracies in the existing degree attainment data published by Statistics Canada (possible under reporting, over reporting or misclassification), these existing statistics contains otherwise unavailable time-series population degree attainment data for the period where women's participation in universities has increased dramatically, but variably by field.

The exploratory graphical strategy developed in this study was designed to use existing statistical resources to facilitate effective visual comparison of the aggregate participation of men and women in science and engineering in the wider context of their participation in other traditionally male dominated areas. Chapter 4 describes the data examined and outlines the creation of a visual database using graphs and Tufte's small multiple design strategy (Tufte 1990).

CHAPTER FOUR: METHODS

1. Data Collection

Participation in degree programs will be examined on a population basis for Canada, using data derived from Statistics Canada publications. The core of the study involves examination the trends in bachelor's degree attainment for men and women in Canada during the period 1962-1989, to the extent that existing data make it possible, in all fields of study where women were under-represented in 1970: physical sciences and mathematics, agriculture and biological sciences, engineering and applied sciences, social sciences and the traditionally male-dominated professional degrees. The data is examined at four different levels of aggregation; Level 1 - Total or Overall Degree Attainment, Level 2 - Natural Sciences and Engineering, Level 3 - Field of study, and Level 4 - Discipline. In order to increase the number of relevant comparisons at the two highest levels of aggregation , some enrolment data, and degree attainment data for the graduate levels is also examined.

2. Creation of a Visual Database

In order to exploit the wealth of existing statistics to generate empirically based hypotheses, i.e. to reason inductively rather than deductively from the data, a new analytical strategy was developed for this study. Although the idea of using quantitative data to generate hypotheses is not new, Glaser and Strauss recommended it in 1967, effective systematic strategies for doing this have not been developed by sociologists.

The strategy developed in this study is essentially a systematic qualitative method for exploring a set of aggregate statistics. In an exploratory study, full access to the detailed empirical evidence is necessary if the analyst is to be effective in finding patterns and relationships. In this study, that exposure is made possible through converting the database to graphical display (Jarett, 1983). This "visual database" facilitates pattern discovery because our visual processing capacities can interact directly with the detail in the data.

Creation of a visual database has only recently become technically feasible. In the past, graphical analysis usually meant the examination of one or a small number of hand drawn graphs. Of necessity, the focus of the analysis was primarily on the data structure revealed by the single graph. The principal change caused by computer graphics is that many similar graphs can be produced, much more quickly than was previously possible (Huber, 1983). This capability opens up possibilities for new analytical strategies.

If statistical graphics are to be harnassed for the generation of hypotheses, the strategies used must fully exploit graphs' ability, as outlined by Krohn, to act as an "interactive site" where visualized empirical evidence is "brought against a conceptually led imagination" (1991:198). These displays must also bear on the question at the heart of quantitative reasoning: "Compared to what?" (Tufte, 1983). Comparison is the most fundamental principle of data analysis (Tufte, 1990; Tukey, 1990; Huber, 1983; Glaser and Strauss, 1967). The obvious advantage of using graphs for data analysis is that comparisons in the data can be made visually. To be effective, graphical analysis strategies must optimize both the breakdown of data into its component parts, and, possibilities for comparison between those parts. In this study, instead of breaking data down into its component statistical parts, as is done in exploratory data analysis, the data is disaggregated into conceptually meaningful categories, and compared. Using a large detailed database and the ability of the computer to produce similar graphs for data in different degree categories means data in many categories can be visually compared. Disaggregation of the data into categories which can be visually compared expands the power of graphical analysis for the social sciences because it increases the potential for productive empirical-conceptual interaction.

A. Comparisons and Data Series

The analytical graphs in this study have been designed to facilitate comparison of trends of degree attainment of men and women 1) in any given category in the data, and, 2) among different categories.[1]

In an exploratory study of quantitative data, it is best to use raw data (or simple derived measures) so that the observed patterns in the data are easily interpretable (Chambers, 1983). It is especially important in this study that the observed patterns be easily interpretable because the principal aim is to look for themes by comparing patterns across a large number of categories. In this study, I decided to plot two different data series in order to compare the degree attainment of men and women: 1) percentage of degrees earned by women, 2) the actual number of men and women graduates. Comparison of degree attainment for men and women is most often done using the percentage of total degrees earned by women. However, using these relative measures alone does not fully exploit the existing data for this purpose. In this study, the trends of actual numbers of men and women graduates provide a second set of comparisons of degree attainment by sex across different categories of degrees.

B. <u>Construction of Visual Displays</u>

The visual displays were designed to facilitate the desired comparisons using these two data series. They were constructed using knowledge derived from graphical perception studies and are consistent with the small multiple design strategy of Edward Tufte (1990).

C. <u>Individual Graphs</u>

The graphs in this study use lines to show the trends rather than bars. Using lines instead of bars to show trends has been found to improve the speed and accuracy with which global patterns in data can be identified (Schutz, 1961a). Another advantage of using lines is that several data series can be depicted on each graph. Because comparison is facilitated if items are close together, being able to place several trend lines on the same graph is an advantage (Schutz, 1961b). Line graphs have also been found to lead to better memory of observed overall trends than bar charts (Washburn, 1927 cited in Lewandowsky

[1] The categories in degree attainment data are fields of study (e.g. social sciences), disciplines (e.g. physics) or aggregates such as Natural Sciences and Engineering (includes three fields of study delineated by Statistics Canada - Agriculture and Biological Sciences, Mathematics and Physical Sciences, and , Engineering and Applied Sciences).

and Spence, 1990) and therefore there is a definite advantage to their use in a study where many different trends are to be compared.

The individual graphs are designed to facilitate the comparison of trends in men and women's participation in each degree category. In the first series, the comparison between men and women is inherent in the trend for percentage of total degree attainment by women itself. Several related trends are presented on each graph to promote comparison between them. In the second series, the trends of numbers of men and women graduates are easily compared because for each degree category, the trends for each sex are plotted on the same graph.

D. Organization of the Graphs

The graphs in this study were usually presented in combination in order to promote comparison of the data in different categories (e.g. among different disciplines). In any given set of graphs where the trends on different graphs were to be compared, the individual graphs in the set have the same size, format and labelling. Repetition of the design structure for all the graphs to be compared, as Tufte (1990) outlines, results in an "economy of perception":

> ...once viewers decode and comprehend the design for one slice of data, they have familiar access to data in all the other slices. As our eye moves from one image to the next, this constancy of design allows viewers to focus on changes in information rather than on changes in graphical composition. A steady canvas makes for a clearer picture (29).

While computers make the production of many similar graphs feasible, most software used to make graphs still does not facilitate the most effective comparison of many graphs at once, and therefore does not fully support the most effective analytical use of statistical graphs. In this study, the computer is used to convert the database to graphical display in the form of many similar graphs. The innovation in this study is that the comparisons among different categories in the data (presented on separate graphs) are facilitated by the physical arrangement of the graphs.

I argue that the ability and speed of the visual cognitive system to process and interpret graphically displayed data can be enhanced if similar graphs representing different categories in the data are organized in a relevant and easily understood physical arrangement. With an effective visual organization of the graphs, several different kinds of comparison can be facilitated among categories in the same data set.

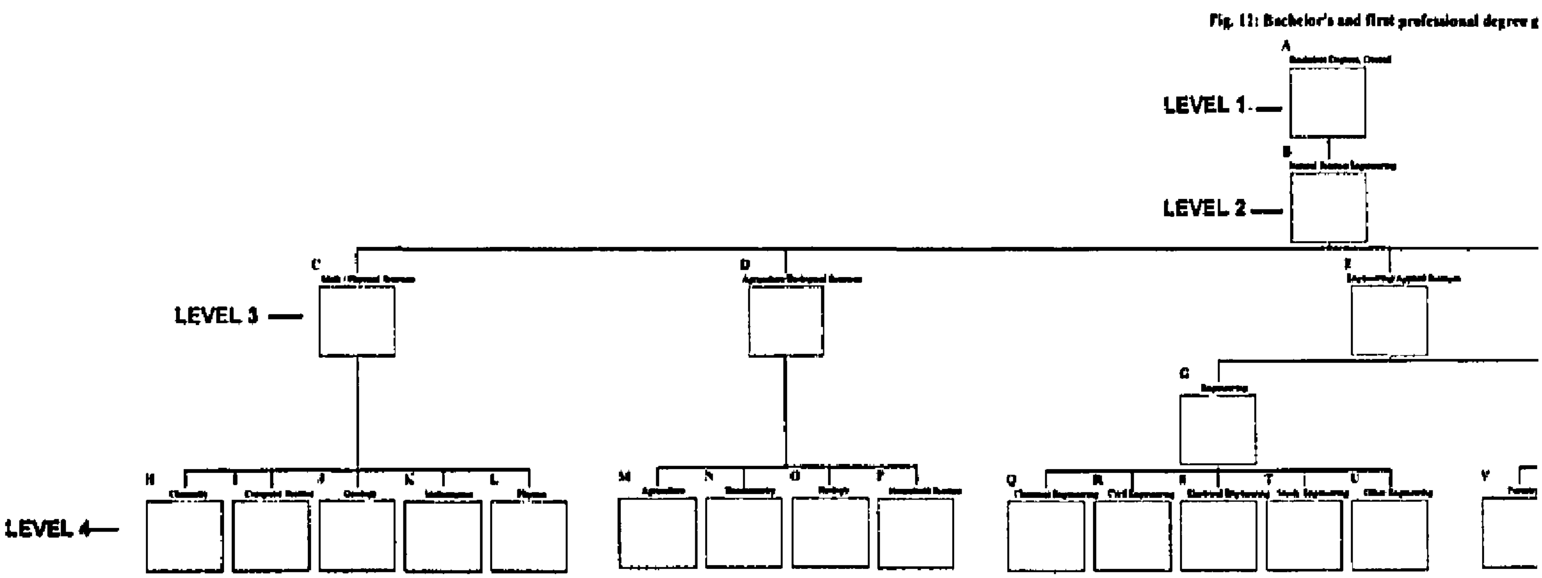
In this study, the database for degree attainment at the bachelors level was converted into two sets of graphs, one depicting women's trends for the percentage of women earning degrees, and the other, numbers of men and women graduates. These two sets form the core of the analysis. In order to facilitate visual comparisons of trends in the data across degree categories, the design of the arrays combines an overview of the data to be explored with several hierarchical layers of detail, all in a relatively compact space. In each set, the database is systematically disaggregated using the visual organization of the graphs through four levels of aggregation[2]. Each of these arrays is therefore an elaboration of the data to progressively finer levels of detail, breaking the data down into meaningful categories that can be readily compared with all of the others in the data set. Each graph in each set is also similar in size, format and style of labelling so that the eye can move quickly between and across categories and levels of aggregation in the database making inter and intra level category visual comparisons. The basic structure of these arrays of graphs is shown in Fig. 1 and Fig. 2. The actual arrays of graphs used to do the analysis are presented in Fig. 11 and Fig. 12 (see Appendices I and II respectively).

E. Small Multiple Design

In order to bring the graphs to be compared "into the eyespan" so that the patterns they displayed could be more easily compared, the graphs were shrunk to a small size, creating what Tufte refers to as a "small multiple design" (Tufte, 1983,1990). As Tufte reminds us, the eye can make a remarkable number of distinctions over a small area (1983;162). If statistical graphics are shrunken, the analyst can take advantage of this visual ability in order to enforce comparisons within the eyespan and provide the data in context all at the same time:

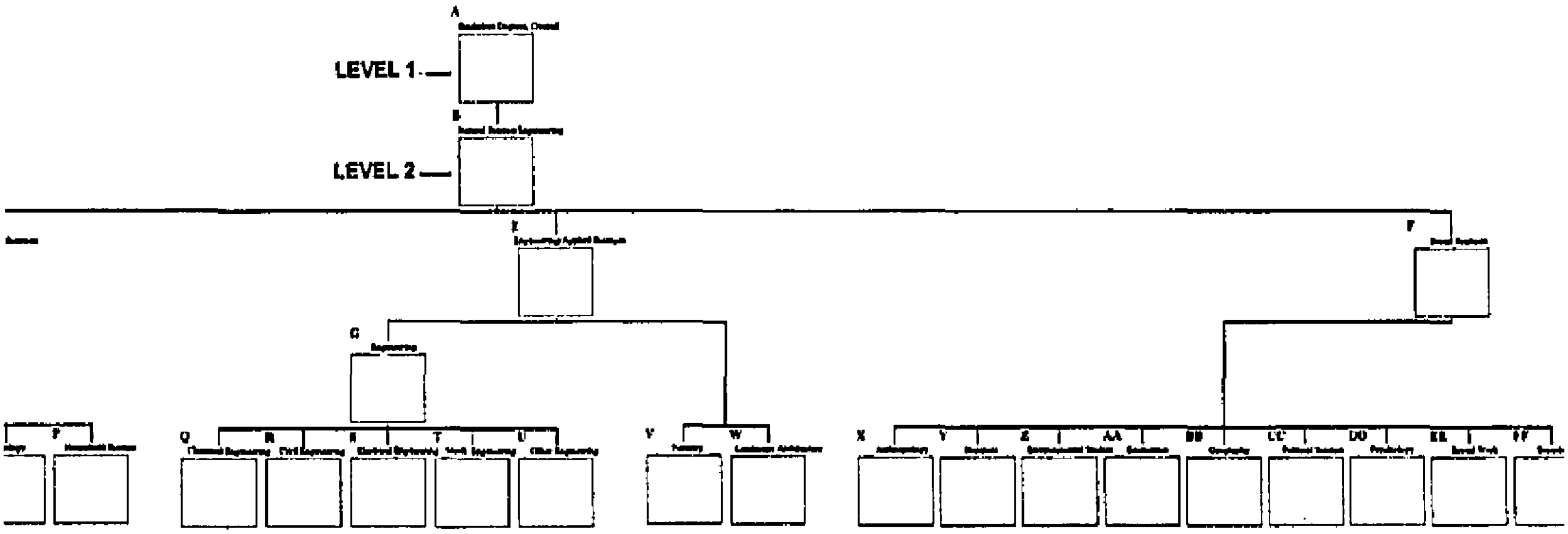
[2]The four levels of aggregation are Total Bachelors Degree Attainment (Level 1), Natural Science and Engineering (Level 2), Fields of Study (Level 3) and Disciplines (Level 4).

Figure 1. Diagram showing the organization of graphs depicting trends in the number of



of graphs depicting trends in the number of graduates in Fig. 12

Fig. 12: Bachelor's and first professional degree graduates, by sex, Canada, 1962-1989



f graduates in Fig. 12

r graduates, by sex, Canada, 1962-1989

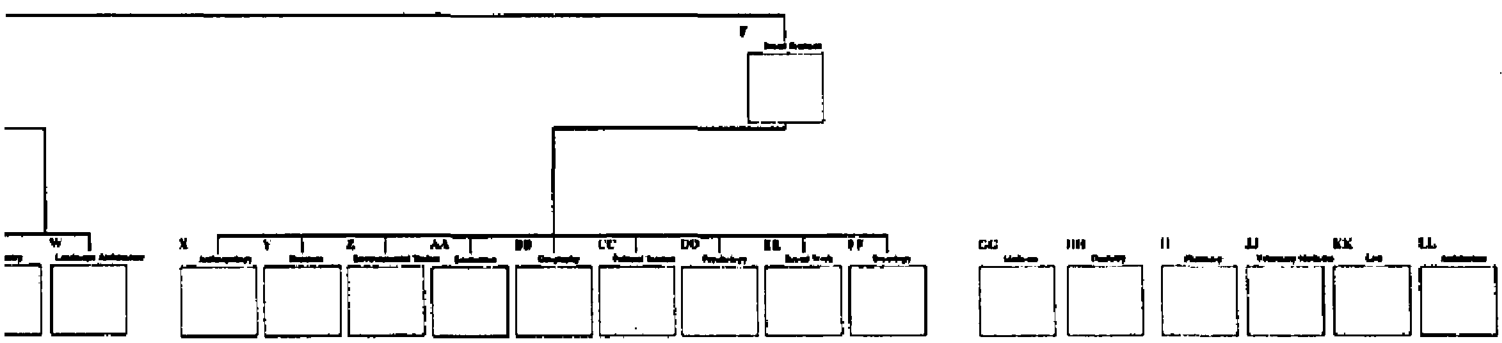
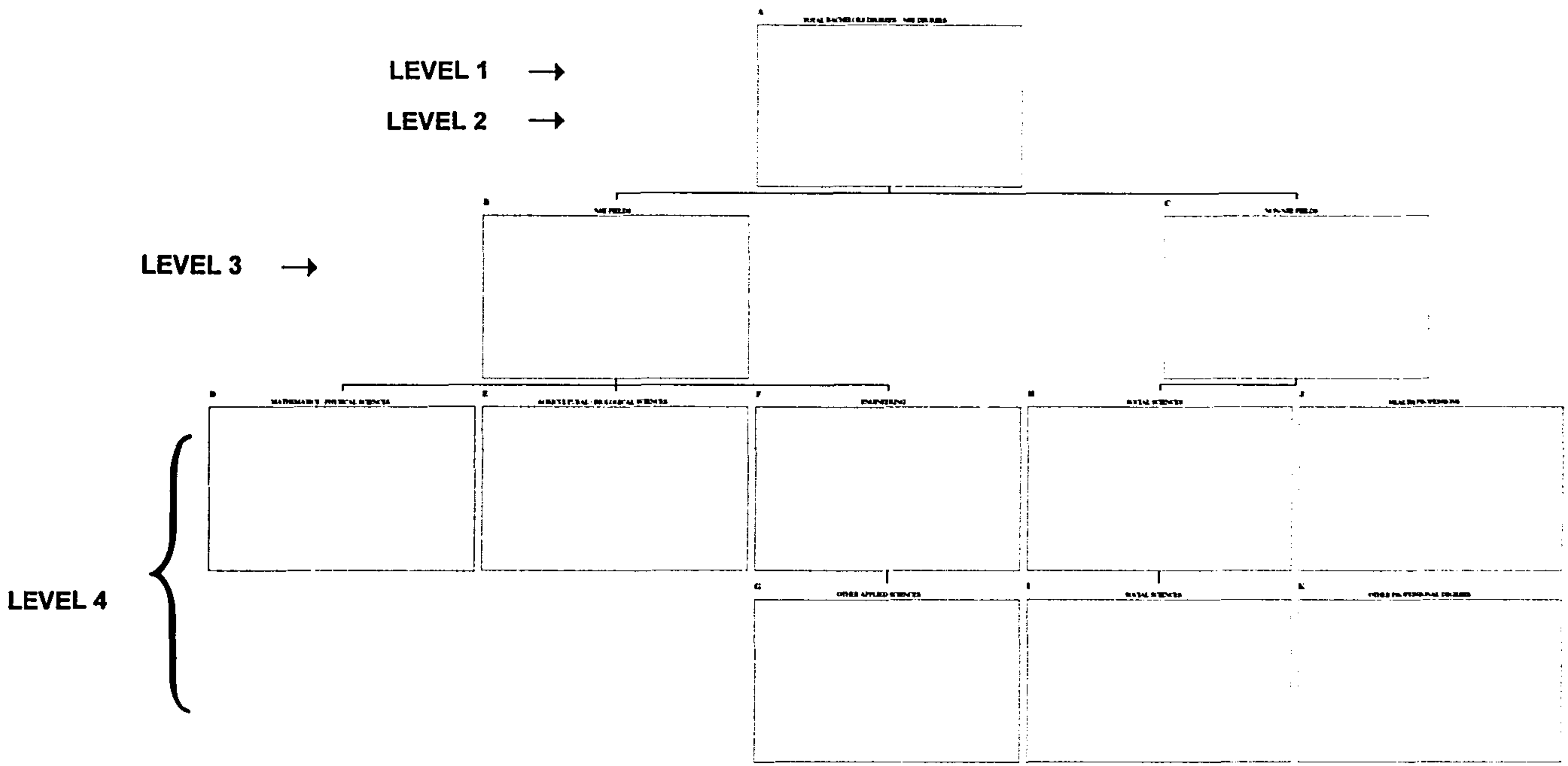


Figure 2. Diagram showing the organization of graphs depicting trends in percentage of degrees granted to women in Fig. 11

Fig 11: Percentage of bachelor's and first professional degrees granted to women, Canada, 1962-1989



> Illustrations of postage-stamp size are indexed by category or a label, sequenced over time like the frames of a movie, or ordered by a quantitative variable not used in the single image itself. Information slices are positioned within the eyespan, so that viewers make comparisons at a glance - uninterrupted visual reasoning. Constancy of design puts the emphasis on changes in the data, not changes in the data frames (Tufte, 1990; 67)

The small multiple design is able to report immense detail, which can be read without confusion.

> Simplicity of reading derives from the context of detailed and complex information, properly arranged. A most unconventional design strategy is revealed: *to clarify, add detail.* (Tufte, 1990; 37)

Tufte argues that visual reasoning is actually likely to improve with display of large data sets at high density:

> If the visual task is contrast, comparison and choice - as it so often is- then the more relevant information *within the eyespan*, the better. Vacant, low-density displays, the dreaded posterization of data spread over pages and pages, require viewers to rely on visual memory -a weak skill- to make a contrast , a comparison, a choice. Micro/macro designs enforce the both local and global comparisons and, at the same time, avoid the disruption of context switching (Tufte, 1990; 50).

The closest possible links between the observed patterns in the data and category information are therefore built into the data displays through 1) the organization of the graphs into a logical and relevant category breakdown (in this case, a systematic disaggregation), 2) using the small multiple design to display all relevant graphs within the eyespan, and 3) through the positioning of the labels, which should facilitate conceptual and empirical interaction. The labels for trends have been placed directly on the graphs instead of in legends - graphical perception studies have found that this closer positioning enhances comprehension and memory of the data structure in connection with its category (Cuthbertson and Powers, 1959).

The study begins by comparing overall degree participation of men and women to demographic trends. Degree attainment by sex is then examined at the four different levels of aggregation in the data; Total Bachelors Degree Attainment (Level 1), Natural Science and Engineering (Level 2), Fields of Study (Level 3), and, Disciplines (Level 4).

CHAPTER FIVE: ANALYSIS AND FINDINGS

1. Comparison of Demographic Trends with Trends in Total Degree Participation

Concern about potential shortages of scientific and technical labour has motivated much of the recent interest of policy makers in women's participation in science and engineering. These concerns are based on the assumption that the smaller size of the university age population in the 1990s will affect the supply of university graduates. For the purposes of this study, it was necessary to investigate the assumption that the number of graduates is related to the size of the underlying population, since it would affect interpretation of the trends for numbers of graduates at the most aggregate levels in the data. In this first section, trends in the size of the university age population were compared with trends for total degree participation during the last three decades in order to determine whether these trends have been directly related.

Comparison of the trend for the estimated number of 23 year olds in the population[1] with the trends in actual numbers of baccalaureates for the 1962-1989 period (total, men, and women) was made using Figure 3. This comparison reveals that degree participation at the bachelors level in Canada has not been directly related to demographic trends during the last two decades, not as a whole, or for men and women separately.

The trend in the total number of bachelors degree graduates rises with the increase in the 23 year old population during the 1960s and 1970s, but it does not reflect the precipitous drop that occurred in the corresponding population during the 1982-1989 period (19.1%). During this period, annual degree attainment of bachelors degrees did not decrease but instead, increased by 21%. Similar observations are made for trends in total enrolment at the undergraduate level. Fig.4 shows that despite a sharp drop in the population of 18-24 year olds between 1982-1989, undergraduate enrolment grew considerably (20%) during this period (also see Fig. 6a).

Trends for degree attainment by men and women differ significantly beginning in the

[1]Based on the number of live births in year (n - 23).

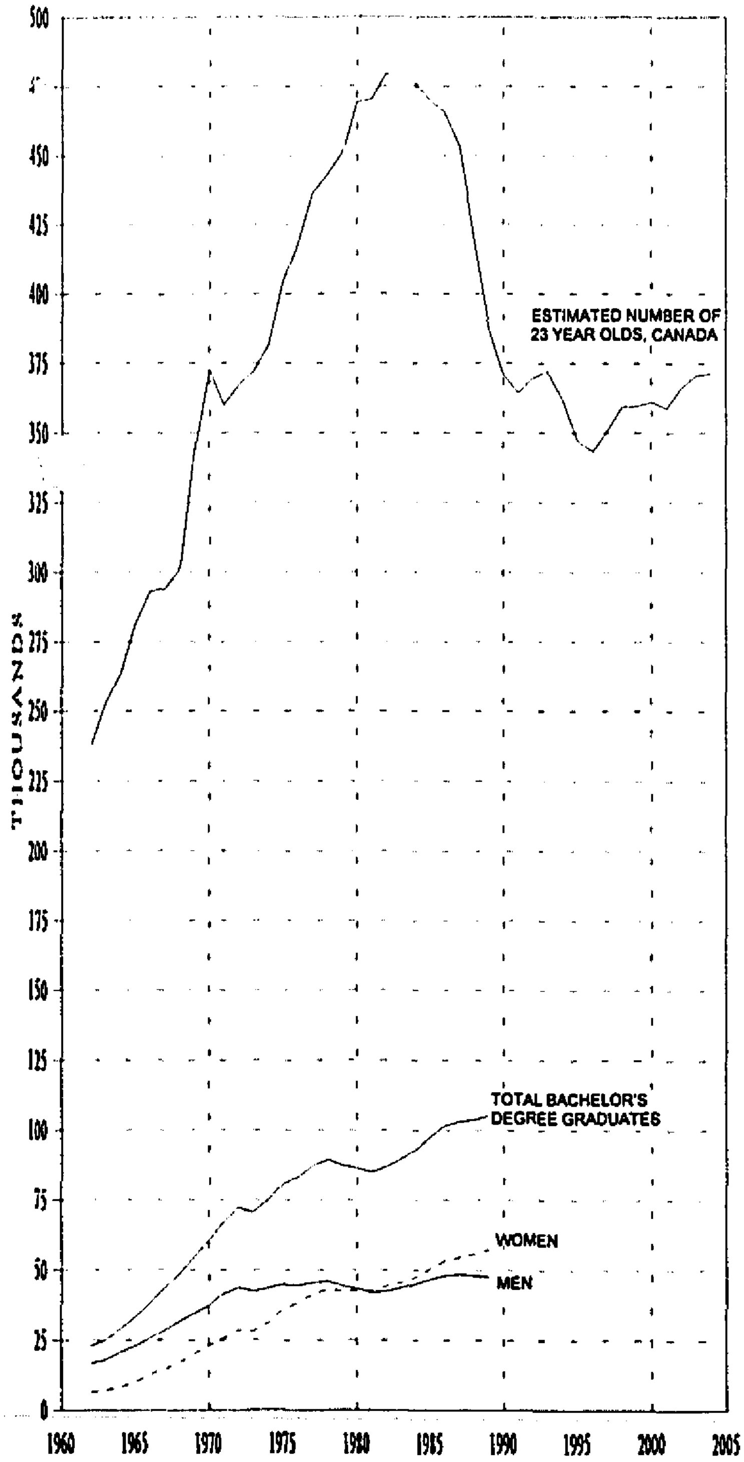


Figure 3. Comparison of estimated number of 23 year olds and number of bachelor's degree graduates, Canada, 1962-1989

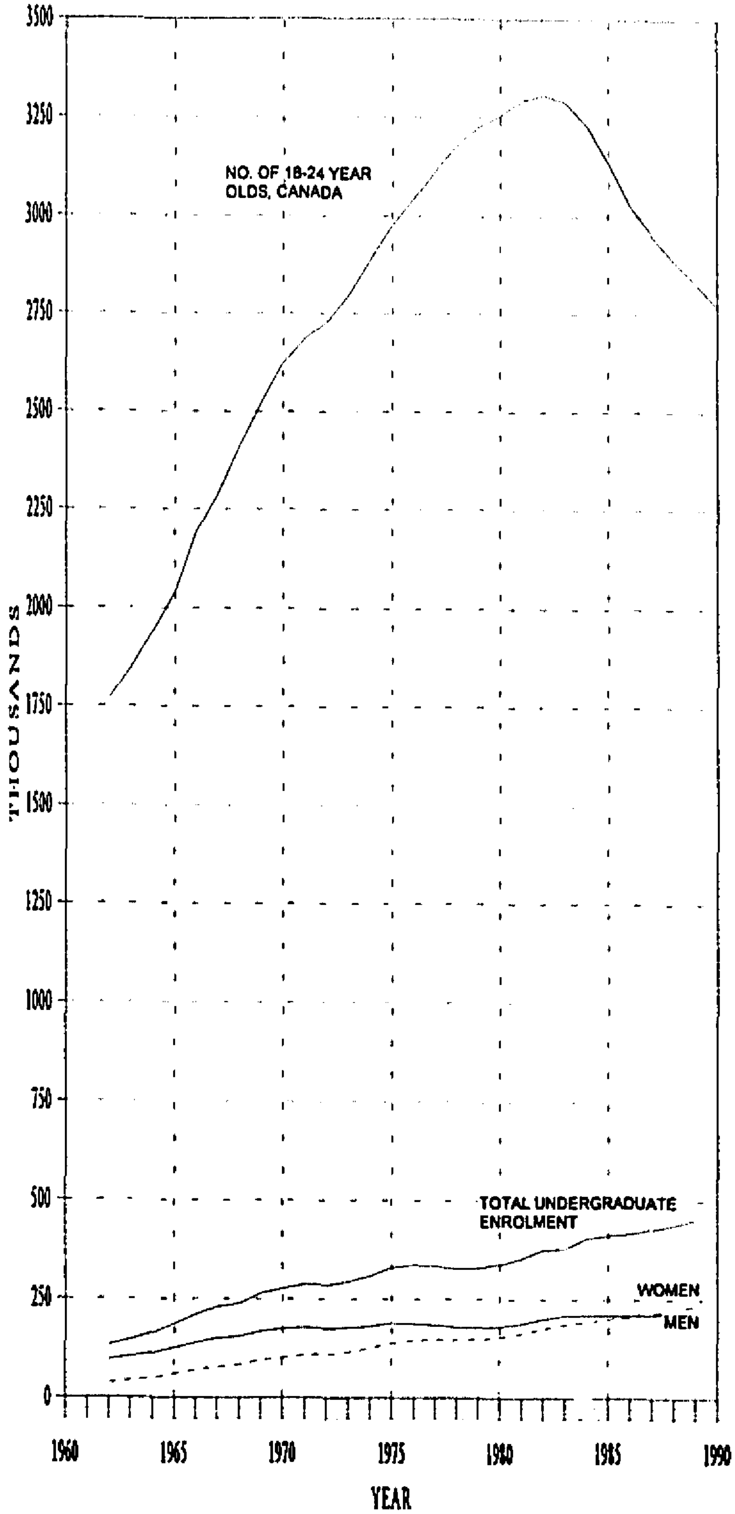


Figure 4. Comparison of number of 18-24 year olds and undergraduate enrolment, Canada, 1962-1989

early seventies. The number of bachelors degrees earned by women has shown relatively steady annual growth over the last three decades. In contrast, annual degree attainment by men, following rapid increase during the 1960s, levelled out in the early seventies, and remained relatively stable through the early eighties.[2] Despite the difference in degree attainment patterns for the sexes, neither men's or women's degree attainment trends reflect the large drop in the size of the 23 year old population that occurred between 1982-1989. The trend for men also did not reflect the major increase in the size of the 23 year old population experienced during the 1972-82 period, the years corresponding to the last decade of the baby boom generation. During this period, a 31% increase in the 23 year old population occurred but degree attainment by men declined by 2.8%. The long period of relative stability in mens degree attainment therefore corresponds to two periods of major change in the size of the 23 year old population yet does not reflect either of them.

At the graduate level, enrolment instead of degree attainment statistics were used to make a similar comparison with the underlying population since no single age can be effectively used as an estimate for age of graduation at the graduate levels. Comparison of the trends in graduate enrolment with trends for the size of the graduate school age population (Fig.5a and 5b), shows that participation in graduate education does not appear to have been directly related to the size of the underlying population either. During the 1962-1972 period, the total enrolment of graduate students increased several times (345%) while only a 24% increase occurred in the size of the corresponding population. Expansion of the Canadian university system during this time almost certainly had more to do with rapid increases in enrolment than size of the corresponding age cohort. During the 1972-1979 period, a 30% increase in the graduate school age population was associated with a slight decrease in enrolment for men.

These findings clearly indicate that degree participation at undergraduate and graduate

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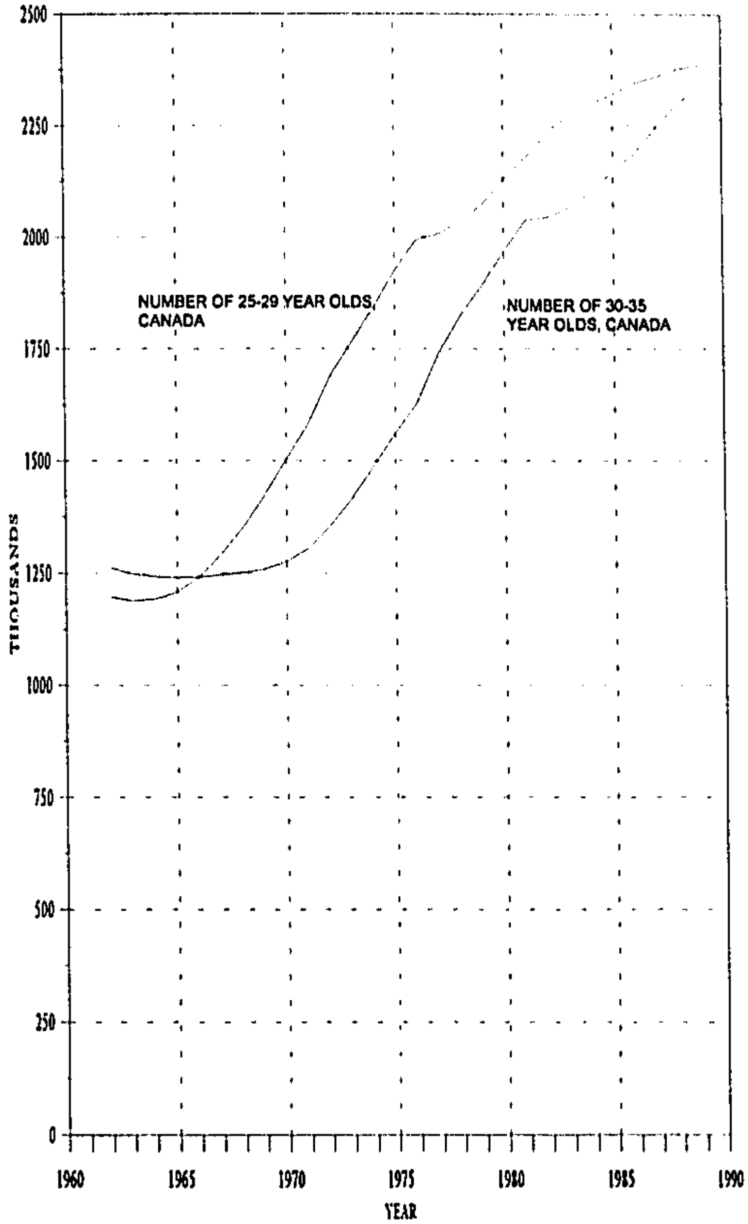
[2] As has been noted elsewhere, (Women in Canada, Statistics Canada, 1987), the considerable growth in the total numbers of bachelors degrees between 1972 and 1989 (45%) is due primarily to growth in the numbers of women attaining degrees annually (net increase in the number of degrees earned per year during the 1972-1989 period by men = 3,870, women = 29,953).

A



B

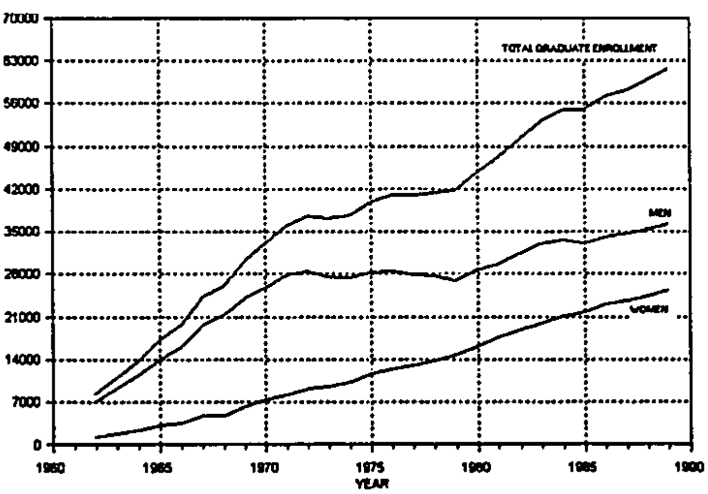


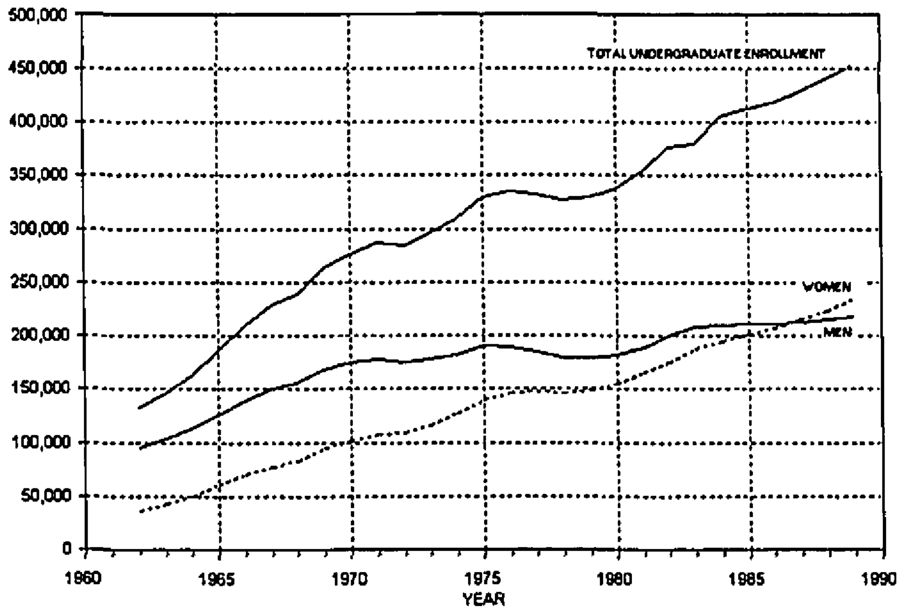
Figure 5. Comparison between size of graduate school age population and graduate enrolment, Canada, 1962-1989

levels in Canada has not reflected major demographic changes over the last two decades. The assumption that the diminishing university age population will necessarily decrease the supply of university graduates in Canada in the 1990s (NSERC 1988) therefore has little empirical precedent.

Although the trends for degree participation at undergraduate and graduate levels did not reflect the changes in the underlying populations, it is easily seen from the comparison of Fig. 6A and 6B that their are remarkable similarities in the enrolment trends between the two levels. At both levels, the annual enrolment of women increased relatively steadily over the 1962-89 period, while that of men leveled out or slowed considerably in the seventies[3]. These findings suggest that degree participation at the two levels was primarily affected not by changes in the size of the corresponding populations, but instead by influences which were experienced differently by men and women. Possible influences and reasons for similarity in the sex specific trends between degree levels in trends in overall degree participation will be discussed further in the next section.

[3] The trends for the enrolment of men at the undergraduate and graduate levels have similar directional changes in slope at similar points on the x-axis, even if the magnitude of the slopes differs; the first at approximately 1971, and the second at approximately 1979.

A



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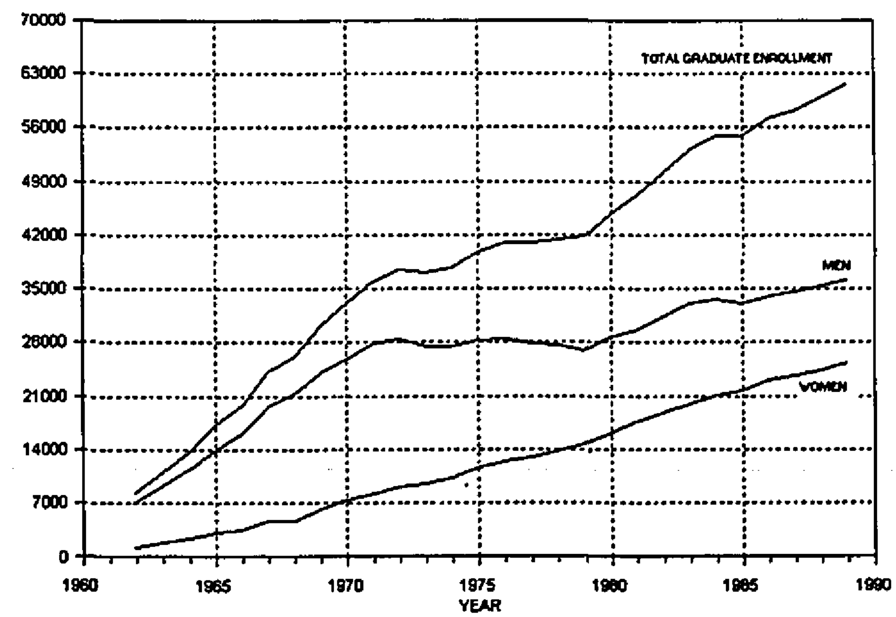

Figure 6. Comparison of undergraduate enrolment and graduate enrolment, Canada, 1962-1989

2. Trends in Aggregate Level Degree Attainment

In order to provide sufficient context for the analysis of trends at the lower levels of aggregation in this study, in this section, the trends for total degree attainment (level 1) and degree attainment in natural sciences and engineering[4] (Level 4) are examined and compared at all three degree levels. This study is primarily a comparison of trends in degree attainment at the bachelor's degree level, but in this section, trends at the master's and Ph.D. levels are also examined in order to increase the number of comparisons possible at the highest levels of aggregation. Increasing the number of categories between which relevant comparisons can be made increases the potential conceptual yield of the analysis.

A. Trends in Women's Representation

The comparison of the graphs in Fig.7 show that women's representation in NSE degrees has been growing relatively steadily at all degree levels since the early 1970s, but that their share of NSE degrees has always been considerably lower than their share of total degrees during the 1962-1989 period.[5,6] Visual comparison of the two graphs, however, also reveals that there is considerable similarity in the patterns of the total and NSE trends: at each degree level, it is observed that the trends for women's representation in NSE degrees have fluctuated very similarly to those for women's overall representation.[7] In addition, at the

[4] The natural sciences are the physical and biological sciences. For the purposes of this study, Natural Sciences and Engineering (NSE) includes 3 fields used by Statistics Canada: Mathematics/Physical Sciences, Agriculture/Biological sciences, and Engineering/Applied sciences. The other five fields used to classify university degrees by Statistics Canada are Education, Fine/Applied Arts, Humanities, Social Sciences, and Health Professions (see Statistics Canada, Universities: Enrolment and Degrees 1991-2, Cat. no. 81-204.)

[5] Comparable data not available for natural science and engineering degrees at the bachelors level in the 1960s.

[6] Since their share of NSE degrees has also been well below 50%, women have been under-represented in NSE at all three degree levels in the 1962-1989 period, as measured in both of the ways used in the literature. In this study, women are considered under-represented in a given area if they earn less than 50% of total degrees.

[7] In this study, similar patterns are those which have similar directional changes in slope at similar points along the x-axis.

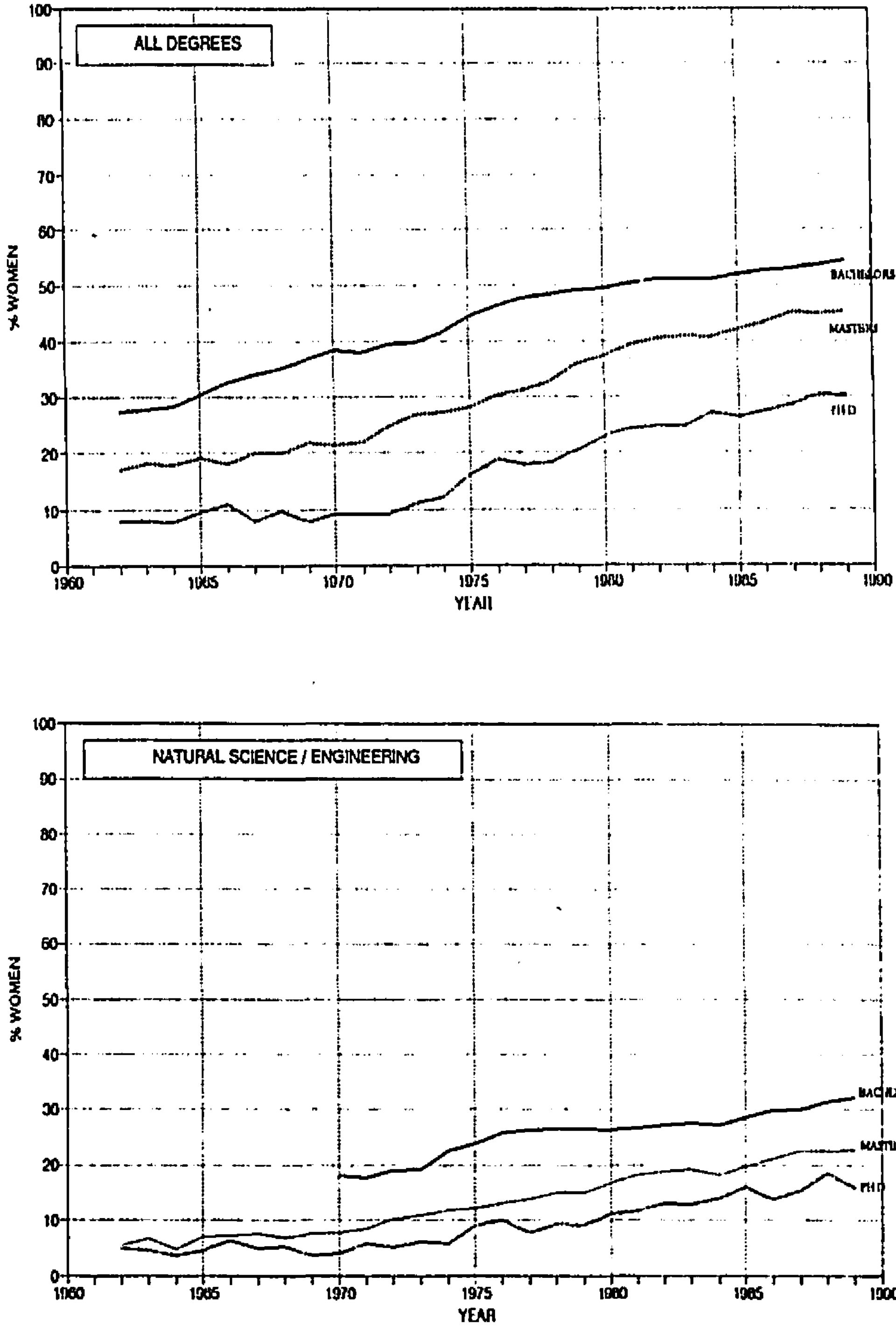

Figure 7. Comparison of trends in women's representation at the bachelor's, masters and Ph. D levels in A) All degrees B) Natural science and engineering.

bachelors level, the magnitude of increase in women's share of total degrees and NSE degrees, during period for which they can be compared (1970-1989), has also been very similar (16.2% and 14.2% respectively).

These similarities between the trends at the two aggregate levels lead me to the hypothesis that, at least at the bachelors level, increases in the share of NSE degrees earned by women might be the direct result of increases in total numbers of women attaining degrees, rather than the result of a shift in the pool of women university graduates towards NSE degrees. This idea would be supported if the distribution of all women graduates between NSE and non-NSE subjects had remained relatively constant while the total number of women bachelors graduates increased, and if no exodus of men from NSE had occurred. In order to investigate this hypothesis, the trends for distribution of men and women graduates between NSE and non-NSE degrees were plotted in Fig. 10 and compared to the trends in the number of men and women graduates (which are examined in the next section). The results of this investigation are discussed in section 2C.

B. Trends in the Numbers of Degree Graduates

i) Total Degree Attainment

Fig.8 shows the trends in actual numbers of graduates over almost three decades at the bachelors, masters and Ph.D degree levels.

The most immediate observations to be made from the comparison of trends for total degree attainment in Fig.8 is that the trends for men differ from those of women, but that the sex-specific trends have similar features at each degree level. The primary differences in the patterns occur in the seventies. While the numbers of women graduates grew relatively steadily over the 1970-1989 period, growth in the number of male graduates ceased at all three degree levels in the early seventies, and did not begin again until the early eighties. The trends in the number of male degree recipients therefore show three separate phases over the 1970-1989 period, similar at each degree level.[8]

[8] Exponential increases in the total number of degrees granted from 1962 to 1972-3 were underlain by steady annual increases in the number of both men and women graduates. After cessation in growth in between 1971-73, total numbers of men attaining degrees at the bachelors and masters levels remained relatively constant until approximately 1982. Following a peak in 1973, numbers of men obtaining doctorates fell during the seventies. This phase was followed by a third which saw the numbers of men begin to rise again during the early eighties.

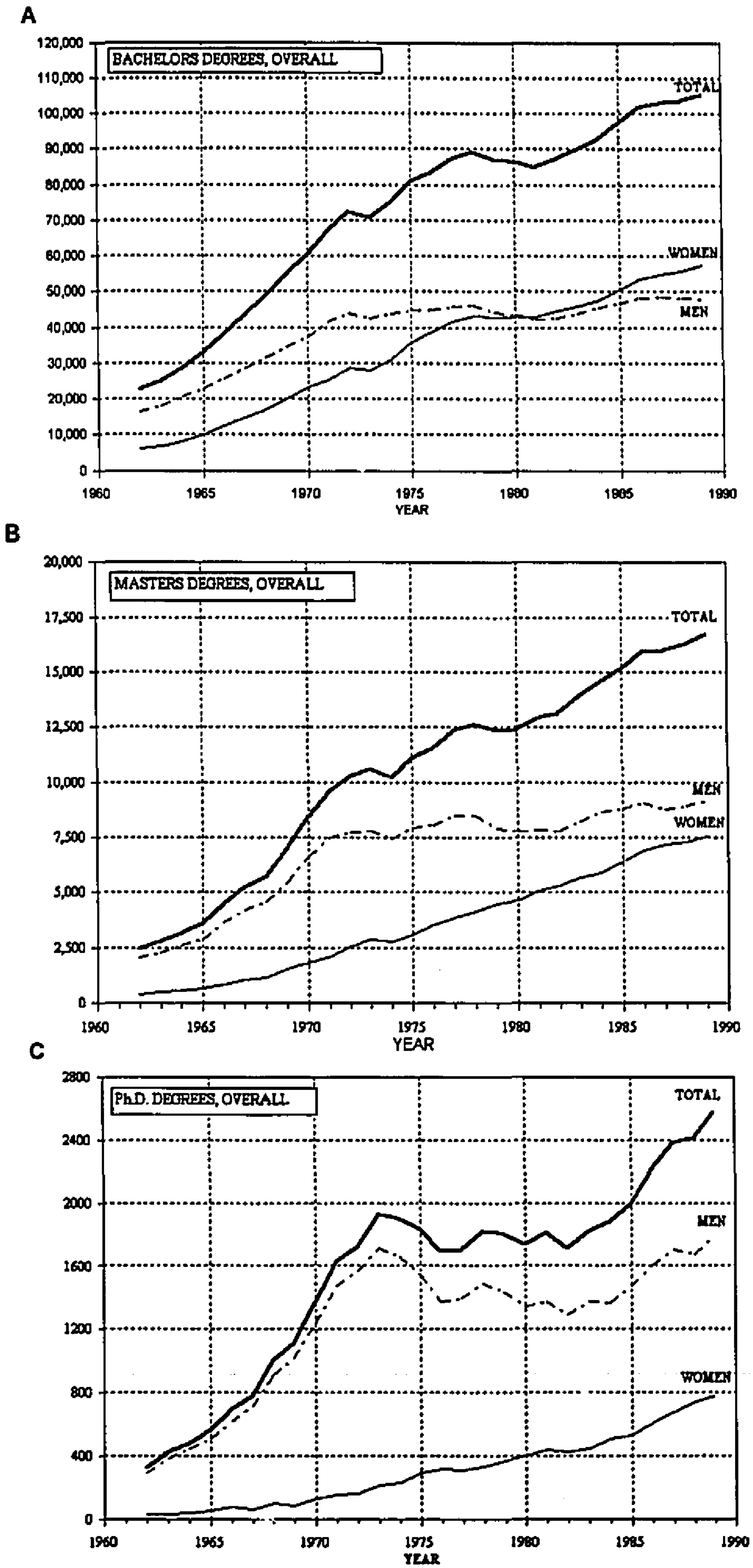

Figure 8. Comparison of numbers of men and women graduate with A) Bachelor's Degrees, B) Master's Degrees, C) Ph.D Degrees, Canada, 1962-1989

The similar patterns of increase in women's annual degree attainment at each degree level, and the more surprising similarities in the patterns of fluctuation for the degree attainment of men at each degree level suggest that the existence of different general influences on the overall degree attainment of men and women during the 1970s. The large increases in the number of women graduates over the last two decades are generally acknowledged to be associated with the influence of the women's movement. The slowdown in total degree production in the 1970s is generally acknowledged to be a reaction of students to the availability of fewer job opportunities for graduates as a result of a slowdown in the economy, and decreases in funding for universities and therefore of new academic positions (and turnover in positions) (Naimark, 1989). (Since the changes in slope in men's trends both in the early 1970s and early 1980s occurs at all degree levels within a two year period, the changes do not appear to have been "pipeline effects", that is, changes related to changes in degree attainment in lower degree levels. This suggests that factors largely external to the university itself were responsible). The interesting suggestion emerging here in the differential trends for the sexes is that the overall degree participation of men and women was not equally affected by the downturn in the economy and the softer labour market for academics: the sex-specific trends suggest that the overall degree attainment of men, but not of women, was affected by there being fewer job opportunities for university graduates. The similarly timed levelling off seen earlier for trends in <u>enrolment</u> for men at both the undergraduate and graduate levels in the early 1970s, but again, not of women (see Fig.6), reinforces this suggestion.

The difference between the trends in the degree attainment of men and women in the seventies could be interpreted in a number of different ways. It could mean that worsening economic and labour market conditions had a negative impact on the desire or ability of men to participate, but not those of women, strongly suggesting that the general economic and labour market conditions did not tend to affect women's decisions to participate in university level education. Alternatively, it could be that men and women were both influenced had but <u>different</u> <u>responses</u> to the change in labour market conditions in the 1970s. The relatively <u>steady increase</u> in women's participation observed at all three degree levels throughout most of the 1962-1989 period seems more consistent with the first interpretation. Similar behavior of trends for men and women at all degree levels in the mid and late 1980s suggest that both sexes may have been responding similarly to changing labour market conditions after the early eighties.

ii) Natural Science and Engineering

The trends for the numbers of graduates in NSE at the bachelors, masters and Ph.D. levels are shown in Fig. 9.

At both the masters and Ph.D. levels, sex-specific patterns for NSE degree attainment are evident (Fig. 9B and 9C) which are similar to those observed for overall degree attainment at these levels (Fig.8B and 8C). As was suggested then, these patterns indicate that at the graduate level, the numbers of male NSE degree recipients, but not the number of women, may have been affected by changing economic and labour market conditions for academics in the early seventies. At the Ph.D. level, the proportionally larger decrease in men's attainment of NSE degrees than of total degrees suggests that the downturn in the economy and the softer market for academics in the early seventies had a more severe effect on men's attainment of doctorates in NSE than it did on their attainment of doctorates in general.

In marked contrast, at the bachelors level, annual NSE degree attainment for men (Fig. 9A) did not stop growing in the early seventies. Both the number of men and the number of women graduating in NSE increase over most the 1970-1989 period, (except for a slight drop in the early eighties), resulting in a net increase in annual degree attainment for each sex of approximately 5000 degrees per year. Calculations show that most of the net increase in men's total bachelor's degree attainment was due to the increase in NSE degree attainment. While men's total degree attainment rose only about 8% from 1972-1989, it increased more than 50% in NSE. The probable reason for this was that there was a relatively strong demand and resulting higher salaries for undergraduate degree holders in the applied fields (e.g. engineering and applied sciences) in the seventies (Ministry of State for Science and Technology, 1981a,22). The fact that men's degree attainment in university in general appears to have been negatively affected by the economic slowdown, while their increasing participation in NSE degrees is related to a period of relatively strong demand for engineers suggests a strong relationship between men's degree attainment and labour market conditions.

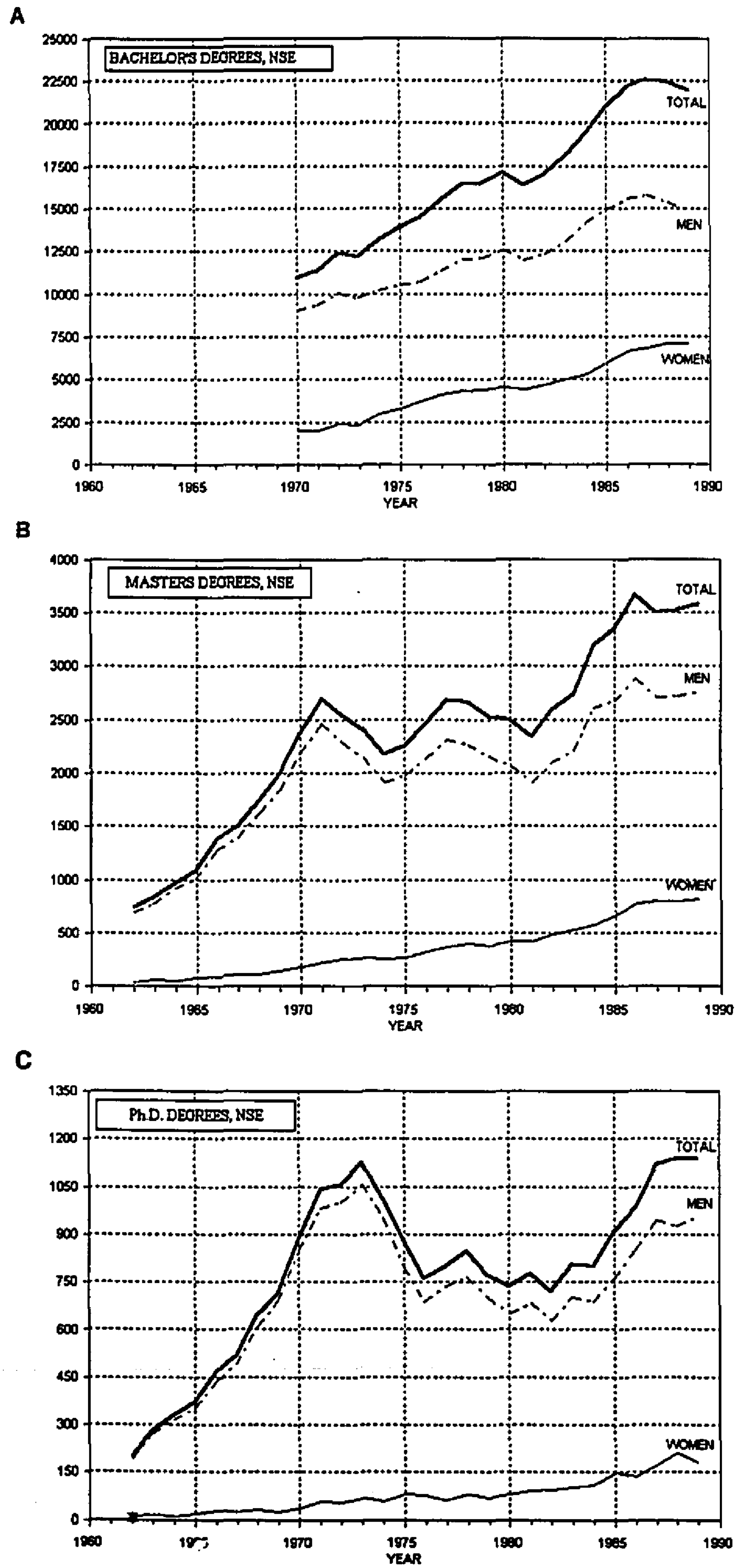

Figure 9. Comparison of number of men and women graduates in Natural Sciences & Engineering (NSE) Canada, 1962-1989, A) Bachelor's, B) Master's, C) Ph.D

The absence of a slowdown in women's degree attainment in the 1970s suggests that only a weak relationship if any existed between these conditions and women's degree attainment. However, the very similar timing of the fluctuations (and magnitude of increase) shown in the trends for NSE degree attainment of men and women at the bachelor's level suggests that within NSE both sexes may have been responding to similar influences on NSE degree attainment during most of the 1970-1989 period.

C. Distribution of Graduates Between NSE and non-NSE Degrees

Fig. 10 shows the trends for the proportion of all graduates earning NSE degrees at the bachelors, masters and Ph.D. levels respectively.

These graphs were drawn to test the hypothesis in an earlier section that increases in women's share of NSE degrees (Fig.7B) are directly related to increases in total number of degrees earned by women rather than a shift in the distribution of women from NSE to non-NSE subjects.

It is immediately evident from these graphs that the influx of women into the university in the last few decades has not been accompanied by a large increase in the <u>proportion</u> of all women graduates attaining degrees in NSE subjects, at any degree level. At the bachelor's and master's levels the proportion of total women graduates earning NSE degrees has exhibited relatively little change over the entire comparable period, remaining close to 10%.

Since we now know that the number of women bachelor's degree graduates has been increasing relatively steadily since 1970 (Fig.8A) and that there has not been an exodus of men from NSE at the bachelors level (Fig.9A), the relative stability of the proportion of women graduates earning degrees in NSE at the bachelors level indicates that increases in women's share of NSE degrees at this level have been primarily related to increases in overall numbers of women attaining bachelors degrees, as was suggested earlier. Although there was an increase in the proportion of women bachelor's graduates earning degrees in NSE over the 1970-1989 period (8% to 12%), this increase alone would have accounted for a net increase

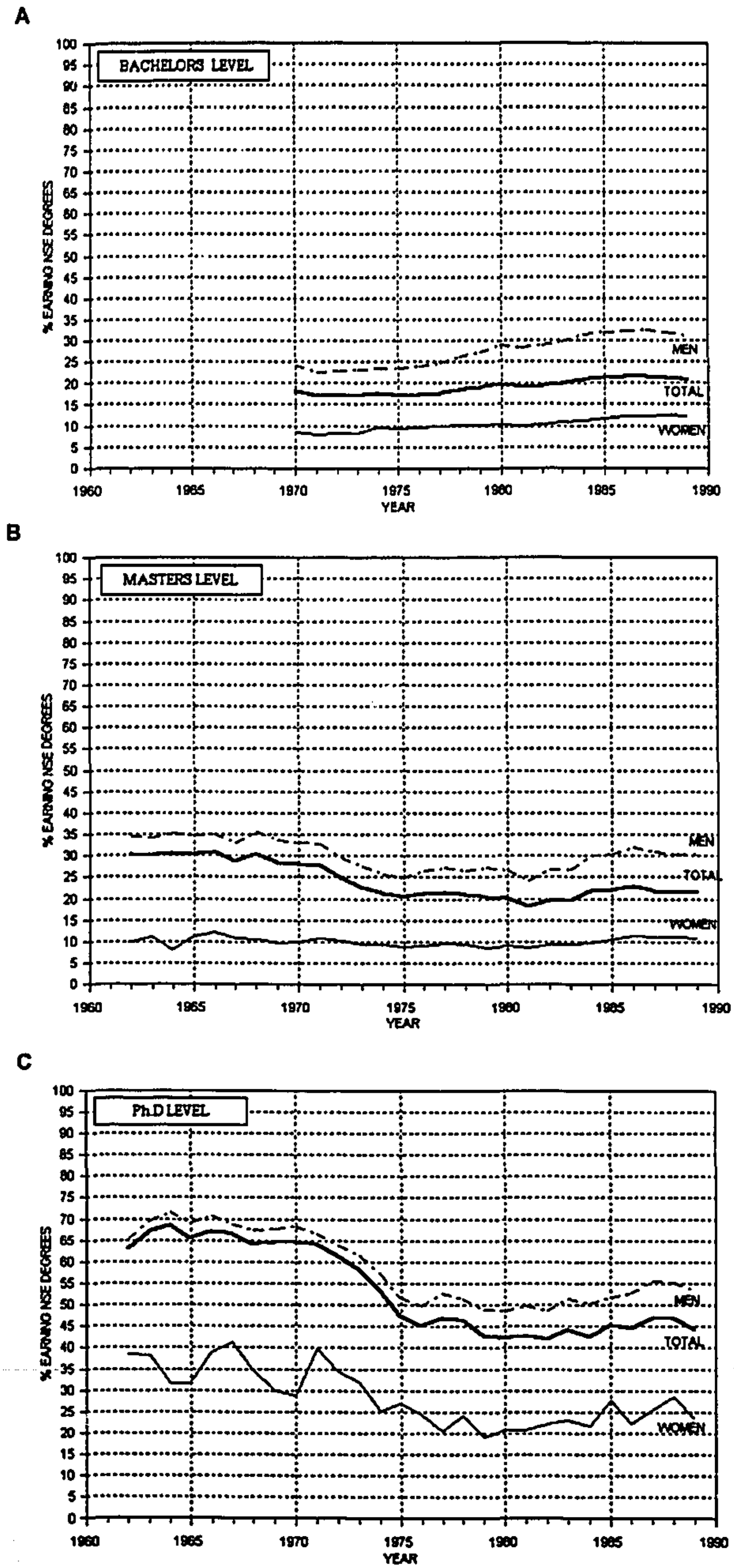

Figure 10. Comparison of proportion of all graduates earning NSE degrees, Canada, 1962-1989

of approximately 900 degrees attained per year, not of 5000, as was observed.[9] In contrast, equivalent comparisons for trends in men's degree attainment suggest that a shift in distribution of men earning bachelors degrees from non-NSE to NSE fields was responsible for a large part of the net annual increase in men's annual attainment of NSE degrees in the 1970-1989 period, since their total degree attainment was relatively stable during this period but the proportion of all male bachelor's graduates earning NSE degrees increased from 24% to 32% (Fig.10A).

The remarkable persistence of the low proportions of total women graduates earning NSE degrees over such a long period of time at the bachelor's and master's level suggests that drastic shifts in distribution of women from non-NSE to NSE fields at these levels is very unlikely. The above observations suggest that the trend of steady increase in the numbers of women attaining NSE degrees at the bachelors level may taper off when the trend of increase in their total degree attainment at the bachelors level does. It would appear that policy makers hoping to see further increases in the numbers of women in science and engineerin[illegible] these levels may have to rely on continuing increases in the total numbers of women e[illegible]ing degrees.

During the seventies there were considerable differences between the bachelor's and graduate levels in the proportion of men graduates earning NSE degrees (Fig. 10). A significant drop in the percentage of all male graduates obtaining NSE degrees occurred at both the master's and Ph.D. levels between 1971 and 1975-6 and was followed by further net decreases at the Ph.D level during the late seventies (Fig. 10B and 10C). Two possible reasons for this drop are suggested. Since the large decreases in the proportion at these levels occurred at the same time as did large decreases in the numbers of male NSE graduates at these levels, it is probable that the shifts in the proportion of graduates earning NSE degrees are at least in part due to the softer market for academics at that time.The strong demand and higher salaries for undergraduate degree holders in applied fields (e.g. engineering and

[9] At the masters and Ph.D. levels, while fairly similar patterns of fluctuation in trends for women's representation in NSE and in total degrees were observed, the equivalent comparisons indicate that increases in women's share of masters and Ph.D. degrees in NSE are not directly related to increases in the total numbers of women earning degrees, since the number of men earning NSE degrees fluctuated (masters) and decreased (Ph.D.) in the seventies.

applied sciences) in the seventies (Ministry of State for Science and Technology, 1981:22) which is probably responsible for the continuing increases in the proportion of NSE graduates at the bachelor's level also probably pulled more NSE bachelor's degree graduates out into the labour market than non-NSE graduates. It is also possible that the proliferation of newly available degree programs in non-NSE areas at the graduate level at this time in the developing Canadian higher education system at this time contributed to the decreases in these proportions.

From 1980 onward, there is actually general similarity of fluctuation for the trends for both sexes at all degree levels with respect to the proportion of bachelors degree graduates earning NSE degrees (see Fig.10). During the early and mid-1980s, an increase in the proportion of both men and women graduates receiving NSE degrees occurs across degree levels, followed by a slight decrease during the late eighties.[10] The similarity in the trends at all degree levels again suggests that an influence outside the university, perhaps the economic recovery after the recession of the early eighties, caused overall increases in the proportion of new degree recipients attaining degrees in NSE. The similarity of fluctuation between the trends for men and women suggests that in the eighties, even though consistently lower proportions of women than men attained NSE degrees, both the male and female student pools may have been responding similarly to influences affecting degree attainment in NSE at similar times. However, the larger issue, of course is still why consistently lower proportions of women than men obtain NSE degrees.

[10] The general behavior of these trends closely resembles the general behavior earlier observed during the same period for trends in the numbers of NSE graduates (Fig.9).

3. Comparison of Trends in Women's Representation (Fig.11)

A. Fields (Level 3)

In 1970, women were under-represented in all three natural science and engineering fields - mathematics/physical sciences, agriculture/biological sciences and engineering/applied sciences - and in the social sciences. In this section, trends for the representation of women in all eight fields of study used by Statistics Canada to classify data for degree attainment were examined in order to locate the fields were women have traditionally been under- represented within the context of all fields at the bachelors degree level. The array of graphs used to do this comparative analysis is presented in Fig.11. This section should be read with Fig. 11 in full view (see Appendix I pocket).

It can be seen from Fig. 11B and 11C that the participation of women relative to that of men has increased in all fields over the past two decades. As a result, the under-representation of women at the bachelors level is now limited to math/physical sciences and engineering/applied sciences.[11] By 1989, women had achieved parity with men in the agriculture/biological sciences and social sciences, and had become over represented in the health professions, education and the humanities, those fields where they were at or near parity in 1970.

While the above paragraph could have been written after examining a table containing only data for 1970 and 1989, graphing the time series data available reveals much more. We can see from Fig. 11B and 11C not just that women's representation has increased in every field between 1970 and 1989, but the pattern of these trends over time. It is readily apparent from the visual comparison of these trends that the eight fields can be divided into two groups with respect to changes in trends in women's representation in recent years. Our argument for visual analysis is reinforced here: visualization of these data in the graphical

[11] It can be seen from the comparison of the trends in Fig.11B and Fig.11C that the phenomenon of under-representation of women among graduates of science and engineering degrees at the bachelors level has not included the agriculture/biological sciences for quite some time; since 1980, women's representation in the biological sciences has always been much higher than in the other two NSE fields, actually approximating the representation in bachelor's degrees as a whole (Fig.11A). The phrase 'the under representation of women in science and engineering' is no longer specific enough at the bachelors level; its continued use misrepresents the existing empirical reality.

form reveals not just that the representation of women has increased in every field between 1970 and 1989, but the additional information that increases continued in only three of the eight fields in the late eighties, having levelled off in four of the other five fields almost a decade before. Increases in women's representation continued during the late eighties in only three of the eight fields, engineering/applied sciences, the health professions and the social sciences. Trends for the representation of women levelled off in the fine/applied arts in the late 1970s, education, the humanities and math/physical sciences in the early 1980s, and in agriculture/biological sciences in the mid-1980s.

These additional observations made possible by graphing the trends represent a significant increase in information available from the existing statistics because the context they provide allows better interpretation of the data. Observing solely that the extent of representation in all fields has increased during the period corresponding to the women's movement is not that conceptually revealing because not much change occurred in the order of the fields as a result of these increases (see Table 1).

Table 1: Percentage of Women Bachelor's Degree Graduates, by Field of Study, 1970 and 1989, Canada, showing changes in the descending order of fields in bold

	1970 %		1989 %
Fine/Applied Arts	61.4	**Health Professions**	70.8
Education	53.7	Education	69.7
Health Professions	51.7	**Fine/Applied Arts**	65.6
Humanities	47	Humanities	62.3
Agric./Biological Sciences	38.9	Agric./Biological Sciences	56.5
Social Sciences	26.8	Social Sciences	53.8
Mathematics/Physical Sciences	17.5	Mathematics/Physical Sciences	27.9
Engineering/Applied Sciences	1.7	Engineering/Applied Sciences	13.4

However, the finding that women's share of degrees in four of the eight fields has been stable for such a relatively long period *is* interesting because it is not expected. The general influx of women into universities was associated with increases in women's representation in all fields during the seventies, but increases in the late eighties continued only in three fields -

the health professions, social sciences and engineering/applied sciences. The relatively long period of stability suggests that the likelihood of further increases in women's representation in these fields is small. What differentiates the fields where women's representation continues to increase from those where women's representation has levelled off? The stability is clearly not related solely to achieving parity with men. While women's share of degrees appears to have stabilized in the eighties at a level where they are over represented in education, fine/applied arts and the humanities, and at parity with men in the biological sciences, their share of degrees in math/physical sciences has been stable for almost a decade at a level where they are still significantly under represented. These findings suggested the possibility that women's representation among graduates might have been continuing to increase in professional diciplines (although not in education) after having stabilized in academic or non-occupational disciplines. This idea was supported and further specified at the next level of analysis - individual disciplines (level 4).

B. Disciplines (Level 4)

Examination of the trends in women's representation at the individual discipline level (Fig. 11, level 4) in the traditionally male dominated fields reveals that increases in women's share of degrees also occurred in almost all individual degree disciplines between 1970 and 1989.[12] It is also apparent from the graphs that these increases have ceased in a majority of disciplines; womens share of degrees stabilized (or peaked then decreased[13]) in most diciplines during the eighties, regardless of whether women's representation was high or low.

In two of the fields where representation of women was still increasing in the late 1980s - engineering/applied science, and the health professions - increases were also occurring in most of their component disciplines. Fig. 11F and 11G show that within engineering/applied sciences, women's representation was increasing in most of the

[12] With the exception of computer science

[13] Computer science, forestry, and economics

engineering specialities and in architecture (see Fig. 11K) but had decreased in forestry and stabilized in landscape architecture. Fig. 11J shows that steady increases have occurred in women's share of degrees in all of the traditionally male dominated health professional degrees (medicine, dentistry and optometry) from very low percentages in 1970.[14]

In the social sciences, however, despite continuing increases in the representation of women at the field level, trends had stabilized in most individual disciplines. Although the representation of women rose in the 1970s in all individual social science disciplines, increases continued in the late eighties only in business and political science. Fig. 11H and 11I also show that the social sciences have been comprised of two separate groups with respect to the extent women's representation. Women's share of degrees in social work, psychology, sociology and anthropology has been 50% or more since the early 1970s, but in business, political science, environmental studies, geography, economics and law [15], their representation in the early seventies was as low as for physical sciences disciplines (below 20%).

Fig. 11D and Fig.11E reveal that the stable trends found at the field level in math/physical sciences and biological sciences in the late eighties are largely representative of those for the individual disciplines they are comprised of. The exceptions were computer science, where womens representation had been decreasing since 1983, and veterinary medicine, a professional degree where women's representation was increasing (see Fig.11K).

The broad suggestions that emerged at the field level (level 3) are therefore supported and further specified with the larger number of degree categories at the discipline level (level 4). The disciplines where share of degrees earned by women is still increasing in the late 1980s were medicine, law, dentistry, architecture, veterinary medicine, business, engineering, and political science. The areas where increases in the share of degrees earned by women were continuing in the late eighties, although at varying rates, are therefore primarily

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[14] Women's share of traditionally female dominated health professional degrees (nursing and rehabilitation medicine) has been slowly decreasing from 100% since the mid-1960s.

[15] The trend for womens representation in law appears in Fig11K..

previously male-dominated professional degrees (with the exception of political science[16]) while representation had stabilized or decreased in most non- professional degrees (see Table 2).[17] There were only two previously male dominated professional degrees where women's share of degrees had levelled off, pharmacy and landscape architecture, and in these disciplines numbers of women graduates had reached parity with men in the late 1980s (64% and 48% respectively in 1989).[18] The exception to this pattern was forestry, the only traditionally male dominated professional degree examined where the percentage of women graduates had been decreasing.

Table 2: Direction of Slope of Trends in Percentage Women Bachelor's Degree Graduates, Disciplines in Traditionally Male Dominated Fields, Canada, 1985-1989, showing traditionally male dominated professional degrees[19] in bold

INCREASING	STABLE	DECREASING
Medicine	Math	Computer Science
Law	Chemistry	**Forestry**
Dentistry	Geology	
Architecture	Physics	
Veterinary Medicine	Biology	
Business	Biochemistry	
Engineering	Agriculture	
Political Science	Social Work	
	Psychology	
	Sociology	
	Anthropology	
	Pharmacy	
	Environmental Studies	
	Geography	
	Economics	
	Landscape Architecture	

[16] It is possible that increases in womens share of political science degrees are linked to increases in their share of law degrees, since political science is often a degree sought by those who intend to apply to law school.

[17] Professional degrees here refer to degrees which lead to professional licencing or certification (e.g. M.D., P.Eng., C.A.).

[18] Representation has also stabilized in the only female dominated profession represented here,social work.

[19] See note 17.

The observed trend for math degrees is also interesting, given the priority math has been afforded in explaining women's underrepresentation in science and engineering. It can be seen from the trends in Fig. 11D that the representation of women in math has been relatively high in comparison with all other quantitatively-based disciplines[20] for most of the 1970-1989 period. Even in 1970, when they were extremely under-represented in engineering disciplines, business, economics, and most physical science disciplines, women earned 24.6% of degrees in mathematics.

The relatively high level of representation of women in mathematics lead me to look at the distribution of men and women graduates in the disciplines within the math/physical sciences field. Table 3 reveals that the majority of women graduates in the math/physical sciences field obtain math degrees, which is not the case for men. These observations undermine the argument that the primary factor in the under-representation in science and engineering is a weaker ability and/or interest in math. If most women who graduate in the mathematics/physical sciences field graduate with math degrees, it suggests the possibility that women's lower representation in quantitatively-based disciplines in the physical sciences and engineering may have more to do with other factors. The most obvious shared feature of the other disciplines which differentiates them from math is an association with equipment

Table 3: Distribution of Bachelor's Degree Graduates in the Mathematics/Physical Sciences Field Among Its Disciplines, By Sex, Canada, 1989

	Women	Men
Mathematics	42.7	25.7
Chemistry	19.2	12.9
Geology	5.8	7.0
Computer Science	26.9	42.1
Physics	5.4	12.4
	100%	100%

[20] E.g. physical sciences and engineering disciplines, business, and economics.

The very steep rise in many of the trend lines in Fig. 11 lead me to the identification of a fertile research site. We can see from Fig.11, Level 4 that there is a group of disciplines within the traditionally male dominated fields which was overwhelming male-dominated in 1970 (19 of the 31 disciplines examined had 12% women or less). By 1989, women's representation in these disciplines ranged from a high of 58% to a low of 8%. Development of such a broad range of outcomes for women in disciplines which twenty years earlier had had similarly low percentages of women graduates presented a valuable opportunity for comparative analysis.

Why had women reached parity or near parity with men in some of these disciplines, while in others their representation remained very low? Most of the degrees in this group where women had very low representation in 1970 provide training for specific professions and occupations. It therefore seems likely that the extent of women's participation in them will be related to decisions they make based on their expectations about the nature of work, benefits and experiences in the professions or occupations typically associated with these disciplines. For the purposes of analysis, a new, more specific question, is asked. What differentiates work in those professions where women's representation in the associated degrees has increased considerably, such as medicine and law, from work in those where it has remained very low, as in engineering?

In order to use the data to reason more effectively, I created a secondary data display listing these disciplines in the order of women's representation in 1989. Scrutiny of this list revealed that several clusters had developed. Women had become equally or nearly equally represented (44% or more) in veterinary medicine, landscape architecture, law, medicine, business and optometry.[21] Their representation had become considerably higher (between 32% and 40%) in environmental studies, agriculture, architecture, dentistry and economics. Geology and chemical engineering (24%) fell in between this group and the group where the

[21] Statistics on the numbers of graduates in optometry were only published for the 1970s. However, given the very rapid increases in women's share of optometry degrees during the seventies, it is assumed for the purposes of this analysis that the value for women's share of degrees in this area would be among the highest group here even though the values are unattainable from published sources.

representation of women remained very low (8% to 16%): forestry, civil engineering, physics, other engineering, mechanical engineering and electrical engineering.

Next, I attempted to delineate characteristics of work environment *shared* by the occupations typically associated with the degrees in the group where women had dramatic gains in representation (high group) which differentiate them from those *shared* by the areas in the low group. These include only characteristics which one could reasonably expect to be perceived by young women making career decisions, even if they cannot articulate them in the way I have. In order to document my ideas, I created a matrix using the list of these disciplines and the shared characteristics of work which seemed to differentiate the high and low groups (see Table 4). If I have attributed a characteristic to the occupation(s) typically associated with a specific discipline, a check was made in the appropriate cell.

Characteristics of Work Environment Differentiating High and Low Groups

All of the disciplines in this group where women now have the highest representation - medicine, law, veterinary medicine, optometry, business, and landscape architecture - are professional degrees. Professional licensing or certification can be obtained in all of these disciplines by earning a bachelors degree and then passing some further exams and/or getting accredited practical work experience.[22] The characteristic that these professions share which seems to differentiate them most from those associated with degrees in the low group is that they provide the opportunity for owning or operating a private practice or business, and therefore for autonomous self-employment.[23]

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[22] While these statements are perhaps readily understood in the case of medicine, law, veterinary medicine and optometry, it is perhaps less obvious in the case of business degrees how these characteristics obtain. Business degrees can lead to professional certification as chartered accountants for graduates who specialize in accounting (eg. C.A., C.M.A., C.P.A.) by passing a series of professional exams usually while working in an accounting firm at an entry level salary. A business degree can lead to designation as a professional manager for graduates who complete an MBA (Masters of Business Administration) or MPA (Masters of Public Administration) program, usually one year in duration for those already possessing an undergraduate degree in business.

[23] This is the usual nature of work in the professions in this group. For business graduates operating small businesses, or for those working as self-employed professionals (e.g. independent C.A.) a similar environment will often exist.

TABLE 4: Bachelor's degrees with very low percentage women in 1970, by shared characteristics of the professions\occupations associated with degrees in the high and low groups, 1989

				Shared characteristics of professions\occupations typically associated with										
				HIGH GROUP, 1989					LOW GROUP, 1989					
	Bachelor's degrees with 12% women graduates, 1970	% women graduates, 1989	Professional Designation	Potential for high income on fee\transactions basis	Sheltered labour market	Possibility of private practice\business	Interactions primarily with clients and support staff	Serves needs of individuals clients	Salaried position in a large organization	Interactions primarily with colleagues\supervisors	Study, construction or management of systems and\or physical world	Considerable sharing or competition for resources necessary	Distant outdoor work sites	Perceived as difficult environment for women
HIGH GROUP, 1989	Veterinary Medicine	58	D.V.M.	y	y	y	y	y						
HIGH GROUP, 1989	Landscape Architecture	48	*	y		y	y	y						
HIGH GROUP, 1989	Business	47	Could lead to CA, MBA	y	y	y	y	y	y					
HIGH GROUP, 1989	Law	47	L.L.B.	y	y	y	y	y						
HIGH GROUP, 1989	Medicine	44	M.D.	y	y	y	y	y						
HIGH GROUP, 1989	Optometry	n\a	O.D.	y	y	y	y	y						
	Environmental Studies	40							y	y	y			
	Agriculture	40				y					y		y	
	Architecture	35	*	y	y	y	y	y		y	y	y	y	
	Dentistry	33	D.D.S.	y	y	y	y	y						
	Economics	32							y	y	y			
LOW GROUP, 1989	Chemical Engineering	24	P. Eng.						y	y	y	y	y	y
LOW GROUP, 1989	Geology	24							y	y	y	y	y	y
LOW GROUP, 1989	Forestry	16	P. For.						y	y	y	y	y	y
LOW GROUP, 1989	Civil Engineering	16	P. Eng.						y	y	y	y	y	y
LOW GROUP, 1989	Physics	14							y	y	y	y		y
LOW GROUP, 1989	Other Engineering	13	P. Eng.						y	y	y	y	y	y
LOW GROUP, 1989	Mechanical Engineering	8	P. Eng.						y	y	y	y	y	y
LOW GROUP, 1989	Electrical Engineering	8	P. Eng.						y	y	y	y	y	y

* Provincial designation

While most of the disciplines in the low group also provide the basis for obtaining professional certification in a specific area (except physics and geology), rather working primarily as self-employed professionals (or business people) dealing with clients, typical employment for graduates with degrees in the low group - most types of engineering, forestry, physics, and geology - will normally involve obtaining salaried positions in large organizations such as corporations, government or universities. Professionals in these areas therefore potentially face considerable competition in finding employment, depending on labour market conditions. In contrast, because admission into most of the degrees in the high group is very limited, upon certification, these professionals will enter sheltered labour markets (except landscape architecture). These two groups therefore differ with respect to the risk of unemployment.[24]

It can be concluded therefore, that due to the fundamental differences with in the work environment, working in a male-dominated profession associated with degrees in the high group has typically means something very different than working in a male-dominated profession near the bottom of the list. Working in the professions in the low group involves not only entering a male-dominated profession, but working in male-dominated work environment. In contrast, professionals associated with the high group are typically self-employed.

Work in professions in the high group normally involves high levels of interaction with other people but because these professionals serve the needs of clients, importantly, these interactions are primarily with clients or support staff. While working in the professions or occupations in the low group can also involve high levels of interaction with other people, since these professionals work in organizational environments, these interactions are primarily with colleagues and supervisors.

In the traditionally male dominated professional disciplines where women have

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[24] The number of people admitted into medicine, law, veterinary medicine and optometry is very limited, controlled by professional societies or associations. In the case of landscape architecture, admission was limited by the fact that only a small number of spaces are available in Canadian universities. Although admission to undergraduate business programs is not as limited as that for the health professional degrees, admission into the professions which require business degrees, such as chartered accountant, is extremely limited. However, even without continuing for certification, business graduates expect that they will more easily find jobs than general arts and science graduates.

become well-represented, success is primarily based on successful interactions with clients; remuneration is client-based. These clients need the professionals expertise and have often sought him/her out. In contrast, interactions to which success is related in disciplines in the lower group are those with co-workers. In these professions, work enjoyment, working effectively, and advancement of your career (i.e. promotions, increases in salary) are often dependent on colleagues, supervisors and support staff. While it is possible for graduates from degrees in the low group to earn relatively high salaries eventually, they are usually hired in entry level positions, and advancement in the form of promotions and raises in pay is dependent on obtaining approval from supervisors or groups of colleagues, rather than attracting and retaining clients, the measure of success for professionals in the high group. Since the work environments in the occupations in the low group are male-dominated environments, most colleagues, supervisors and support staff can be expected to be males used to working interdependently with other males. Even in a best case scenario, a women may anticipate some problems fitting into an interdependent male dominated work environment, and being able to command the shared material and human resources necessary to work effectively and advance. Some of these professions have developed reputations as hostile environments for women (women working as engineers report that sexism is an existent part of male engineering culture[25]). For these reasons, women may see professions where finding a job, advancement and success are dependent on the approval and support of supervisors and co-workers as much more difficult in a predominantly male environment than their male counterparts with equivalent skills; even when women possess the cognitive and technical abilities necessary for these professions, they may tend to avoid them.

Instead of serving the needs of clients as individuals, work in all of the areas in the low group involves the study of, and/or management and control of physical systems or environments. In engineering, for example, work involves the design, construction, maintenance and destruction of physical structures and equipment. In marked contrast to the relatively independent work of professionals in the health professions, law or small businesses, engineers often work interdependently with other colleagues in teams since

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[25]See McKay, 1993

projects often involve large or complex structures, may have several phases of production, usually involve equipment and can involve outdoor/isolated sites. The typical work of foresters, geologists and physicists can also involve interdependent team work, considerable equipment and remote outdoor work sites.

There were several disciplines in this group where the representation of women in 1989 fell in between that of the disciplines in the high and low groups; environmental studies[26], agriculture, architecture, dentistry, and economics. Their middle position on this list may be partly explained by the fact that, as can be seen from Table 4, these professions or occupations share some of the characteristics of the professions in the high group, as well as some of those associated with the low group. Architecture and dentistry degrees, for instance, both lead to professional certification, provide the opportunity for private practice or business, and the potential of high incomes obtained on a fee basis from clients. Architecture, however, shares with the professions at the bottom of the list the association with constructing something physical, the necessity of working closely with males (engineers and contractors) and usually involves site work. Dentistry shares all the characteristics of the professions in the high group; it is not possible therefore on the basis this analysis to explain the lower representation of women among dentistry graduates. It is possible that it could be related to its sharing with engineering lower social prestige; dentists and engineers, unlike doctors and lawyers, businessmen, and even veterinarians are rarely glorified in the media.[27]

Although the representation of women in economics is higher than in those in the low group, its profile shows that it shares none of the characteristics associated with the high group. Like professionals in the low group, economists also study or manage systems (economic) and will normally be employed in large organizations. The higher percentage of women in economics than in those disciplines may be related to the fact their work will not also involve the other characteristics shared by those professions, such as sharing or

[26]No precise interpretation of trends for environmental studies is attempted in this study because Statistics Canada has combined environmental studies degrees and urban planning degrees; the data therefore does not relate to a group homogeneous enough to be used as a conceptual category.

[27] Dentists themselves report being perceived by their patients as 'boring' and as people who 'cause pain' (Globe and Mail, Mar.3,1993, p.22).

competing for necessary physical and human resources, and working in teams in outdoor worksites.

4. Comparison of Trends in Actual Numbers of Graduates

In this section, the trends for actual numbers of men and women graduates are compared. The array of graphs used to do this comparison is presented in Fig.12. This section should be read with Fig. 12 in full view (see Appendix II pocket). Larger versions of the graphs in Fig. 12 can be found in Appendix III.

A. Fields (Level 3)

One of the first things I noticed when looking at the array of graphs in Fig. 12 was that trends for the numbers of graduates of both sexes resemble each other in the two fields where women's representation has stabilized in recent years - math/physical sciences and biological sciences (Fig.12C and 12D). That is, in both of these fields, the trends for men and women have similar directional changes in slope at similar points along the x-axis, even if the magnitude of slopes differed (see below).[28]

Math/Physical Sciences

Fig.12C

Agriculture/Biological Sciences

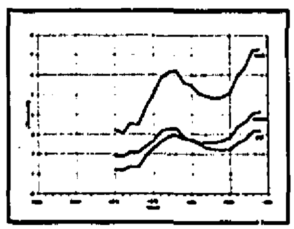

Fig.12D

In contrast, in the fields examined where women's share of degrees is still increasing - the social sciences and in engineering/applied sciences, the pattern for the trend of number of men graduates differed from that of women; the number of women graduates increased over most the 1970-1989 period, while the number of men rose and fell (Fig. 12E and 12F).

[28]Larger versions of these graphs can be found in Appendix III.

Engineering/Applied Sciences

Fig.12E

Social Sciences

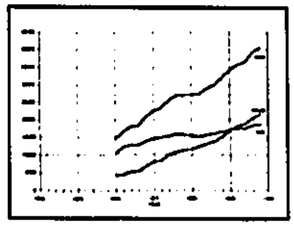

Fig.12F

B. Disciplines (Level 4)

At the discipline level (Fig.12, level 4), similar observations can be made over a period of at least the last 10 years examined: the behavior of the trends of numbers of graduates of both sexes fluctuated similarly during this period in about half of the degrees examined,[29] and differed in the other half. With access to the larger number of degree categories at the discipline level, a basic theme emerged: the trends for the sexes have fluctuated similarly in most of the basic disciplines examined, but differ in the professional disciplines[30] (see Table 5). More specifically, in the non-professional disciplines, similar changes in general direction of slope occur at similar times in the trends for both sexes. In contrast, in the professional or more occupation-specific disciplines, the number of women graduates has continued to increase relatively steadily over the entire 1970-1989 period,[31] while number of male graduates was stable, fluctuated or decreased.

The similarity in behavior of the trends for the sexes in non-professional disciplines is demonstrated both in disciplines where there are approximately equivalent numbers of men

[29] In some disciplines, similar patterns for men and women were evident over the entire 1970-1989 period.

[30] See note 17.

[31] There is a plateau in numbers of women graduates in pharmacy during the late 1970s and early 1980s, and in agriculture during the 1980s.

TABLE 5

A. Similar Behaviour of Trends for Men and Women in Non-Professional Disciplines

Chemistry

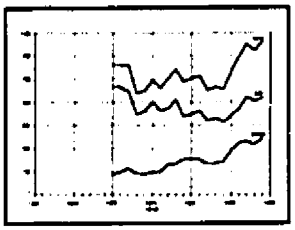

Fig.12H

Computer Science

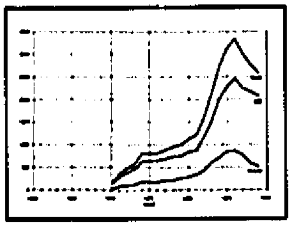

Fig. 12I

Geology

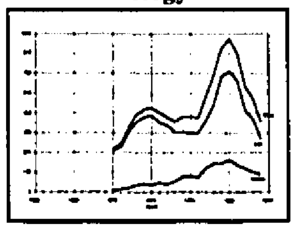

Fig.12J

Mathematics

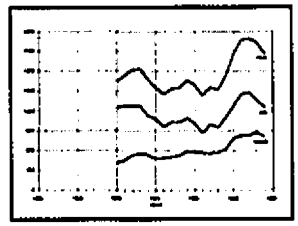

Fig.12K

Physics

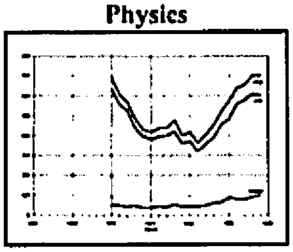

Fig.12L

Biochemistry

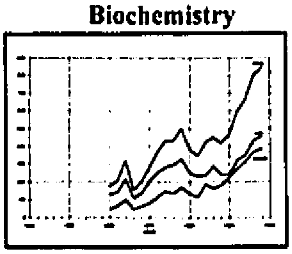

Fig.12N

Biology

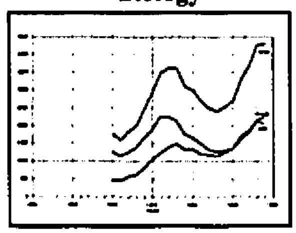

Fig.12O

Anthropology

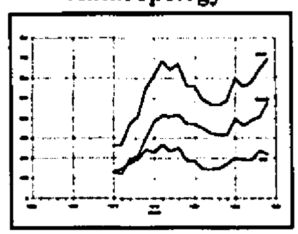

Fig.12X

Environmental Studies

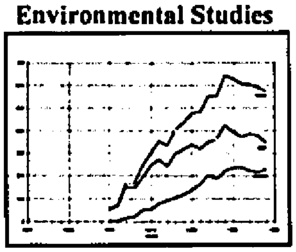

Fig.12Z

Economics

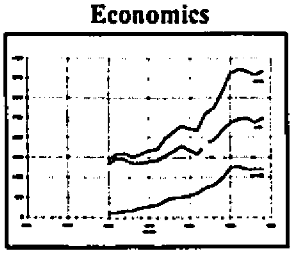

Fig.12AA

Geography

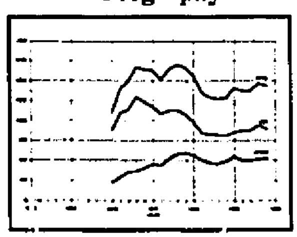

Fig.12BB

Political Science

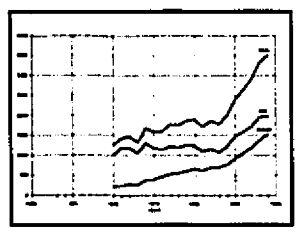

Fig.12CC

Psychology

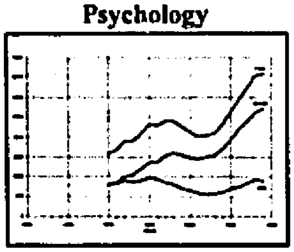

Fig.12DD

Sociology

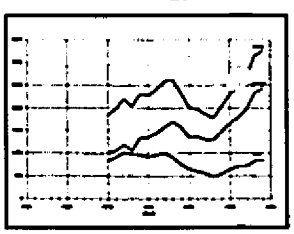

Fig.12FF

TABLE 5 (Continued)

B. Different Behaviour of Trends for Men and Women in Professional Disciplines

Agriculture

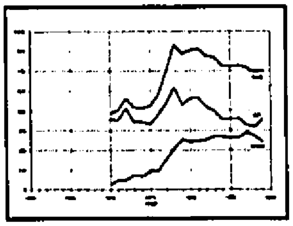

Fig.12M

Chemical Engineering

Fig.12Q

Civil Engineering

Fig.12R

Electrical Engineering

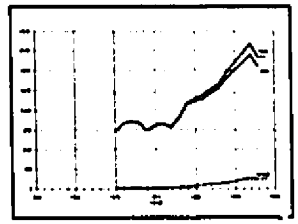

Fig.12S

Mechanical Engineering

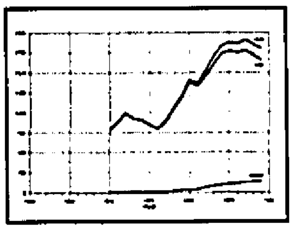

Fig.12T

Other Engineering

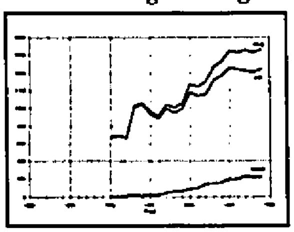

Fig.12U

Forestry

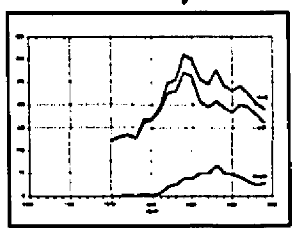

Fig.12V

Landscape Architecture

Fig.12W

Business

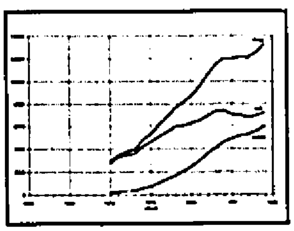

Fig.12Y

Social Work

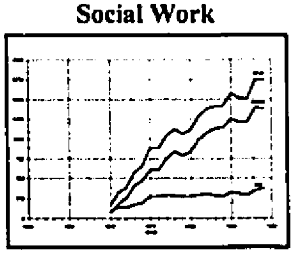

Fig.12EE

Medicine

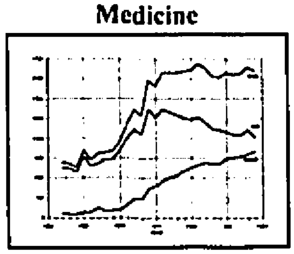

Fig.12GG

Dentistry

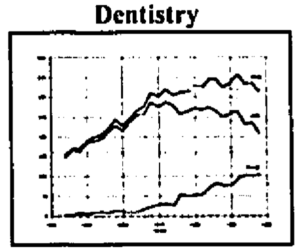

Fig.12HH

Pharmacy

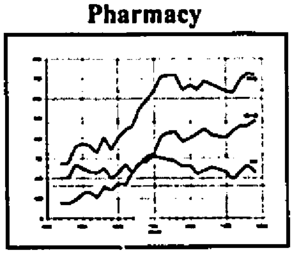

Fig.12II

Veterinary Medicine

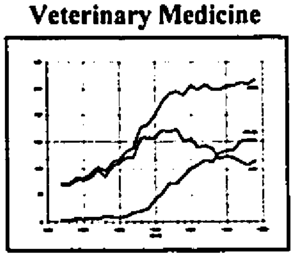

Fig.12JJ

Law

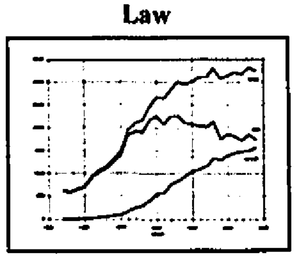

Fig.12KK

Architecture

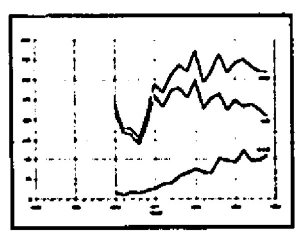

Fig.12LL

and women graduates, such as biology, as well as in those where the number of graduates of one sex is much higher, as in psychology, geology and physics (see below).

Biology

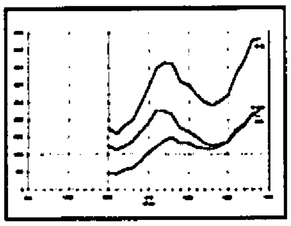

Fig.12O

Psychology

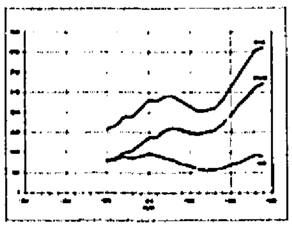

Fig. 12DD

Geology

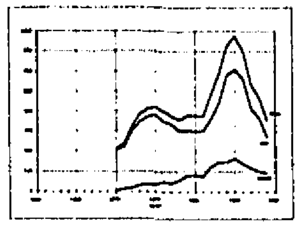

Fig. 12J

Physics

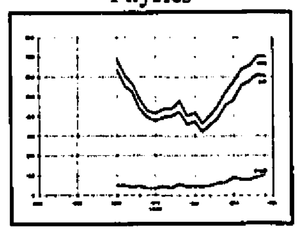

Fig.12L

The graphs suggest that the reason for difference in trends of number of graduates for the sexes in some of professional degrees examined (medicine, dentistry, pharmacy, veterinary medicine, architecture and law) is not just related to increased interest of women in these areas but that there is a controlled admission to these programs. It can be seen in Fig. GG through KK that the total number of graduates in all of these degrees either stabilized or slowed their growth dramatically during the mid or late seventies, suggesting that admissions to these professional programs were effectively capped during this period. Although the numbers of men graduates began to fall relatively steadily after that point, numbers of women graduates continued to increase[32]. In programs with restricted total admission, increases in number of women necessarily mean decreases in the number of men. However, these increases in the number of women are still very significant in competitive entry degree programs, because it probably means that more and more qualified women were applying to these programs each year.[33]

However, even in the professional fields where the total number of graduates has been

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[32]Except in pharmacy

[33]There is reportedly less attrition of men and women from professional disciplines than there is from arts and science disciplines (Gilbert, 1991).

growing - engineering disciplines, business, and social work- trends for men and women differ. While the numbers of women graduates continued to increase rapidly in social work, the lower number of male graduates was relatively stable for much of the period from the mid-seventies to the mid-eighties. Similarly in business, while the numbers of women continued to increase relatively steadily, the numbers of men stabilized in the early eighties. In engineering, the number of women continued to climb relatively steadily in all disciplines into the late 1980s, while the trends in numbers of men fluctuated (mechanical and electrical engineering), or decreased (civil and chemical engineering). The pervasive differences in the behavior of trends of the sexes in professional disciplines suggests that women have been making a relatively steady numerical push towards the professional disciplines during the period examined, both in professional disciplines with controlled entry, and in those where a more open labour market exists.

In order to investigate this finding of similarity and dissimilarity in the trends further, I took the five year period where the representation of women in most disciplines had stabilized (1985-1989) and determined the general direction of the slopes of the trends (positive, negative, or zero) in the numbers of men and women in each individual discipline. These values are presented in Table 6. In Table 7, the information from Table 6 has been reorganized in order to better compare the behavior of the trends for men and women trends in terms of categories (e.g. disciplines).

The results of this comparison of the general behavior of trends for the sexes in different disciplines over a specific period of time reinforce the initial visual indications of dissimilarity in trends in numbers of graduates for the sexes in professional disciplines, and their similarity in non-professional areas. There are a few differences. In environmental studies, men and women's patterns are similar over most of the period examined, but differ in the last five years.[34] In agriculture, social work and forestry, trends for the sexes differ over most of the period examined but the slopes of these trends have similar directions in the last five years.

As can be seen in the top section of Table 7, most of the disciplines where the general

[34]See note 26

Table 6: Behavior of Trends in Numbers of Bachelor's Degree Graduates, by Field and Sex,1985-89

FIELD	DISCIPLINE	SLOPE OF TREND IN # OF GRADUATES, 1985-89	
		WOMEN	MEN
Total Degrees		+	-
MATH/PHYSICAL SCIENCES		-	-
BIOLOGICAL SCIENCES		+	+
ENGINEERING/APPLIED SCIENCES		+	-
SOCIAL SCIENCES		+	+
MATH/PHYSICAL SCIENCES	Chemistry	+	+
	Computer Science	-	-
	Geology	-	-
	Math	0	0
	Physics	+	+
BIOLOGICAL SCIENCES	Agriculture	0	0
	Biochemistry	+	+
	Biology	+	+
	Household Sciences	+	+
ENGINEERING/APPLIED SCIENCES	Chemical Engineering	0	-
	Civil Engineering	+	-
	Electrical Engineering	+	0
	Mechanical Engineering	+	-
	Other Engineering	+	0
	Forestry	-	-
	Landscape Architecture	0	0
SOCIAL SCIENCES	Anthropology	+	+
	Business	+	0
	Economics	0	0
	Environmental Studies	0	-
	Geography	+	+
	Political Science	+	+
	Psychology	+	+
	Social Work	+	+
	Sociology	+	+
OTHER TRADITIONALLY MALE DOMINATED PROFESSIONAL DEGREES	Architecture	0	-
	Dentistry	+	-
	Law	+	-
	Medicine	+	-
	Pharmacy	+	0
	Veterinary Medicine	+	-

TABLE 7: Bachelors Degrees by Behavior in Trends of Numbers of Graduates and by Sex, 1985-89

	SLOPE OF TREND IN # OF GRADUATES, 1985-89					
	POSITIVE (+)		STABLE (—)		DECREASE (-)	
	WOMEN	MEN	WOMEN	MEN	WOMEN	MEN
SIMILAR TRENDS	Chemistry	Chemistry	Math	Math	Comp. Sci.	Comp. Sci.
	Physics	Physics	Agriculture	Agriculture	Geology	Geology
	Biology	Biology	Economics	Economics	Forestry	Forestry
	Biochemistry	Biochemistry				
	Anthropology	Anthropology				
	Geography	Geography				
	Political Sci.	Political Sci.				
	Psychology	Psychology				
	Sociology	Sociology				
	Social Work	Social Work				
DIFFERENT TRENDS	Civil Eng.		Env. Studies	Elec. Eng.	Land. Arch.	Chem. Eng.
	Elec. Eng.		Architecture	Other Eng.		Civil Eng.
	Mech. Eng.		Chem. Eng.	Business		Mech. Eng.
	Other Eng.			Land. Arch.		Env. Studies
	Business			Pharmacy		Architecture
	Dentistry					Dentistry
	Law					Law
	Medicine					Medicine
	Pharmacy					Vet. Medicine
	Vet. Medicine					

direction of the trends for number of men and women graduates were similar in the late 1980s were non-professional disciplines. Among these disciplines in the late eighties, the trends of numbers of men and women graduates were increasing in the same disciplines, decreasing in the same disciplines and stable in the same disciplines. Social work was the only professional degree in this group.

Among the disciplines where the slope of the trends for men differed from those for women in the late eighties (the bottom section of Table 7) - medicine, law, dentistry, pharmacy, veterinary medicine, architecture, landscape architecture, business, engineering and environmental studies - all but one were professional degrees.[35] In the majority of these disciplines, the number of women graduates was increasing in the late 1980s: the only professional degrees in which women numbers were not increasing in this period were architecture, landscape architecture and chemical engineering.[36] In contrast, the number of men graduates was not increasing in any of the traditionally male dominated professional disciplines. [37] Instead, in the majority of the disciplines where the trend in their numbers differs from that of women, their numbers of men graduates was decreasing.[38]

C. Engineering

The relatively low numbers of women in all engineering specialties made it difficult to compare participation of the sexes among different engineering specialties using the trends in percentage women graduates (see Fig.11F). However, comparison of the trends of numbers of graduates show that there have been some marked differences in degree

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[35]The trends for environmental studies are not interpreted in this study, see note 26.

[36]Numbers of women graduates stabilized in the late eighties in architecture and chemical engineering and were decreasing in landscape architecture.

[37]The number of men graduates in the late eighties was, however, increasing in social work, which is a traditionally female dominated discipline.

[38]The previously male dominated disciplines where the trend in the number of male graduates differs from that of women and their numbers were stable (rather than decreasing) were business, pharmacy, landscape architecture, and, electrical and other engineering.

attainment patterns for the sexes among engineering specialities.

Despite their much lower participation in engineering, numbers of women graduates rose steadily and have shown large proportional increases since the mid-seventies. Continuous increase in numbers of women graduates[39] over the most of 1970-1989 period examined is shared only with fields in all of which women had much higher representation in 1989, most of them professional degrees: medicine, dentistry, veterinary medicine, law, business, social work, political science, and biochemistry. It is suggested that this similarity in behaviour with these disciplines is important. Within natural science and engineering itself, a considerable increase in the proportion of women NSE graduates graduating in engineering between 1970 and 1989 has been associated with these increases (Table 8). Very little redistribution of men between NSE fields occurred, suggesting a shift towards the professionally oriented disciplines among women with NSE.

Table 8: Distribution of NSE Bachelor's Degree Graduates, by Field and Sex, 1970 and 1989

	Women	Men
1970		
Engineering/Applied Sciences	3.6%	44.6%
Math/Physical Sciences	32.2%	33.6%
Biological Sciences	64.2%	22.1%
	100%	100%
1989		
Engineering/Applied Sciences	15.0%	46.0%
Math/Physical Sciences	26.7%	32.8%
Biological Sciences	58.2%	21.2%
	100%	100%

[39] Numbers of women graduates had stabilized in the late eighties in chemical engineering.

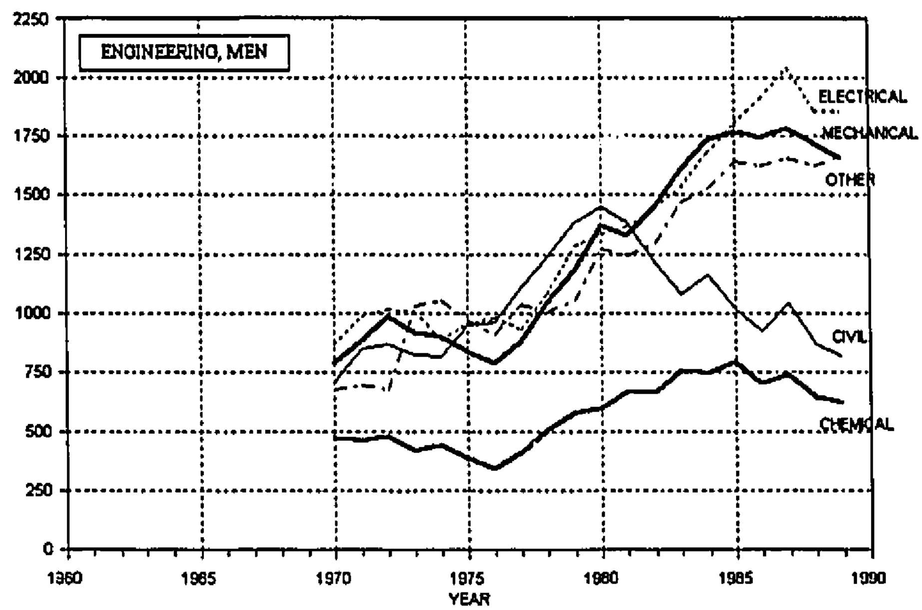
Interestingly, the distribution of graduates by sex among engineering disciplines differs considerably. As can be seen from Fig. 13A and Table 9, men's participation in engineering has not been evenly distributed among the individual disciplines, particularly in last 10 years examined. The number of men graduates in mechanical, electrical, and civil engineering was relatively similar until 1980, but by the late 1980s, their numbers in electrical and mechanical engineering were much higher than in civil or chemical engineering. Their participation in chemical engineering has been considerably lower than their participation in other engineering disciplines over most of the 1970-1989 period. In contrast, women graduates in engineering are seen to have been much more evenly distributed among the disciplines (Fig.13B and Table 9).[40] This finding, and the relatively steadily increasing numbers of women in all engineering disciplines over the 1970-1989 period suggest that while women are drawn to engineering as a profession, their participation has largely not been affected by changing demands for discipline-specific engineering labour (trends for women in the late 1980s however, indicate that this may be changing).

Table 9: Distribution of Bachelor's Graduates in Engineering among its Disciplines, by Sex, 1989

	Women	Men
Chemical	17.5%	7.6%
Civil	18.2%	13.2%
Electrical	18.7%	29.7%
Mechanical	18.7%	26.5%
Other	27.0%	23.0%
	100%	100%

[40] Women's much higher relative participation in chemical engineering than in other specialities (Fig.11F) can therefore be seen to be the result of the lower participation of men in it than in other engineering disciplines, rather than a result of women's preference for it over other engineering disciplines.

A



B

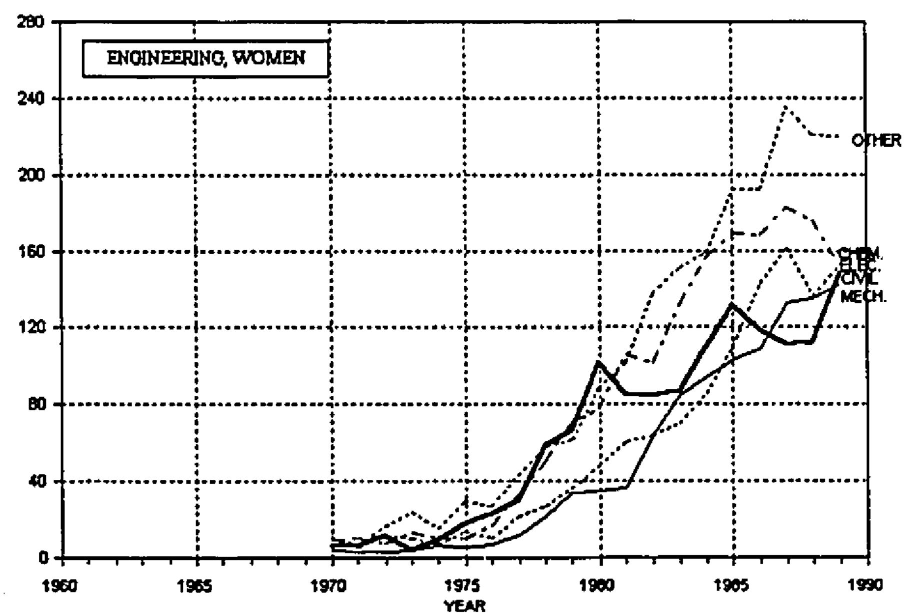


Figure 13. Number of bachelor's graduates in engineering, by discipline, Canada, 1962-1989 A) Men, B) Women

CHAPTER SIX: SUMMARY OF MAIN FINDINGS

Examination of the trends at the most detailed levels of aggregation in the data yielded the most theoretically compelling suggestions in this study. However, patterns at the highest levels of aggregation provided essential context for the findings at the detailed levels as well as evidence of internal consistency in the data (Miles and Huberman, 1994). Broad suggestions which emerged at the aggregate levels were often supported and further specified at the detailed level.

Comparison of trends for degree participation with trends in the size of the university age population reveal that degree participation at the bachelor's level in Canada has not been directly related to changes in the size of the underlying population, either as a whole, or for men and women separately. There is, therefore, little empirical support for the assumption by policymakers that the decrease in the university age population in the 1990s will necessarily decrease the supply of graduates in science and engineering.

The findings suggest that the observed increases in women's share of NSE degrees over the 1970-1989 period were primarily related to the increase in total degree attainment by women, rather than a shift in the distribution of women from NSE to non-NSE disciplines. Despite the influx of women into universities over the last two decades, the proportion of total women bachelor's graduates earning NSE degrees has increased only slightly, remaining close to 10% over the 1970-1989 period. The stability of this low proportion over a twenty year period when women's total degree attainment at the bachelor's level has more than doubled suggests that increases in the number of women attaining NSE degrees may level off if their total degree attainment does.

The findings at the highest levels of aggregation in the data also suggested that there has been a much stronger relationship between general labour market conditions and degree attainment for men than for women. It is generally recognised that a slowdown in the economy and worsening job market and starting salaries for graduates caused a slowdown in degree attainment in the seventies (Ministry of State for Science and Technology, 1981a).

Interestingly, the trends in total bachelor's degree attainment suggest that the degree attainment of men, but not of women may have been negatively affected by the slowdown in the economy and worsening of labour market conditions for graduates: men's degree attainment levelled out in the early seventies, but the numbers of women continued to increase.[40]

This suggestion that the participation rate of men is responsive to labour market conditions is echoed at the lower levels of aggregation. In the natural sciences and engineering, the number of men attaining degrees did not level out but increased relatively steadily throughout the seventies. This period coincides with a period of relatively strong demand for graduates in engineering and applied fields (Ministry of State for Science and Technology, 1981a) reinforcing the suggestion at the overall level. Further, in professional degrees without limited total admissions, such as engineering and business, the pattern for the degree attainment of men not only differs from the pattern of relatively steady increase found for women in most professional degrees, but importantly, varies between disciplines, suggesting again that men, but not women, responded to changes in labour market demand.

The degree attainment of women in the eighties seems to have been characterized by a steadily increasing desire to enter professional disciplines leading to certification which (in those disciplines where it is relevant), unlike the degree attainment of men, shows little evidence of being negatively affected by unfavourable labour market conditions.

It is well known that increasing proportions of baccalaureates in recent decades have been in the more explicitly occupation-related fields (notably business, health sciences and engineering). The examination of the trends in degree attainment by sex indicates that it is actually only increasing numbers of women who continued to produce these increases in the numbers of graduates in most of the male-dominated prpfcssional disciplines in the late eighties, while the numbers of men have leveled out or decreased (see Table 7).

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[40] As is well-known, the slowdown in male degree participation is related to a decline in their participation rates, which offset the growth in the underlying population. Increases in female degree participation are related to their increasing participation rates (Ministry of State for Science and Technology, 1981b;3).

The trends at the more detailed levels of aggregation in the degree attainment data (field and discipline levels) clearly suggest an increasingly greater interest among women in obtaining professional degrees. The data show that the representation of women increased in all eight fields over the 1970-1989 period, but increases continued in only three of these fields in the late eighties - the health professions, engineering and the social sciences. This pattern suggested that women's representation might be continuing to increase in professional disciplines, but not in non-professional disciplines.

This suggestion was supported and further specified at the discipline level. In almost all individual disciplines in the four previously male-dominated fields - mathematics/physical sciences, agriculture/biological sciences, engineering/applied sciences and social sciences - women's representation increased between 1970 and 1989. It levelled off in the majority of them in the eighties, regardless of whether representation was high or low. The only disciplines where increases in the representation of women were still occurring in the late eighties (with one exception) were professional degrees where women had been severely underrepresented in 1970 - medicine, law, dentistry, architecture, veterinary medicine, business, engineering disciplines and political science. Representation of women had stabilized (or decreased) in the eighties in most of the non-professional degrees.

This indication in the trends for representation of women of an increasingly greater interest of women in professional degrees (as compared with men) in the eighties is further supported by the comparison of the trends for the actual number of men and women graduates. The number of women graduates have been steadily increasing in almost all of the professional programs during the 1970-1989 period, while the numbers of men have decreased, fluctuated or leveled out. In sharp contrast, in the basic or non-professional degrees examined in this study, the number of men and women graduates fluctuated similarly for the period of at least the last 10 years examined. These pattern suggests that degree attainment of both sexes has been subject to similar influences in non-professional areas, but not in professional disciplines.

The differences in patterns of participation for men and women in the professional degrees suggest that women have been subject to different general influences than men on their participation in these areas. In professional disciplines with less restricted admissions, increases in the number of women suggest an increasing interest of women in these areas. In the professional degrees with controlled admissions were it appears that total admissions may have been capped in the mid-1970s - medicine, law, dentistry, architecture, veterinary medicine -the continued increases in the number of women suggests that they are increasingly more successful in competing for admission to these limited admission degrees. This suggests that more and more of the talented, work-oriented women students may be selecting to compete for admission to these degrees.[41]

Evidence of an increasingly professional orientation of women can also be observed within natural sciences and engineering. Although there was very little re-distribution of men among the three natural science and engineering fields between 1970-1989, there was a considerable shift of women within NSE toward engineering degrees. Engineering disciplines were also the only NSE disciplines where the representation of women in the late eighties was increasing. However, while women may be being increasingly drawn to engineering because it is a profession, their approximately equal distribution among engineering disciplines contrasts with the uneven distribution of men. This finding again suggests that men but not the women tend to respond to changing discipline-specific labour market demands.

The broad range of values for percentage women in 1989 previously male-dominated disciplines where the percentage of women was very low in 1970 provided a very productive site for comparative analysis. The findings suggest that women's participation in traditionally male dominated degrees may have been mediated by their perceptions of their opportunity for success in the work environments associated with these professions. It was found that the characteristic shared by the professions associated with the disciplines where the percentage

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[41] It is unlikely that even admissions policies favouring qualified women applicants would <u>increasingly</u> favour them as their proportion of total graduates increased.

of women graduates has increased substantially that differentiates them most from those shared by those professions associated with the disciplines where the percentage of women has not increased that much is the type of work organization. Professionals in the former group typically work in self-employed situations characterized by professional-client relationships, whereas professionals in the latter group typically work in in salaried positions in large organizations such as corporations, universities, and government.

Due to fundamental differences in the typical work organization, working in a profession associated with the traditionally male-dominated degrees where the representation of women has increased dramatically often means something very different than working in those where it has remained very low. Since professionals in those disciplines where representation has remained low are not typically self-employed, entering these professions in the group involves not only entering a male-dominated profession, but a male-dominated work environment. Professionals in disciplines such as medicine and law enter a male-dominated profession without entering a male-dominated work environment. The success and advancement of anyone in an organizational work environment are potentially subject to many competitive challenges involving the subjective decisions of others, first in being hired, and then to advance. A woman may anticipate some problems fitting this kind of environment. She may see success in occupations where finding a job and advancement are dependent on the respect and support of supervisors and co-workers as much more difficult in a predominately male environment than males with the requisite skills. Although males in these environments will also be under competitive pressures, females considering these environments may expect to receive less support or have their competence challenged even more than will males in a milieu dominated by males. On the chance that this may occur, women may tend to choose professions without organizational environments.

The emergent suggestion is that the differential success of women in previously male-dominated disciplines may have been related to their expectations of greater chances for success working as an autonomous self-employed client-based professional than as a professional working in male-dominated organizational environment. To the extent that women's influx into universities and male-dominated disciplines can be explained by the concept of human capital investment, the findings of this study suggest that the perception of what constitutes a good "investment" for women among traditionally male-dominated disciplines may include consideration of whether the typical work environment in a given male-dominated profession is organizational.

CHAPTER SEVEN : DISCUSSION AND CONCLUSION

The findings of this comparison study suggest that the selective success of women in traditionally male-dominated disciplines may be related to expectations that their chance of success are greater working as an autonomous professional than as a professional in a male dominated organization environment.

What implications do these findings have for the narrower issue of the under-representation of women in science and engineering programs?

A multifaceted explanation is needed to explain the phenomenon of women's continued under-representation in engineering and the physical sciences. The problem is that we have not yet delineated all of the factors and processes involved. This study suggests additional factors potentially involved in that explanation, seen clearly only by examining participation in these areas in the context of participation in all male-dominated disciplines over the last two decades.

We know that many of the disciplines where women are still underrepresented are also quantitatively-based disciplines. This factor alone however cannot explain their relatively lower participation in these areas (Ferrini-Mundy and Balamenos, 1986). Studies show, for example, that even when women have sufficient mathematics background they often do not enter quantitative disciplines (Berryman 1983,1985). In this study, women's participation within mathematics/physical sciences was found to be strongly skewed toward mathematics, suggesting that there may be other factors involved in women's relatively lower participation in quantitatively-based applied disciplines.

The arguments that women tend to have a lower level of preparation in math and have been affected by early childhood socialization are both probably part of the explanation for the relatively lower participation of women in engineering and the physical sciences programs. These ideas, however, are not sufficient to explain the phenomenon of women's continued underrepresentation in these areas. While these factors may be responsible in large part for why relatively fewer women than men choose these disciplines at university entry in the first place, they are much less adequate in explaining the higher rate of attrition for women than men from these disciplines during their university years. Some researchers actually have assumed that these factors have been overcome by those women who enter university programs in these disciplines (Nevitte et al. ,1988).

The findings of this study suggest that the underrepresentation of women in science and engineering may have been effected in two ways by the broader range of options available to work-oriented women once traditionally male-dominated professions opened up to them in the seventies. First, work in science and engineering takes place in large organizations such as universities, government or corporations. If traditionally male-dominated organizational work environments have been less attractive to women than self-employed professions with a professional/client basis, this could in part explain lower representation of women in engineering and those areas of science which were still heavily male-dominated in the early 1970s (e.g. physical sciences).

The findings also suggest an additional factor affecting the representation of women in the sciences. Among traditionally male-dominated areas, it is only in professional degrees that the relative participation of women, whether high or low, is increasing[42]. In professional degrees, including engineering, there have been relatively steady increases in their representation and steady increases in the number of women graduates throughout the 1970-1989 period. In science disciplines, the representation of women, whether high or low, stabilized during the 1980's, and the actual numbers of women graduates fluctuated in the same way as those of men in these areas. These findings indicate that professional degrees, including engineering, regardless of whether representation of women is high or low, share features that basic science disciplines do not possess which are increasingly attractive to women.

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[42]Women's share of degrees was also increasing in the late eighties in political science.

Concerns about perceived difficulties for women in male-dominated organizational environments are perhaps readily understood with reference to engineering, but these suggestions cause us to look again at science.

Despite the fact that the work of science is carried out in organizations, science has been assumed to operate without influence from organizational dynamics. It is widely accepted by scientists that they share an institutionalized goal, the production of certified knowledge (Mulkay, 1980; 111). The pursuit of that goal is assumed to operate under normative principles, first identified by sociologist Robert Merton in his 1942 essay as universalism, communism, disinterestedness and organized skepticism (Merton [1942] 1973). Universalism dictates that "rewards or resources are to be allocated on the criteria of scientific merit and that judgements of scientific merit are to be made only in terms of contributions to knowledge" (Merton [1942] 1973). An individual's contributions to knowledge are seen as the extent and quality of their research publication. Given such a visible and objective measure, it is also assumed that deviations from the norm of universalism (eg. discrimination) would be easily uncovered (Bielby, 1991).

Because science is also largely presumed to operate according to universalistic principles by sociologists of science, most researchers have studied sex differences in the career outcomes of scientists using research designs which model the distribution of rewards and resources as a function of the productivity of the individual scientist (Reskin, 1978; Cole, 1979). However, the efficacy of this general approach is now being questioned by some researchers. Suggesting that explaining the effects of organizational dynamics on productivity may be a crucial component of a comprehensive explanation of these sex differences, William Bielby argues that the predominant use of the meritocratic model as an ideal type will not be sufficient to develop an adequate explanation of this phenomenon:

> Functionally irrelevant criteria are presumed to operate when the meritocratic model fails to account fully for sex difference in the career outcomes of scientists. However, structural, cultural and other sources of discrimination are rarely studied directly, especially in quantitative studies of scientific careers. Instead, they are typically inferred from the residual net difference between men and women after controlling achievement related variables in the meritocratic base-line model. As a result, we know much more about the extent to which "supply-side" factors do and do not account for reward and productivity differences between men and women scientists than we do about the impact of specific structural barriers and cultural

stereotypes (1991:174).

Bielby suggests that it will be necessary to relinquish the idea that science, as an institution, is essentially meritocratic in order to develop a full understanding of sex differences in scientists' careers. He argues that the few studies that have examined the effects of organizational attributes in science suggest that, as in other institutions, structural factors and organizational dynamics do exert an independent influence on the careers of scientists (1991:177,186); continued use of an investigative approach which abstracts scientists careers from the environment in which the work is done cannot possibly address the issue of how the structural and interactional features of those settings affect individual careers (1991;186).

Mary Frank Fox argues that science is not essentially different from other institutions. She maintains the organizational environment in which science is carried out does influence performance:

> ...it is difficult to separate the performance of the individual scientist from his or her social and organizational context. Work is done within organizational policies and procedures; it relies upon the cooperation of others; it requires human and material resources. Further, the scope and complexity of research and the use of advanced technology have heightened reliance on facilities, funds, apparatus, and teamwork. Performance is tied to the environment of work - the signals, priorities, resources and reward schemes that provide the ways and means of research. (1991: 189).

Contending that we will not be able to understand gender inequities in the careers of scientists until we understand productivity differences between men and women scientists, she argues that we will have to understand more about how the social and organizational environment of science affects that productivity, and its differential effects on women:

> ... a given environment does not necessarily operate uniformly, neutrally, or androgynously. Within the same type of setting, women scientists can have fewer and different collaborative arrangements, claims to enabling administrative favours, collegial opportunities for testing and developing ideas, and entrees into the informal culture of science and scholarship. These issues are central to science because research is a social process of communication, interaction and exchange. Exclusion from this process limits the possibility not simply to be part of a social circle but rather to do research, to publish, to be cited - to show the crucial marks of productivity in science. (1991;204)

While some researchers are beginning to argue that science may not be an atypical institution; that indeed social and organizational dynamics may differentially effect the productivity of women in science, I am proposing, based on the findings of this study, that it is possible that the personal realization that science is such an environment may be one of the contributing factors in under-representation of women in science.

The addition of this 'organizational' factor to an explanation of the lower participation of women in engineering and physical sciences degrees is theoretically compelling, because it can much better explain previously inexplicable findings of other studies.

First, this factor can much better explain the differential patterns of attrition observed within science and engineering; the higher attrition of women than men from science, as well as the higher attrition of women from science than from engineering (Nevitte et al., 1988).

I have proposed that the knowledge that a male-dominated organizational environment exists in engineering may tend to lead professionally-oriented women to pursue other professional degrees. However, those that choose engineering are not then likely to be surprised by what they find - engineering is a professional career path "that provides unusually clear expectations about career rewards and professional norms" (Nevitte et al., 1988).

If science, however, contrary to its image in the general public as a individual pursuit, is an organizational milieu where there is increasingly intense competition for resources and support necessary to do research, science may be a chameleon.

What students learn about the social and organizational structure of science during their university years may conflict with an expectation that a career in science is a relatively independent endeavour. I propose that the impact of this realization may differentially effect the sexes. If professionally-oriented women, as I have proposed, have a tendency to avoid male-dominated organizational environments, realization during their education that science is such an environment, may lead them to decide that their investment would be better placed elsewhere.

Studies have also found that among the significant factors influencing the choice of a science major by women are a desire to be self-sufficient (Gilbert and Pomfret, 1991), a strong desire for control, prestige and influence and positive interaction with others (Ware et al., 1985), desires which may certainly be more difficult to fulfill in a male-dominated organizational environment.

The proposed mechanism could certainly better explain the counter intuitive findings of Canadian studies of undergraduate science students. Nevitte et al. (1988) have found that women with higher grades in science are much less likely be planning graduate studies than their female counterparts with average grades. Gilbert and Pomfret (1991) also found that high achieving women students who leave science disciplines do not drop out of university but tend to transfer to non-science disciplines. Their study of men and women undergraduates in science also provided valuable insight into differences in the educational experience of high achieving men and women science students. They found that high achieving women students, much more than their male counterparts, value working in a supportive environment. They conclude that high achieving women may be leaving science partly in response to pressures created by a lack of fit between their expectations about science, and the realities of the educational environment of science (1991;38).

Gilbert and Pomfret interpret this "lack of fit" of expectations as related to value orientations. They suggest that science is associated with a 'justice and rights' orientation characterized by the autonomy of self and emphasis on limited and clearly defined reciprocal relationships with others, the key image being the lone, self-sufficient scientist engaged in the pursuit of scientific knowledge (1991; 6). Given that more men than women prefer the 'justice and rights' orientation (more women preferring a 'response and care' orientation), they argue that more women may be uncomfortable with science:

> To the extent that university level science education responds more effectively to male than to female concerns, the difference in value orientations will have a indirect effect in retention in so far as it results in the recruitment of individuals (including intellectually

> competent women) who experience difficulty in dealing with the non-cognitive, social and value orientations of the educational environment. The value orientation difference may have more of an impact on grade differences by producing initially much lower grades for women with only a practical recovery later in their educational career. Women need time to construct an appropriate response to various unexpected and unsatisfying environmental features to the extent that low marks influence women to quit science and value orientation differences affect marks, then value orientations indirectly effect the retention experiences of women. The lack of fit between the value orientations of women and the science curriculum may be also a source of the high level of stress experienced by women.

Differences in values between men and women however are not enough to explain the key finding of Nevitte et al. (1988) that women with higher grades in science are much less likely to be planning graduate studies than their average performing female counterparts. The hypothesis generated in this study permits a re-interpretation which is more theoretically compelling because it better accounts for this particular finding.

I suggest that instead of, or in addition to, a mismatch in value orientations, high achieving women may be experiencing a mismatch of their expectations about the work environment of science. I argue that it is likely that women considering a career in science would expect that science is associated with a justice and rights orientation, since the image of the lone scientist is the image science has in the public. Gilbert and Pomfret's own findings show that this expectation may be one of their primary expectations; high achieving women in science are more likely than their high achieving male-counterparts to report an expectation that science will reward their self-management abilities (1991; 36).

It is possible that the brighter women are more likely than their average counterparts to figure out that, contrary to its image, science is an organizational environment, not an individual endeavour which is therefore mismatched with their expectations and their self-reported self-management abilities. Given that it is also a male-dominated environment, these women may also decide that this situation has a potentially greater negative impact on their chances for success and satisfaction than on those of their male counterparts.

This mechanism also provides another interpretation of the finding that high achieving women in science programs value working in a supportive environment much more so than comparable male students (Gilbert and Pomfret, 1991) and the reports by women that instances of a "chilly" climate in university have negatively affected their careers. It may be that instead of needing a supportive environment more than men do , they sense on discovery of a male-dominated organizational environment in science that support is less available to them than their male counterparts. Rather than desiring it more, they find on arriving in undergraduate science, that they lack the support systems of their male counterparts, the environment therefore being accurately perceived by them as being potentially less supportive than it will be for male students in developing a scientific career.

Conclusion

The exploratory strategy developed in this study to examine degree attainment by sex in the context of participation in all traditionally male dominated degree programs facilitated the visual comparison of the behaviour of trends in the data. The patterns found suggest factors that may be contributing to the selective success of women in traditionally male dominated fields.

Two general themes emerge. The findings suggest that a professional/non-professional distinction[43] is an important factor in explaining the selective success of women in traditionally male dominated degrees. The analysis further reveals that the largest gains in representation of women in the traditionally male dominated disciplines have been in those where the associated professions or occupations are typically autonomous self employed professions rather than salaried positions in large organizations such as corporations and government. These findings suggest that women's selective success in previously male dominated degrees may be related to their expectations that working in male dominated fields where self-employment is typical represents a better investment than working in a male dominated organizational environment. These findings have implications for the continued under representation of women in the physical sciences and engineering.

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[43] See note 17

If science, contrary to its image in the general public as an individual endeavour, is actually an organizational milieu which has differential effects on the productivity of women, it is possible that this realisation during the university years differentially affects the sexes. If professionally oriented women, as I have proposed based on the findings of this study, have a tendency to avoid male dominated organizational environments, then the realisation during their university years that science is such an environment, despite its popular image, may lead to a decision to switch fields. This process could help to better explain the patterns of attrition of women from science and engineering, particularly the finding that high achieving women science students are more likely than both their male counterparts and average performing women counterparts to leave science and switch to other fields of study.

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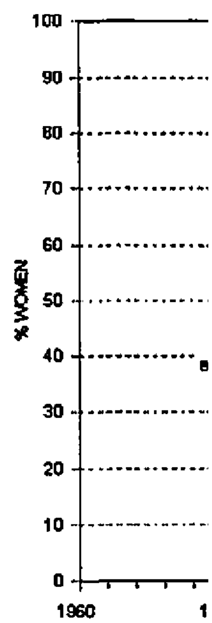
B



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E

FIG. 11: PERCENTAGE OF

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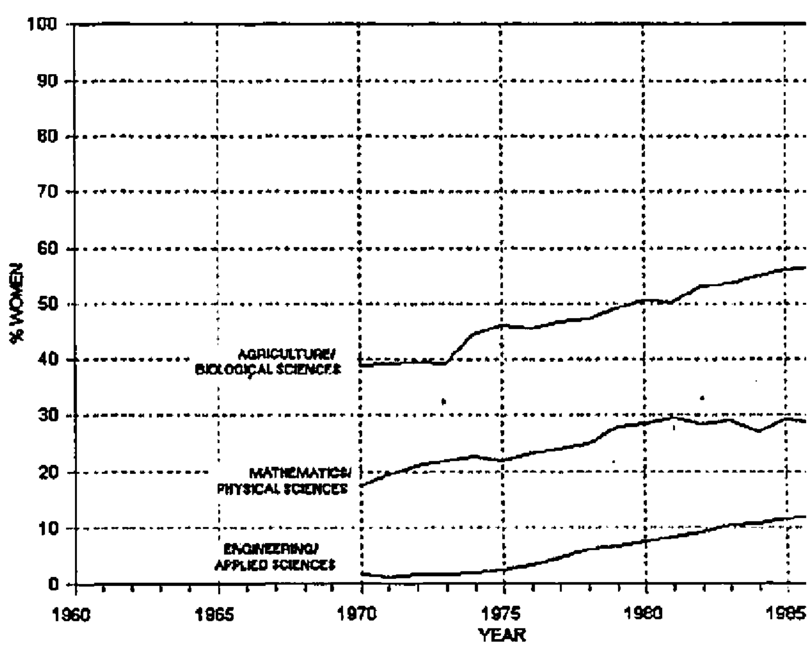
NSE FIELD S



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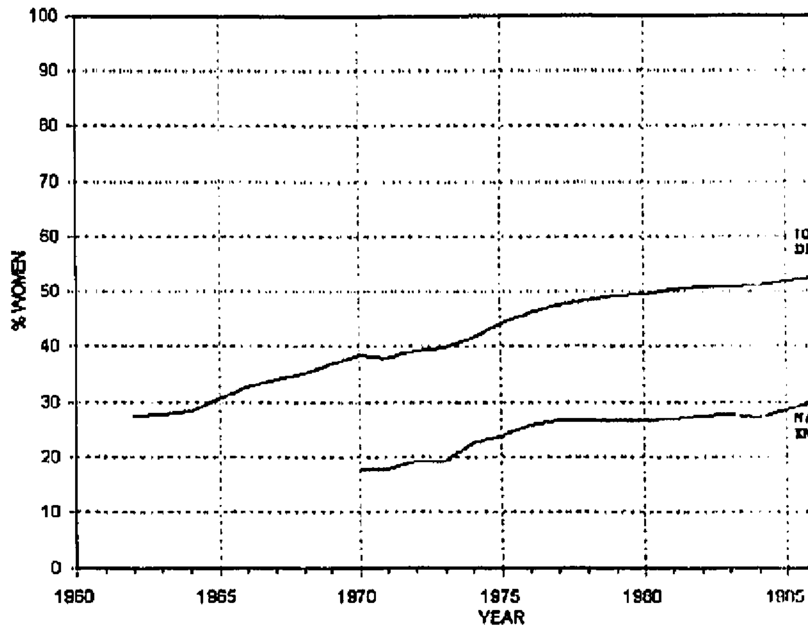
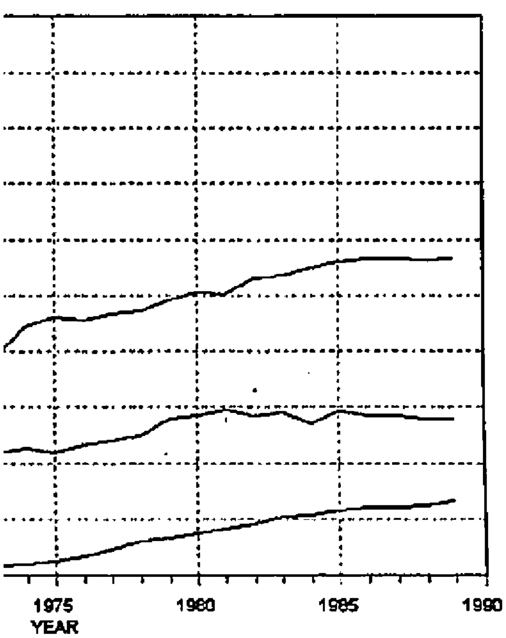
: PERCENTAGE OF BACHELOR'S AND FIRST PROFESSIONAL DEGREES

A

TOTAL BACHELORS DEGREES ; NSE DEGREES



FIELD S



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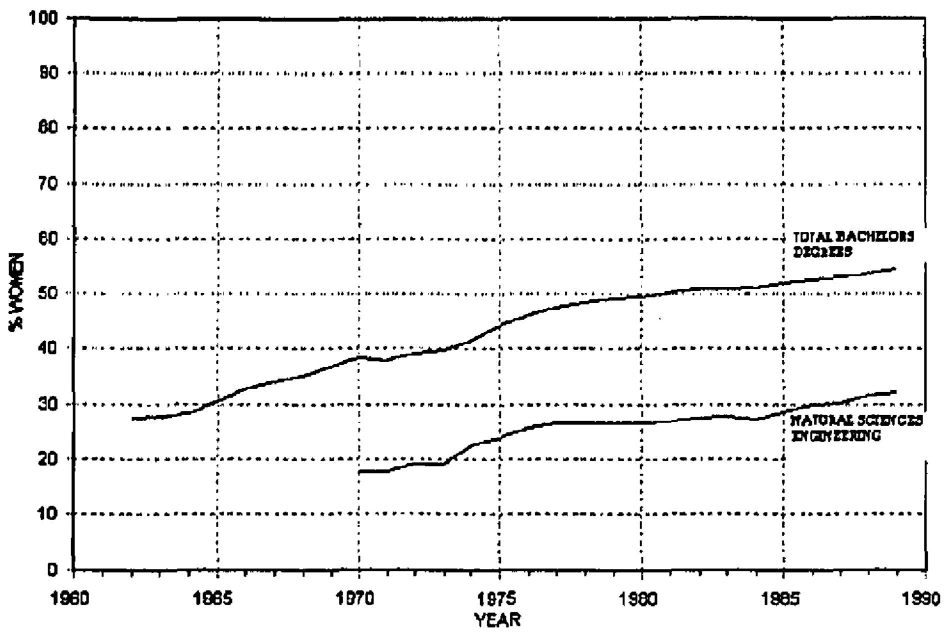
;S LOR'S AND FIRST PROFESSIONAL DEGREES GRANTED TO WOMEN, CANADA

A

TOTAL BACHELORS DEGREES ; NSE DEGREES



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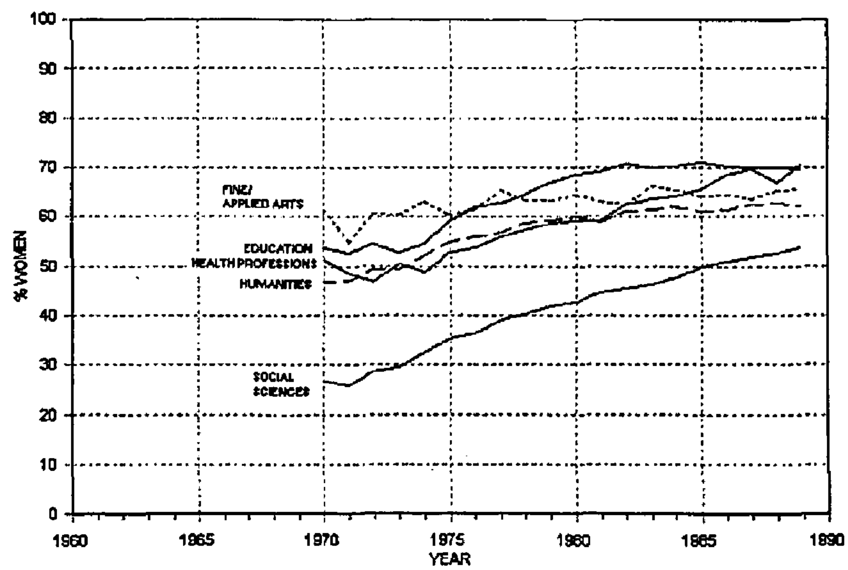
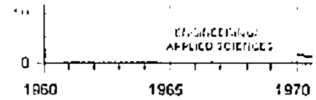
WOMEN, CANADA, 1962-1989

C

NON-NSE FIELDS





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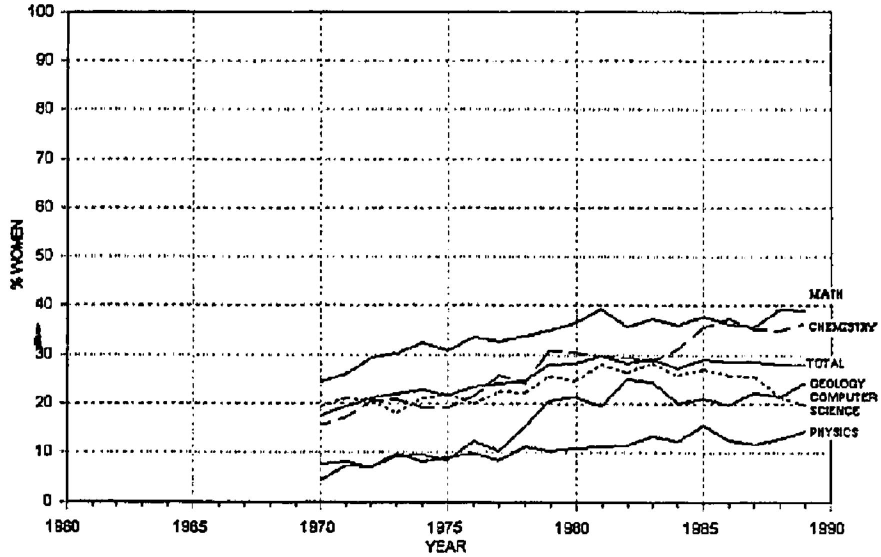

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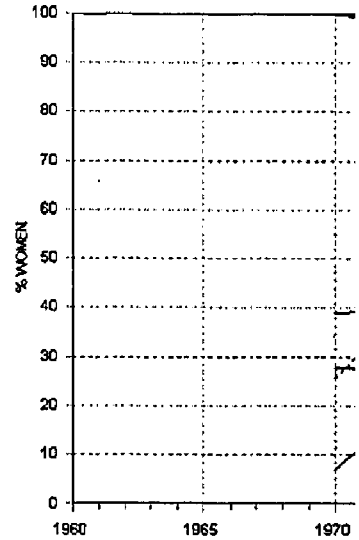

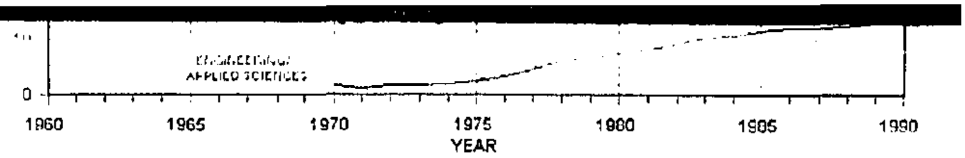

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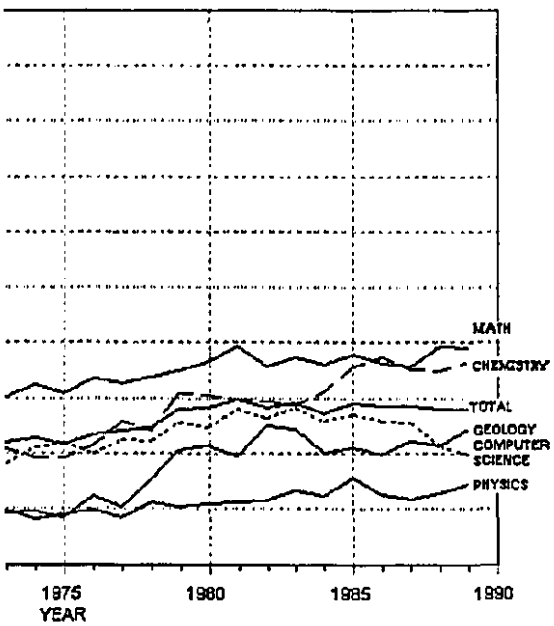
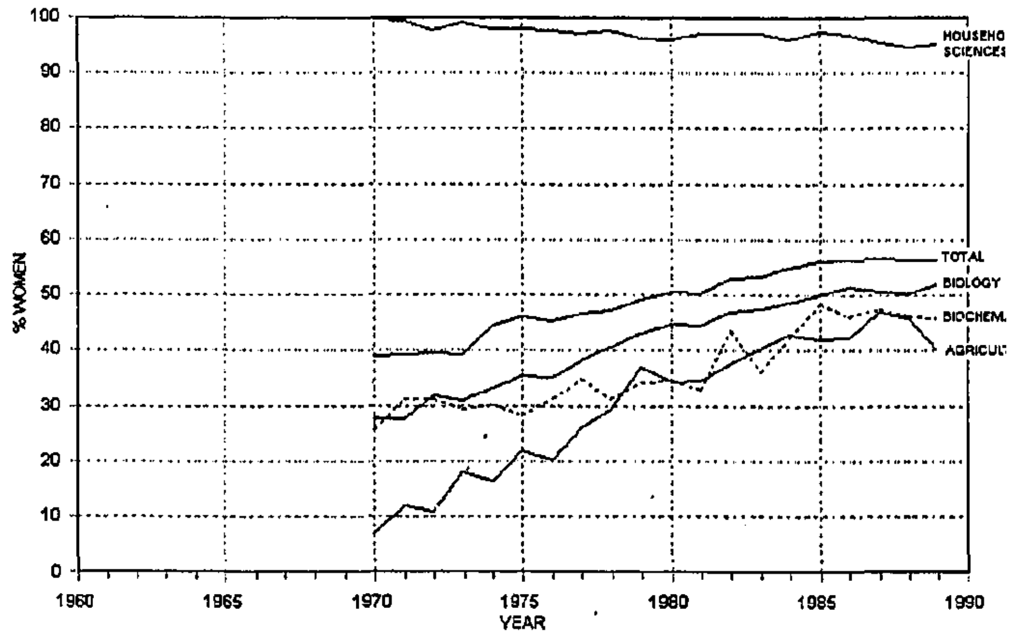
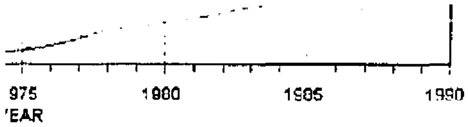
/ PHYSICAL SCIENCES

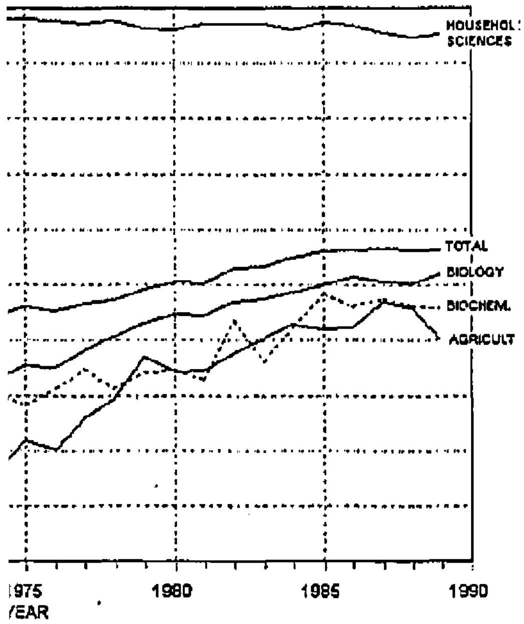


AGRICULTURAL / BIOLOGICAL SCIENCES





ꓷLOGICAL SCIENCES



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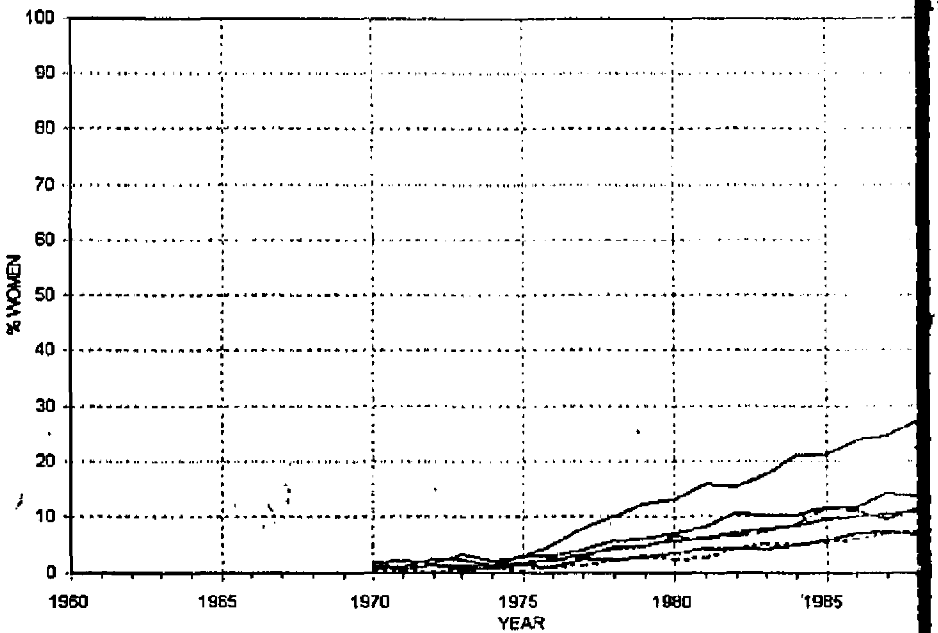

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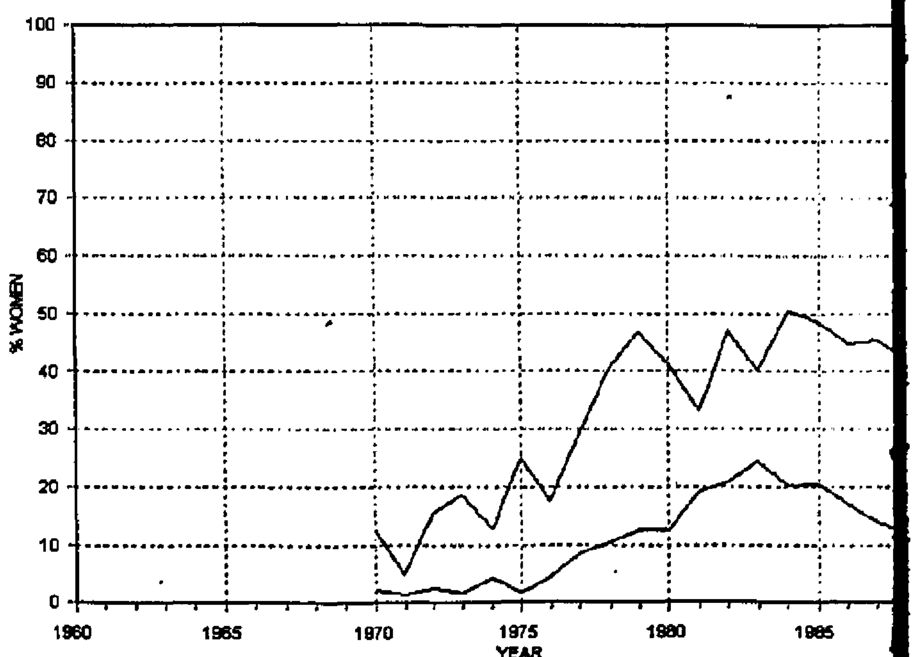
OTHER APPLIED SCIENCES



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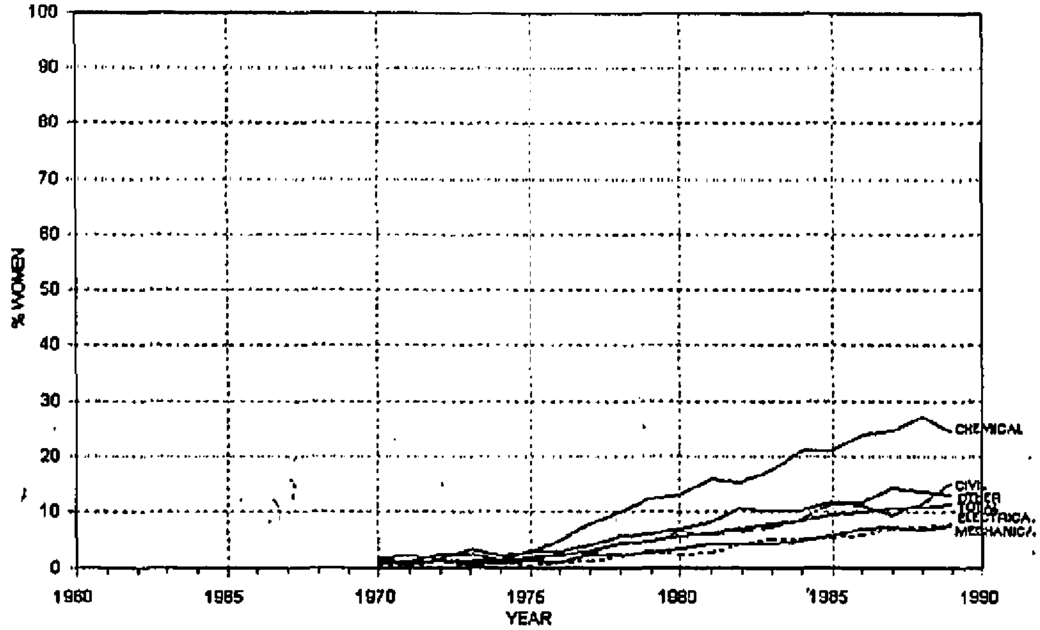
ENGINEERING



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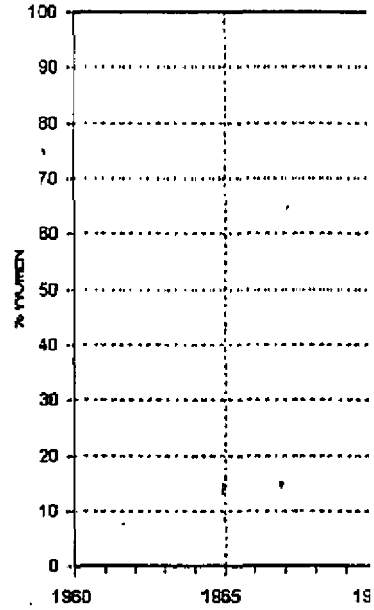

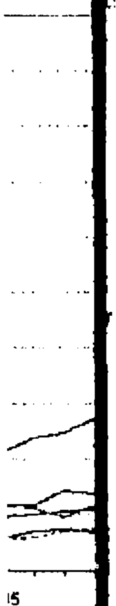

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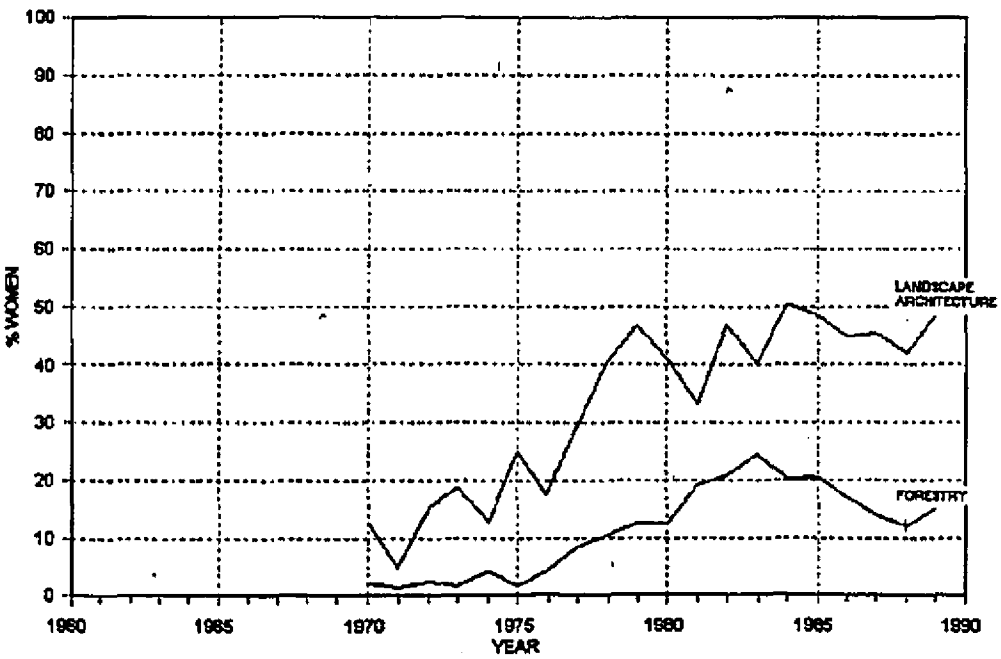

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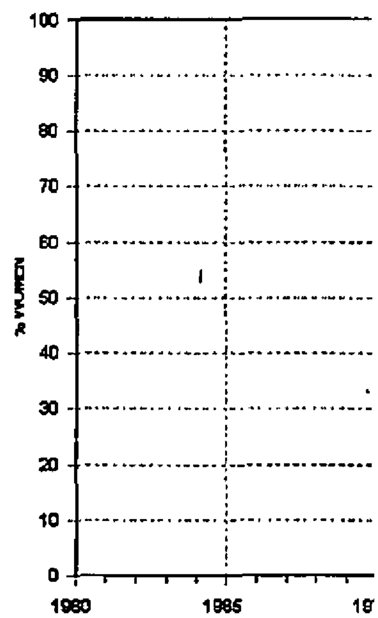

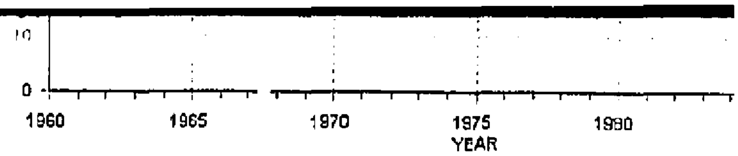

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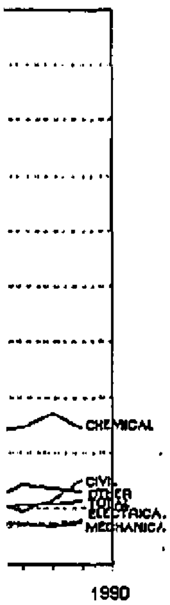
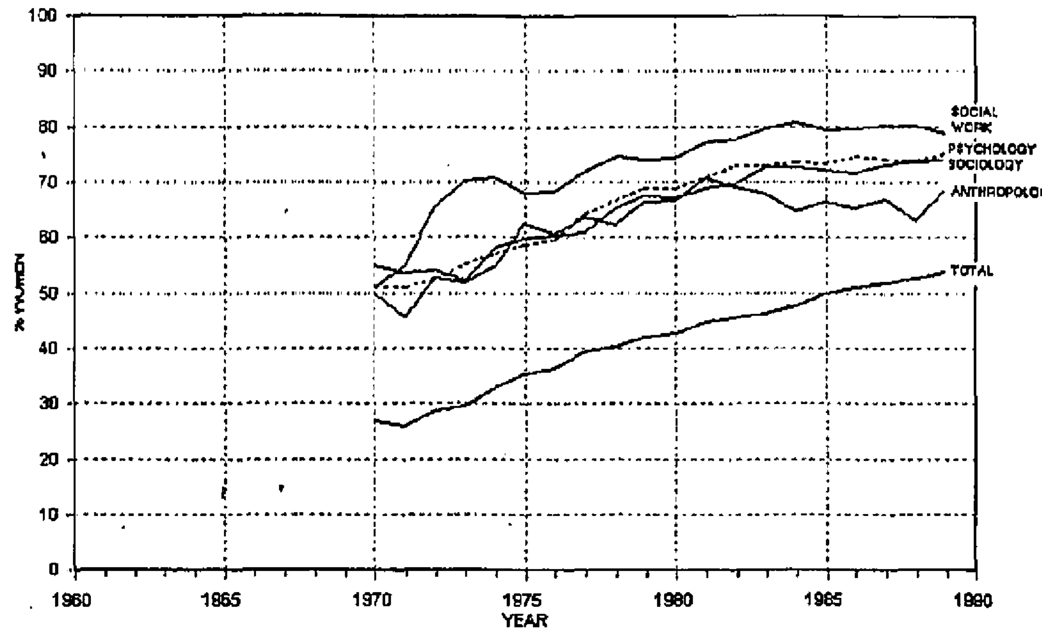
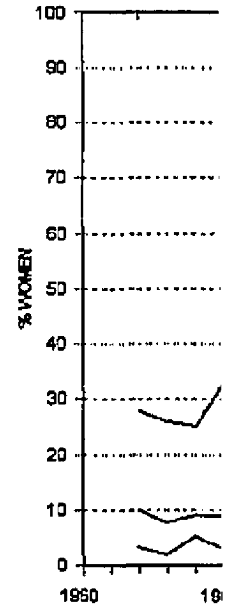
SOCIAL SCIENCES







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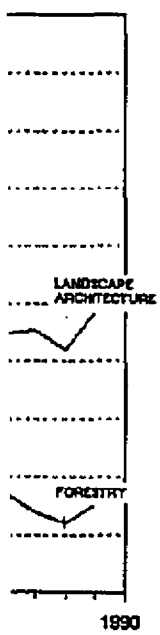
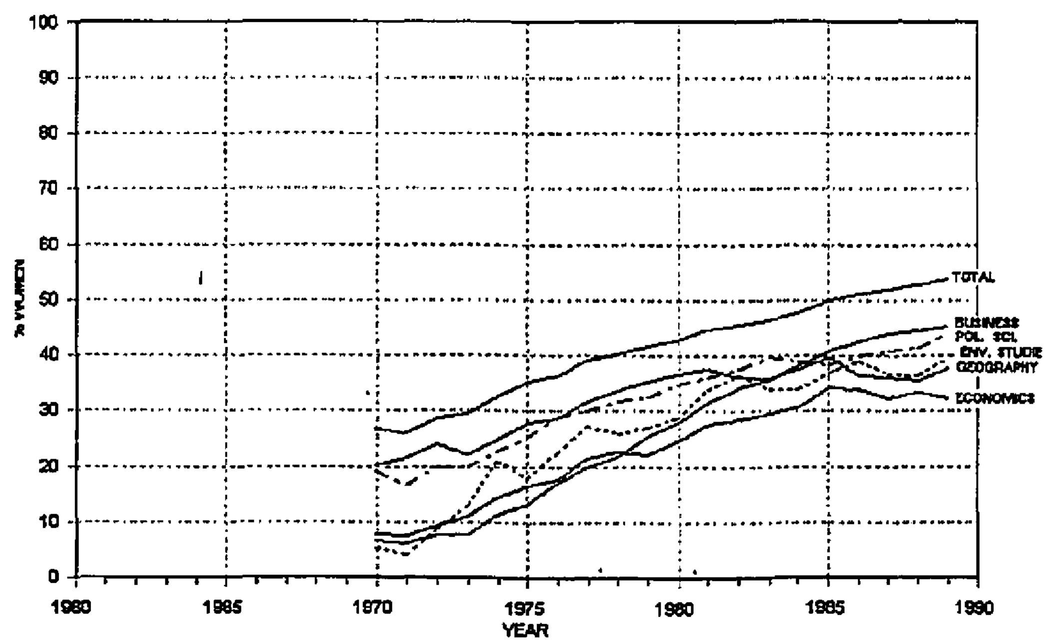
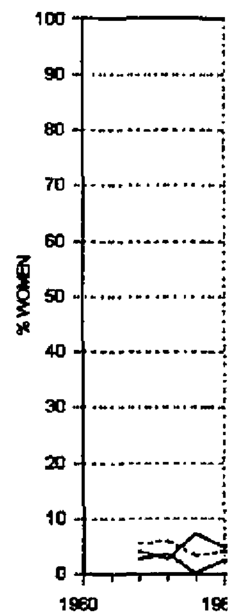
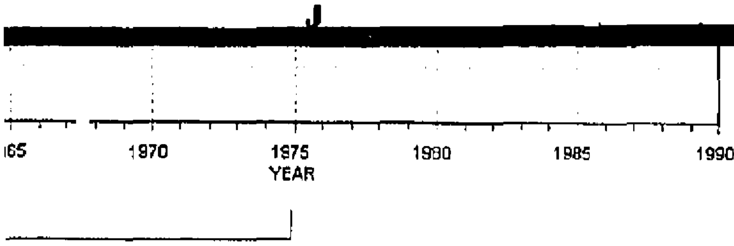
K

SOCIAL SCIENCES









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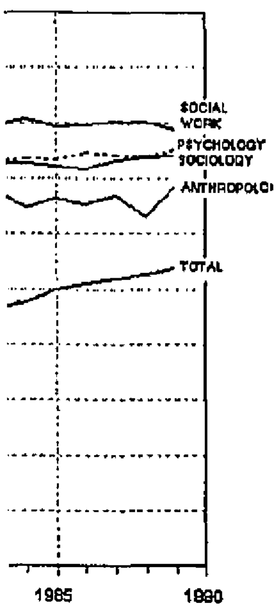
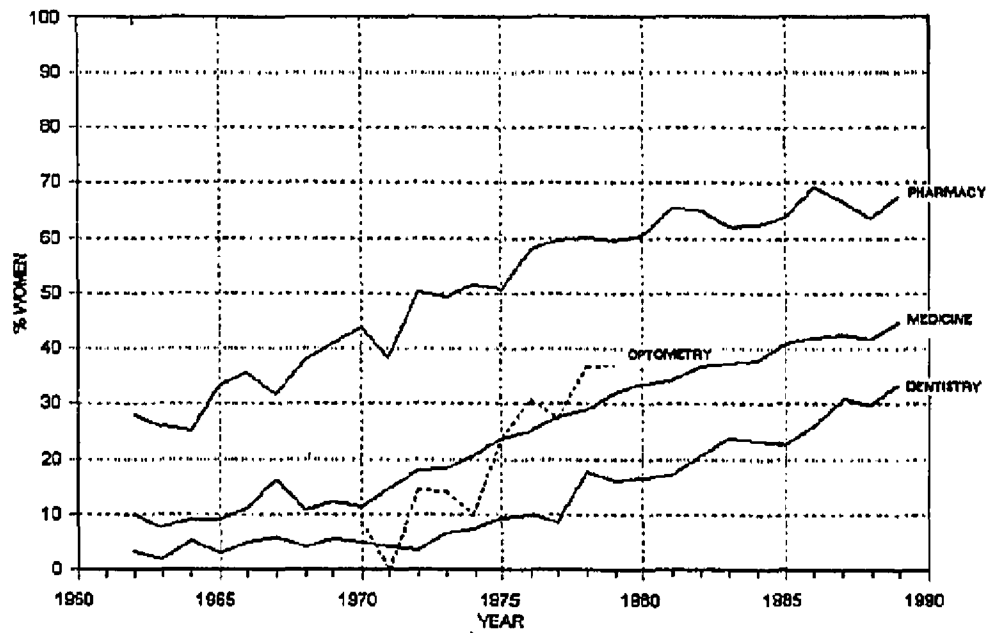
HEALTH PROFESSIONS





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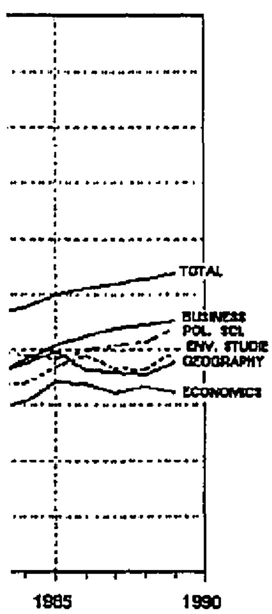
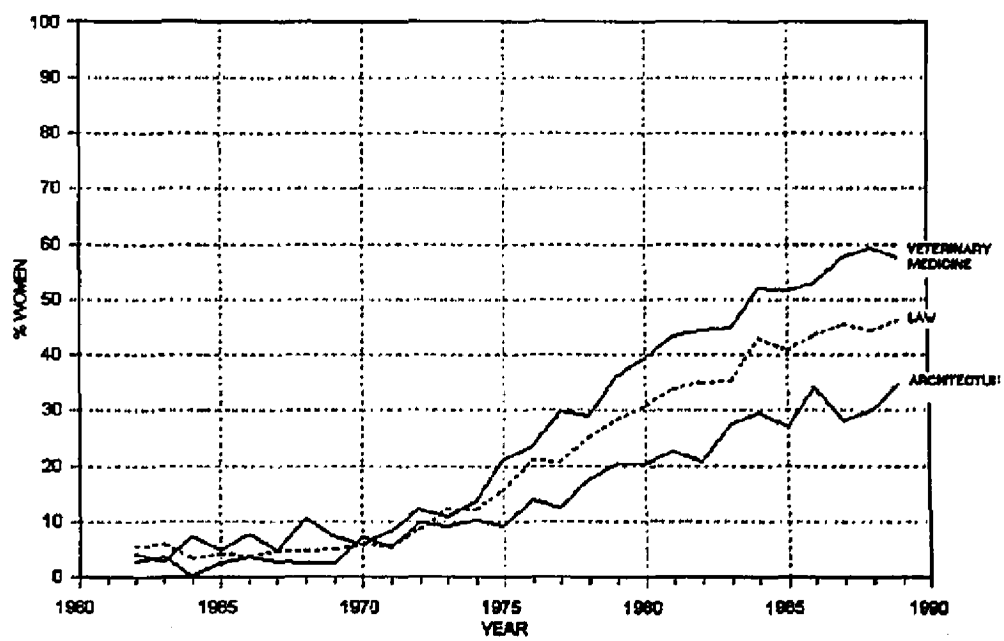
OTHER PROFESSIONAL DEGREES



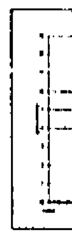


Note: The upper trend represents the total number of graduates in a given year. In 1970, the middle trend represents the number of male graduates in all cases except Household Sciences, Psychology, Social Work, Sociology, and Anthropology. For the graphs where the trends have crossed, the middle trend in 1989 represents the number of women.

LEVEL 3 →

C

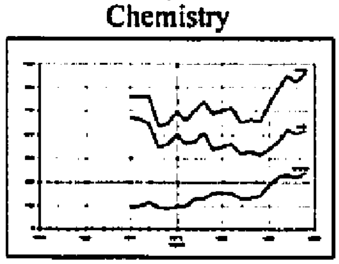
Mat



LEVEL 4 →

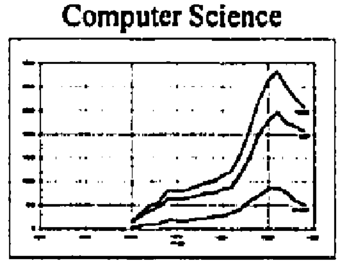
H

Chemistry



I

Computer Science



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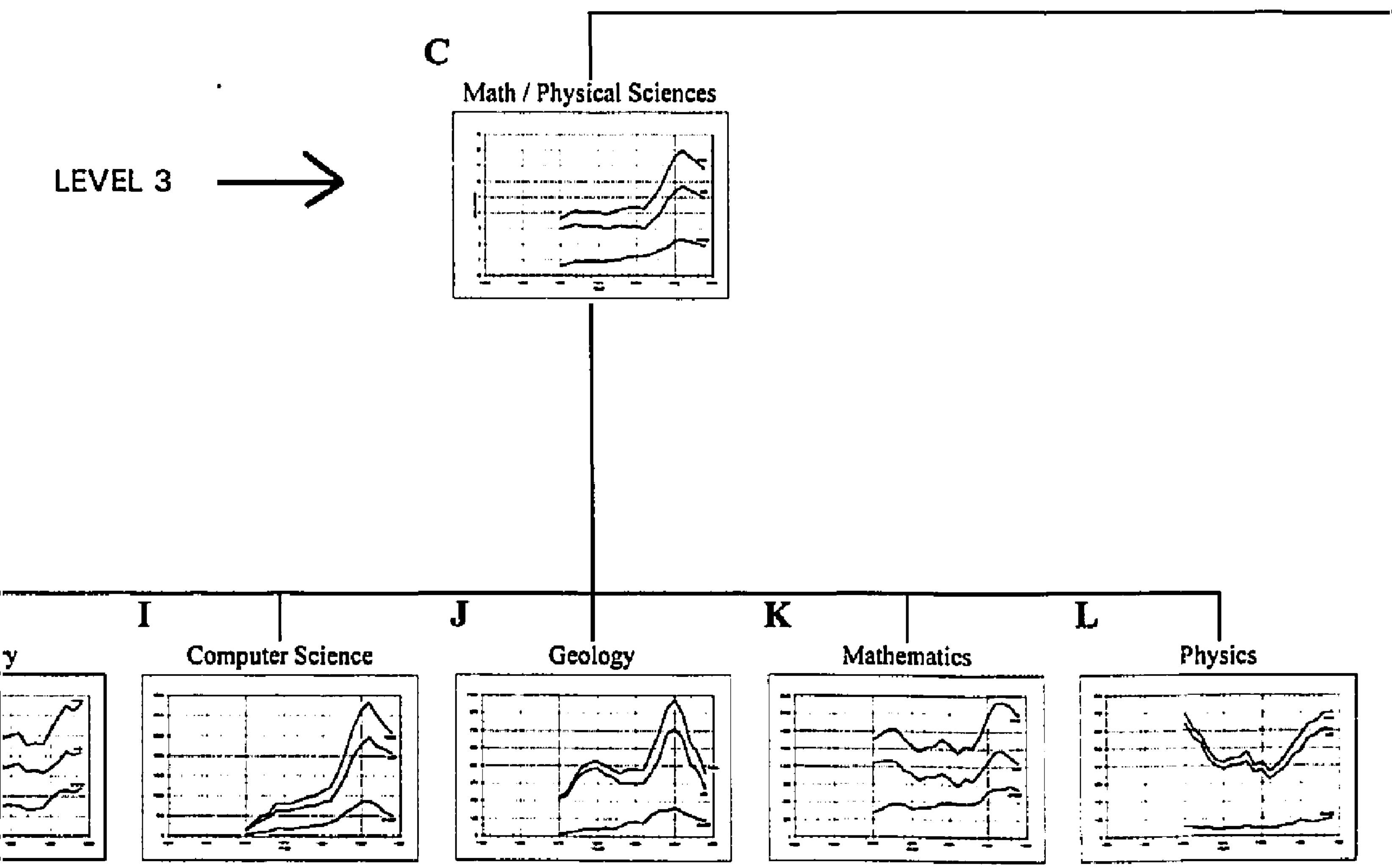
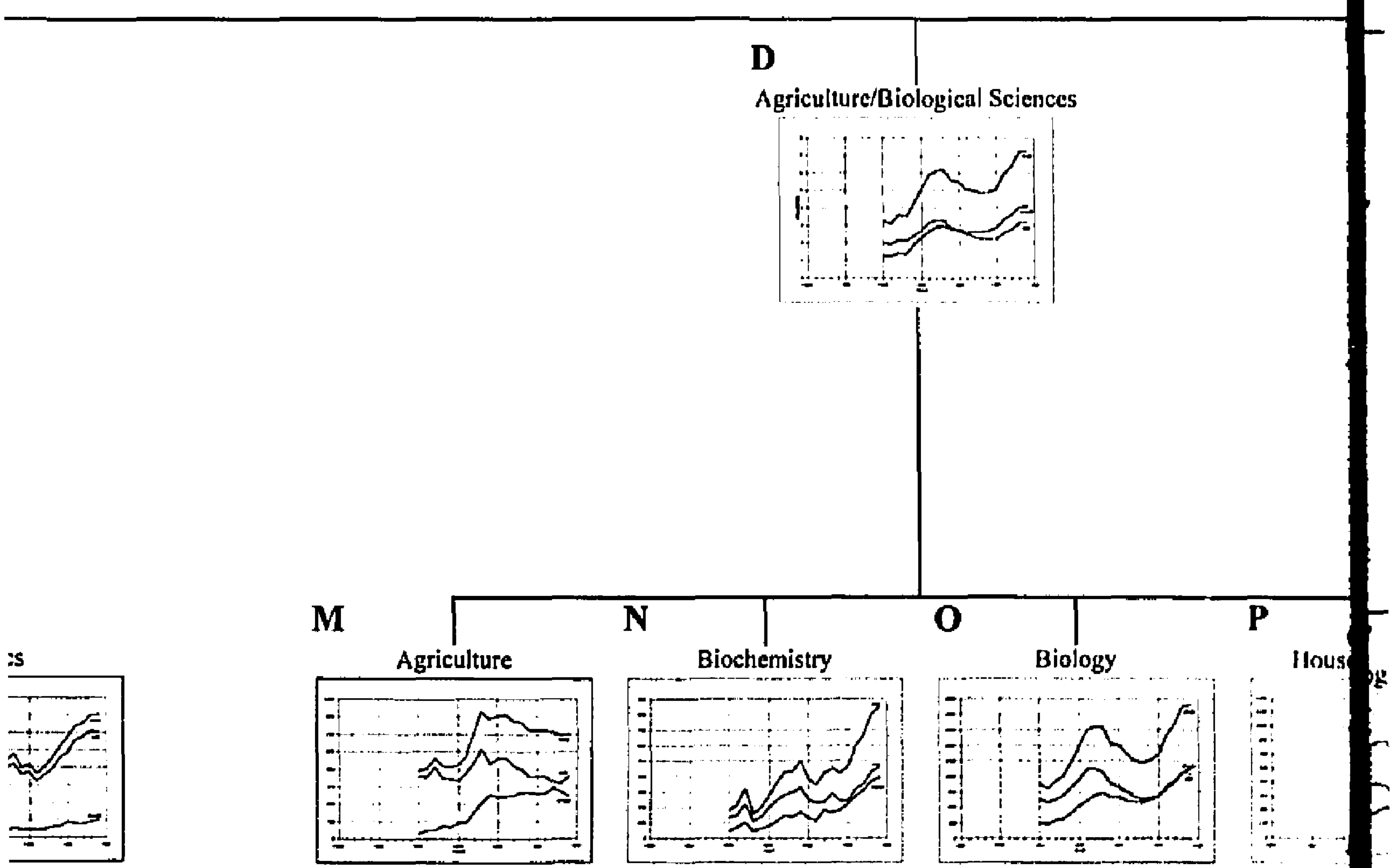

LEVEL 3
C
Math / Physical Sciences
I
Computer Science
J
Geology
K
Mathematics
L
Physics
y


D
Agriculture/Biological Sciences
M
Agriculture
N
Biochemistry
O
Biology
P

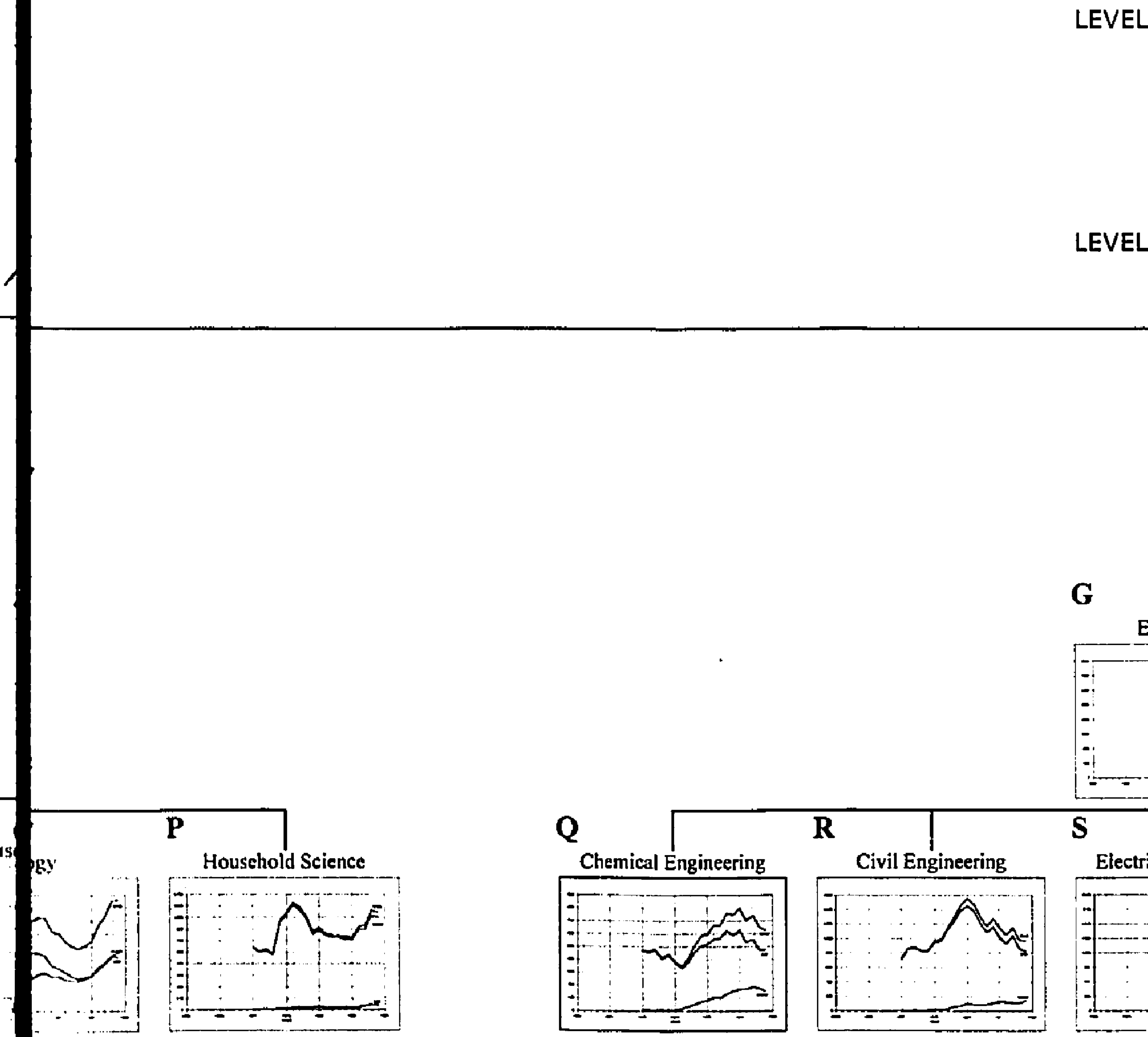
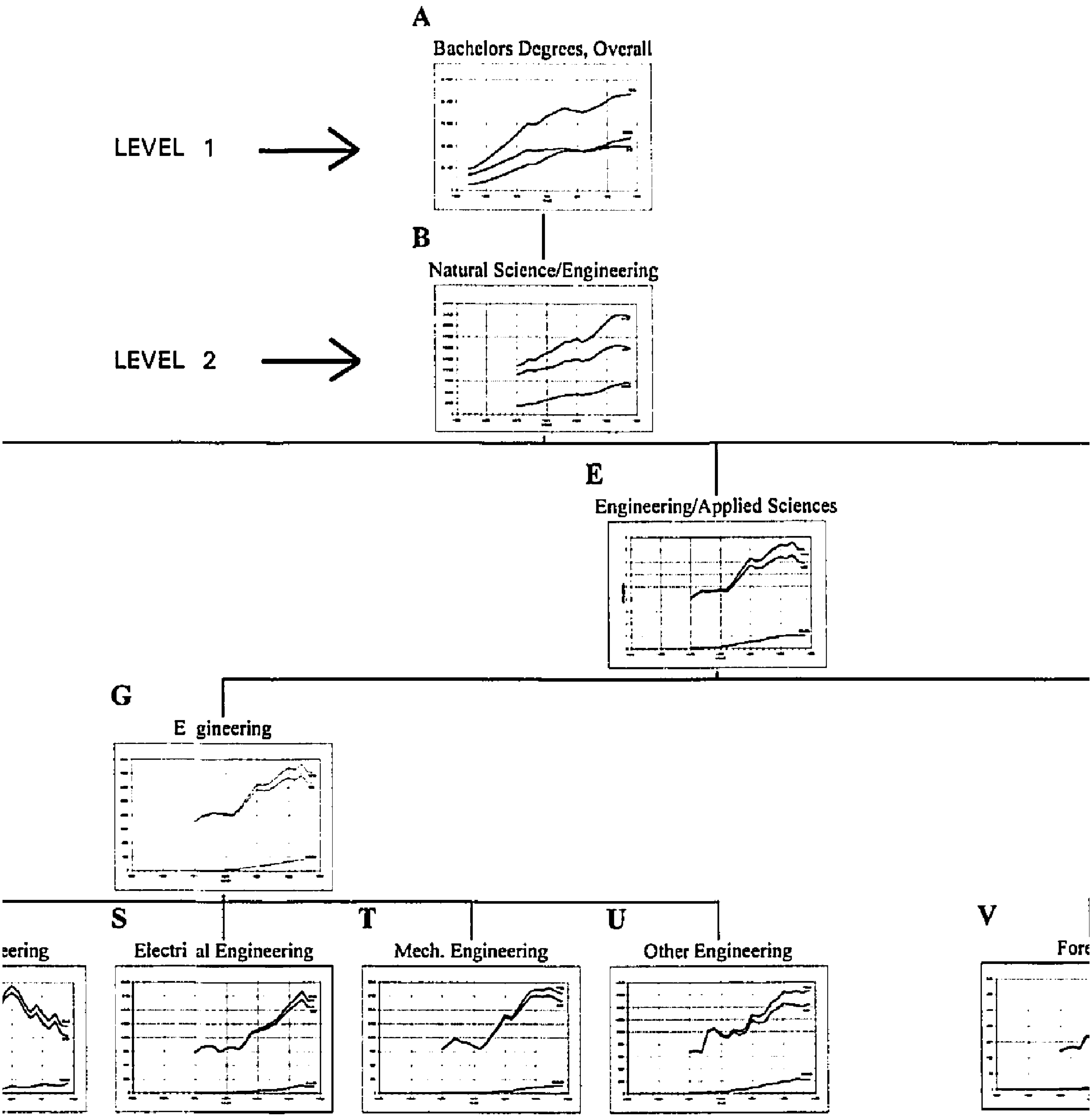

LEVEL
LEVEL
G
P
Household Science
Q
Chemical Engineering
R
Civil Engineering
S

Fig. 12: Bachelor's and first profession



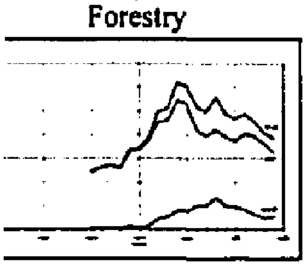
'essional degree graduates, by sex, Canada, 1962-1989

W

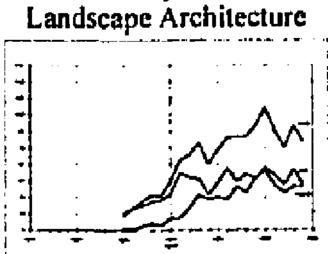
X

Y

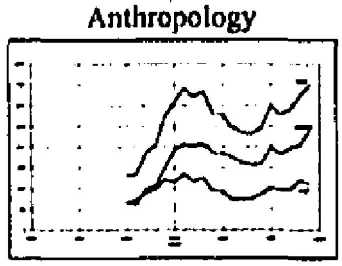
Forestry



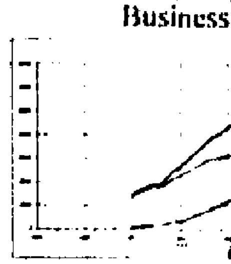
Landscape Architecture



Anthropology

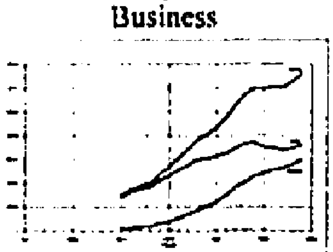


Business



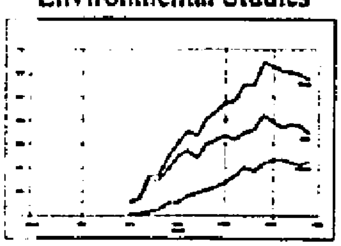
Y

Business



Z

Environmental Studies



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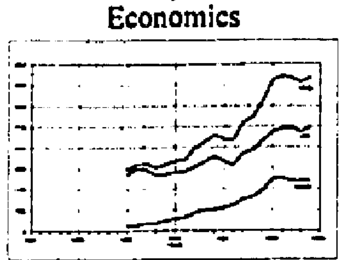
Economics



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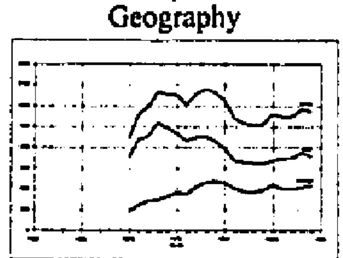
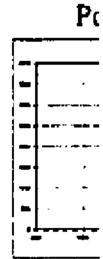
Geography



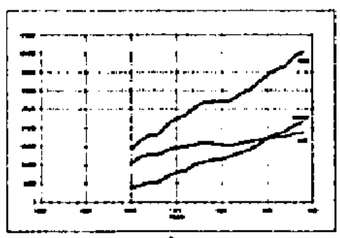
CC

Po



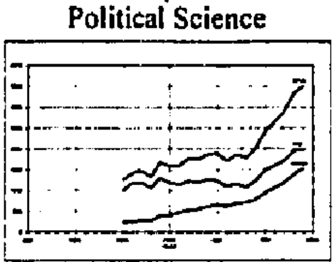
F

Social Sciences



CC

Political Science



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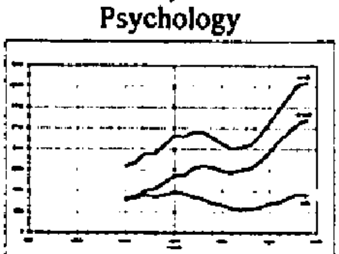
Psychology



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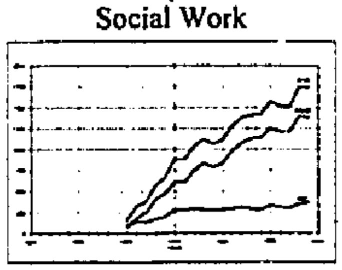
Social Work



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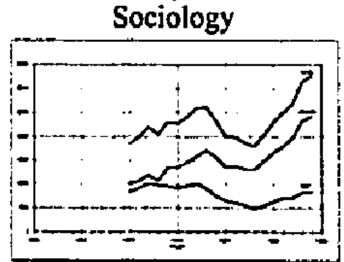
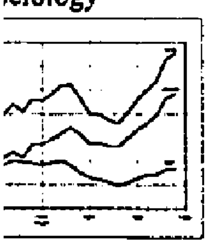
Sociology



ciology



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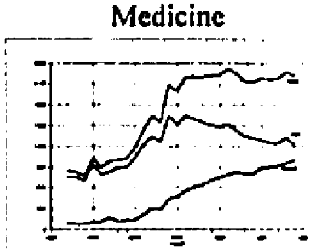
Medicine



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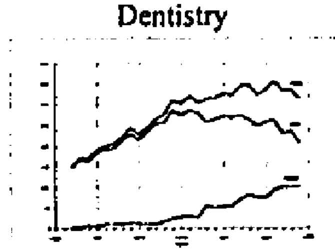
Dentistry



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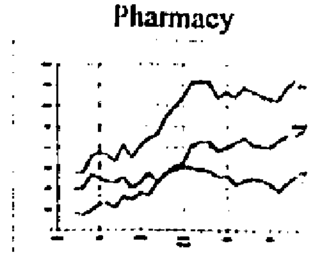
Pharmacy



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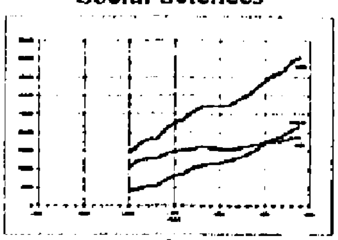
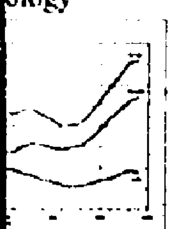
Social Sciences



ology



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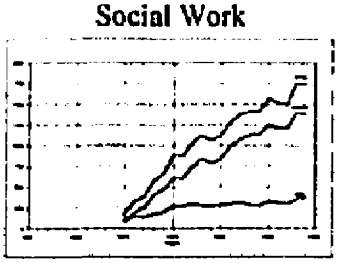
Social Work



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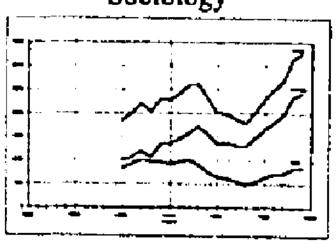
Sociology



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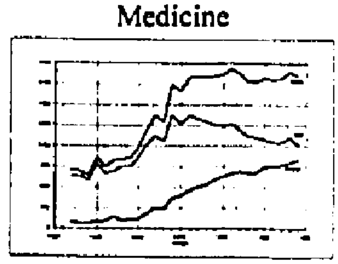
Medicine



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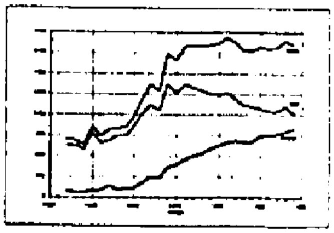
Medicine



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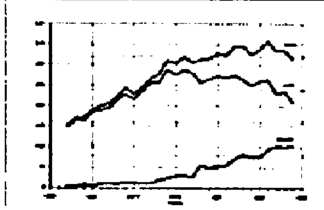
Dentistry



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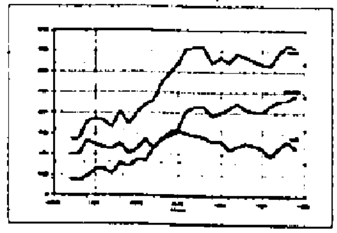
Pharmacy



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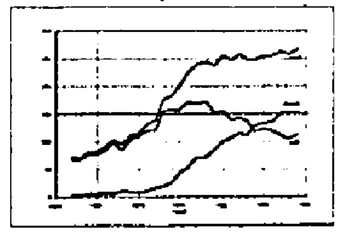
Veterinary Medicine



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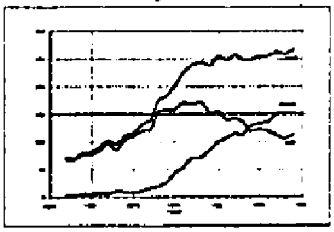
Veterinary Medicine



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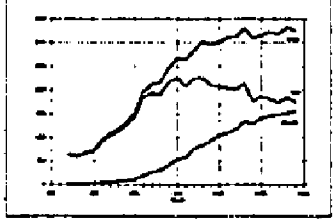
Law



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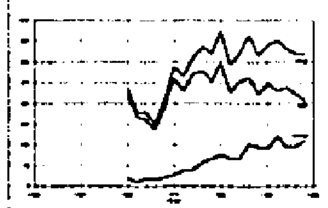
Architecture



Appendix III

Bachelor's Degree, Overall

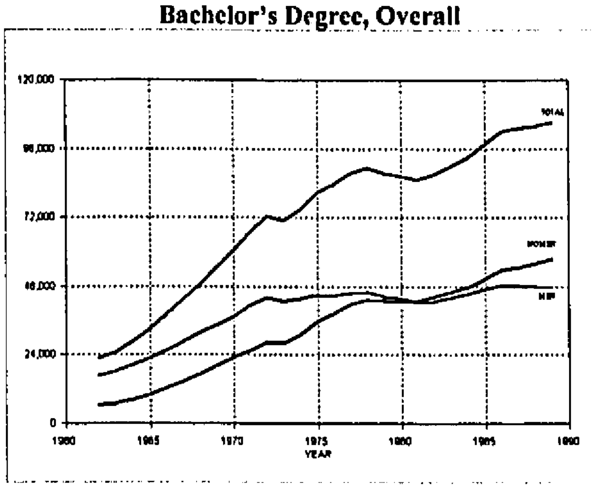


Fig. 12A

Natural Sciences/Engineering

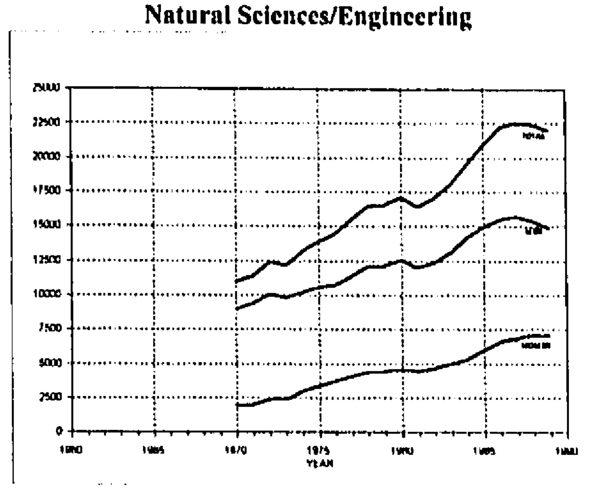


Fig. 12B

Math/Physical Sciences

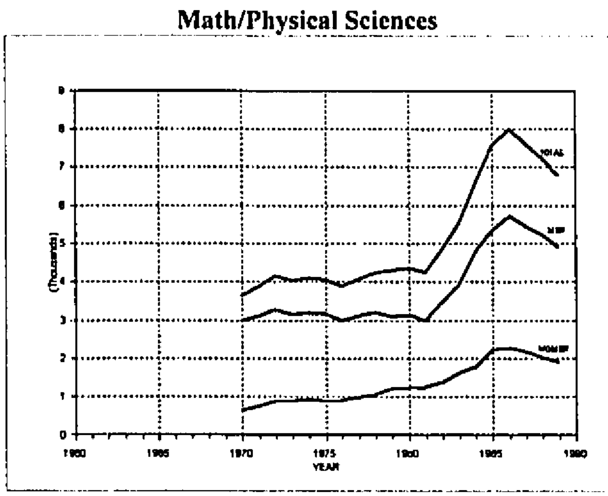


Fig. 12C

Agriculture/Biological Sciences

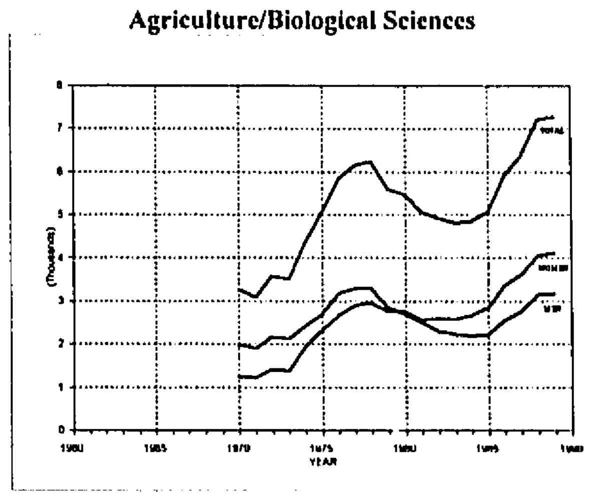


Fig. 12D

Engineering/Applied Sciences

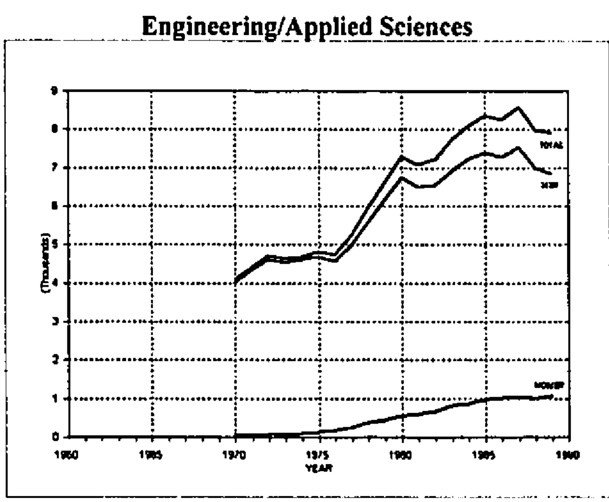


Fig. 12E

Social Sciences

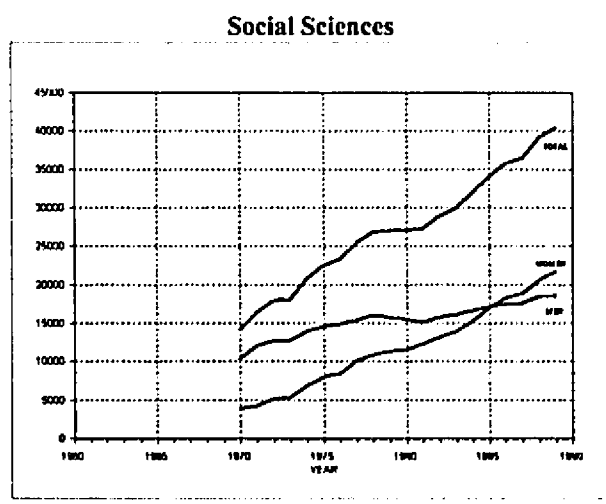


Fig. 12F

Engineering

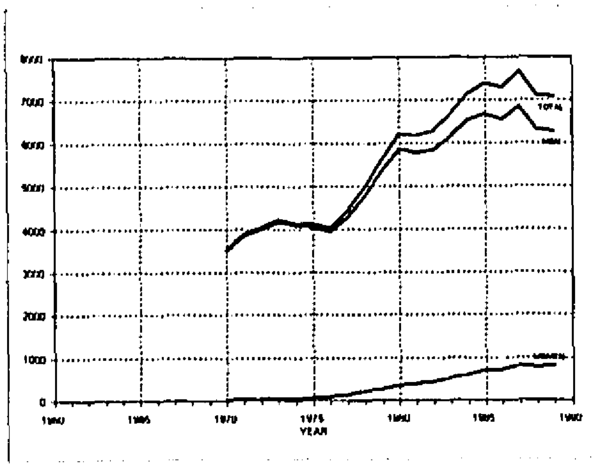


Fig. 12G

Chemistry

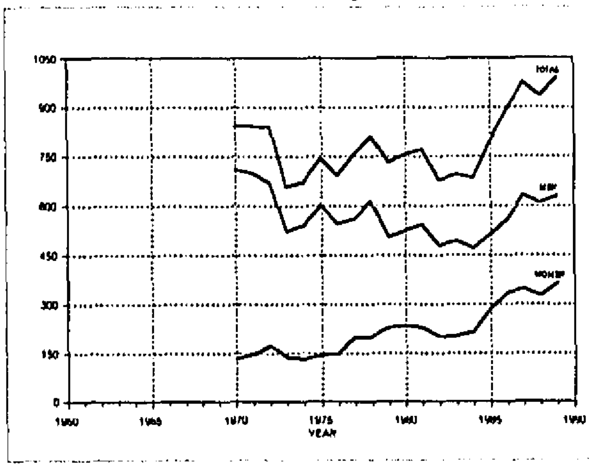


Fig. 12H

Computer Science

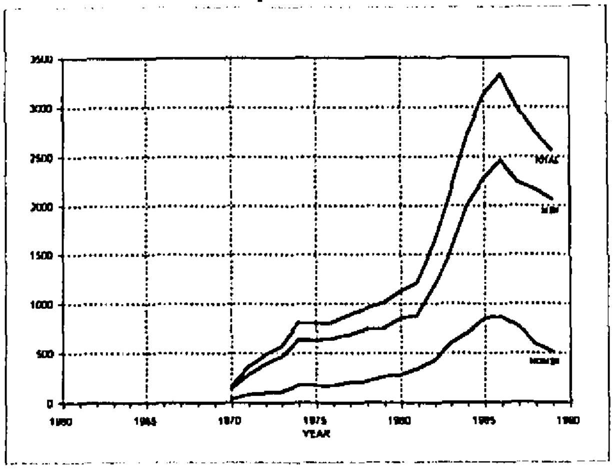


Fig. 12I

Geology

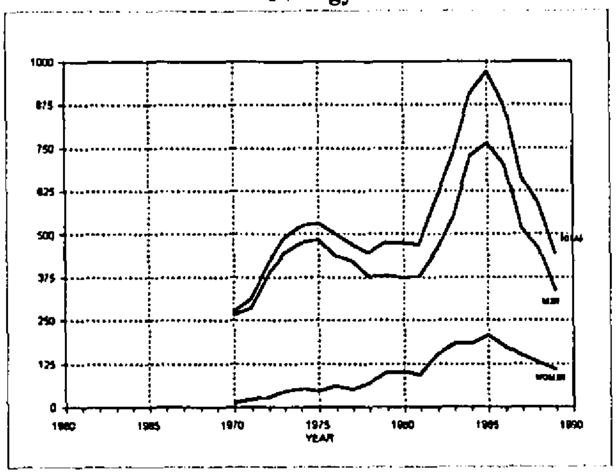


Fig. 12J

Mathematics

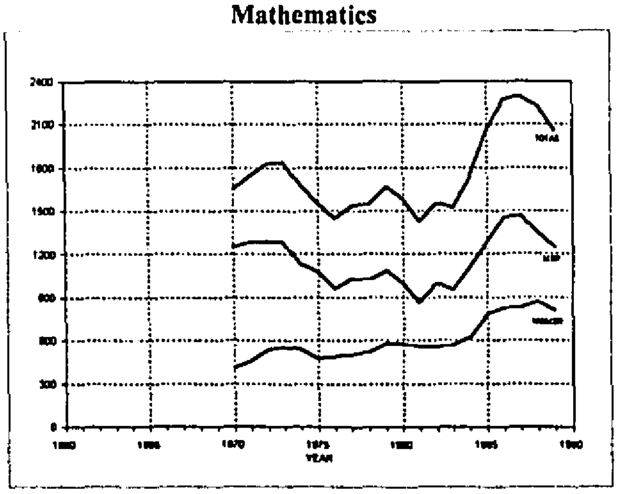


Fig 12K

Physics

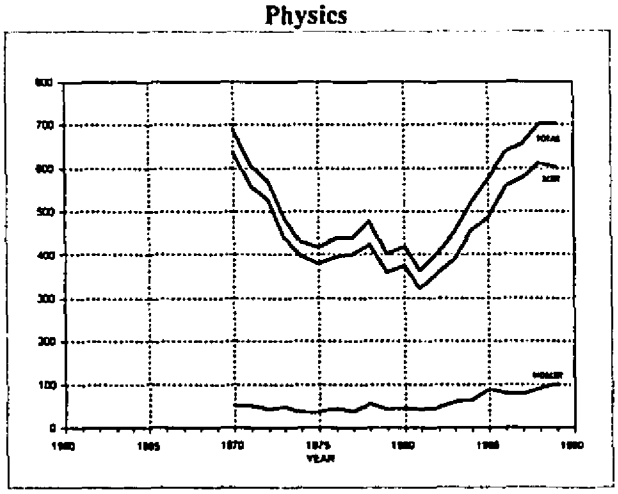


Fig. 12L

Agriculture

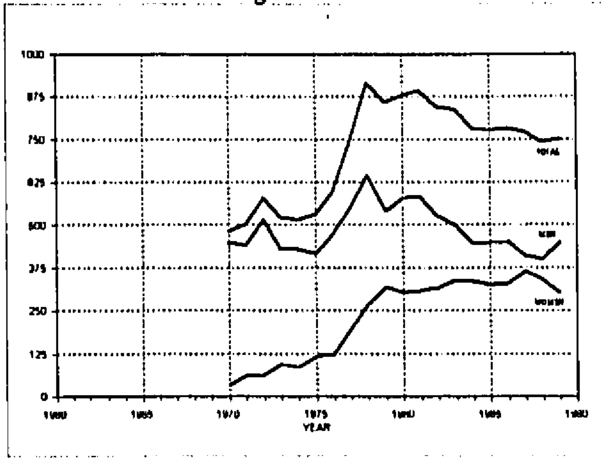


Fig. 12M

Biochemistry

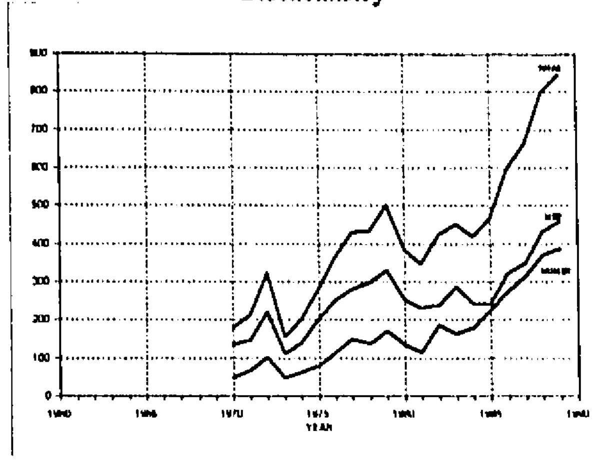


Fig. 12N

Biology

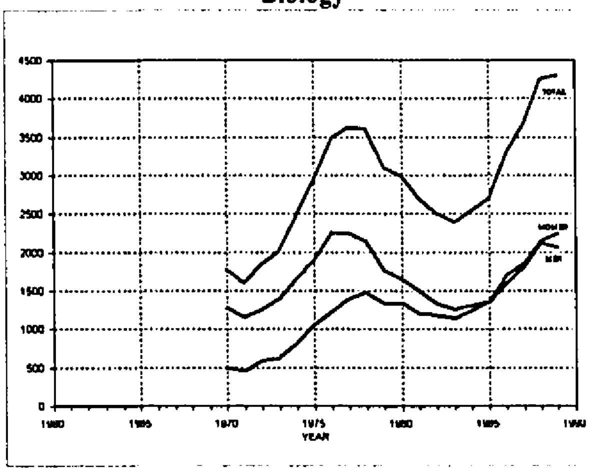


Fig. 12O

Household Science

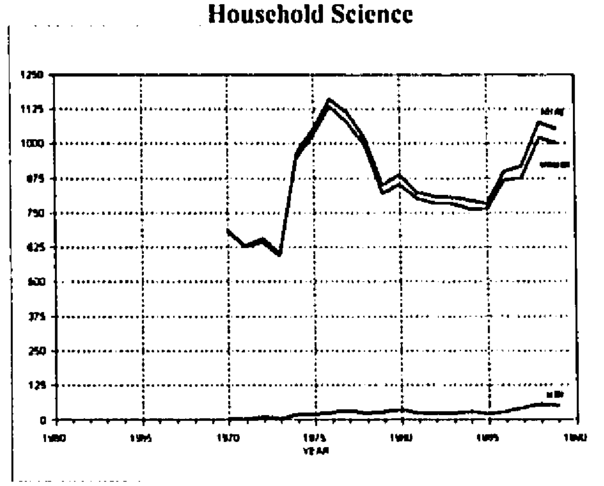


Fig. 12P

Chemical Engineering

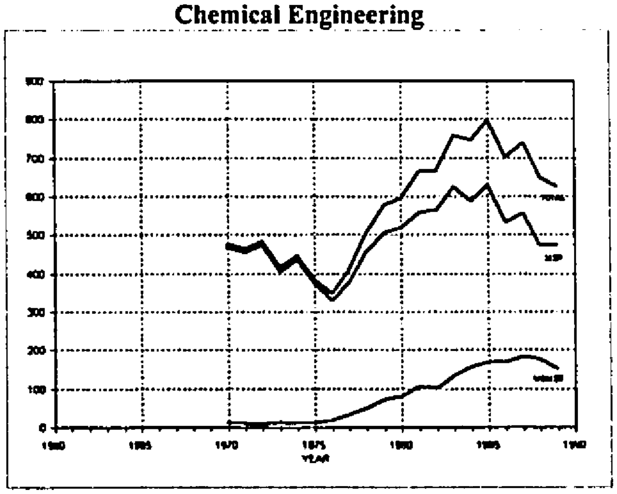


Fig. 12Q

Civil Engineering

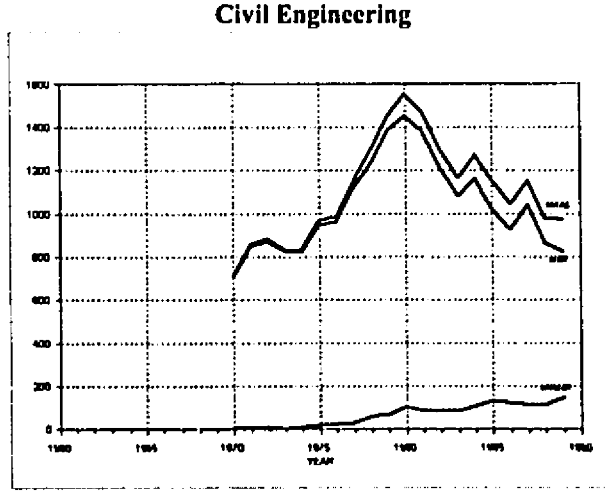


Fig. 12R

Electrical Engineering

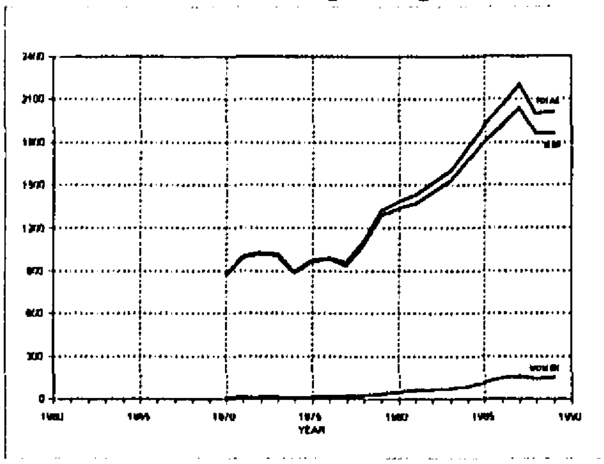


Fig. 12S

Mechanical Engineering

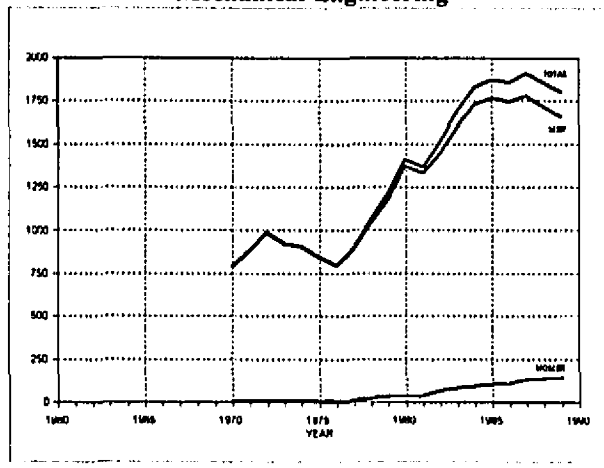


Fig. 12T

Other Engineering

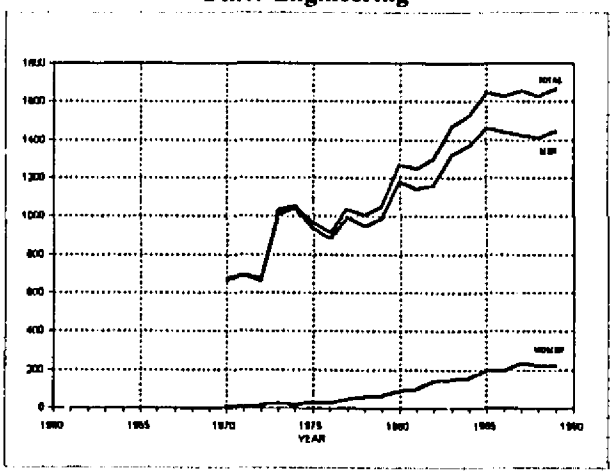


Fig. 12U

Forestry

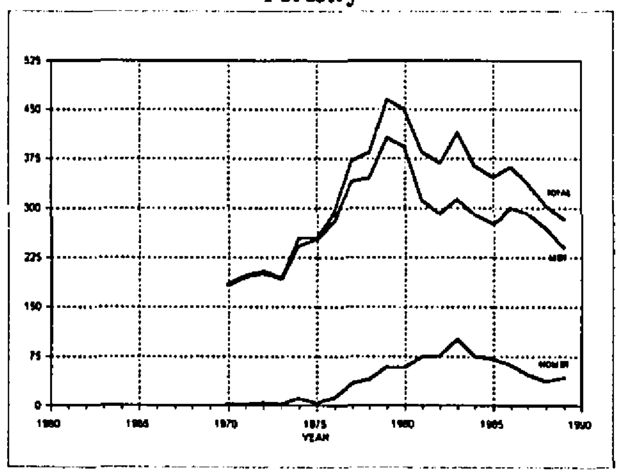


Fig. 12V

Landscape Architecture

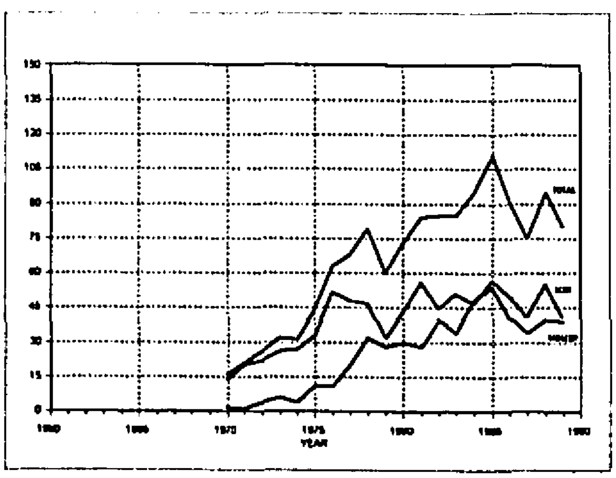


Fig. 12W

Anthropology

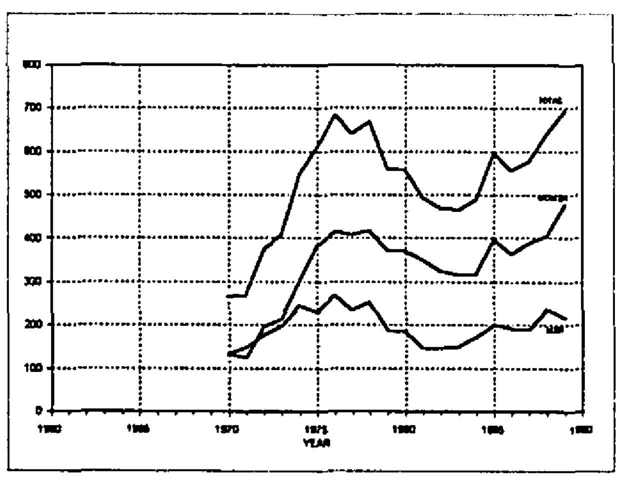


Fig. 12X

Business

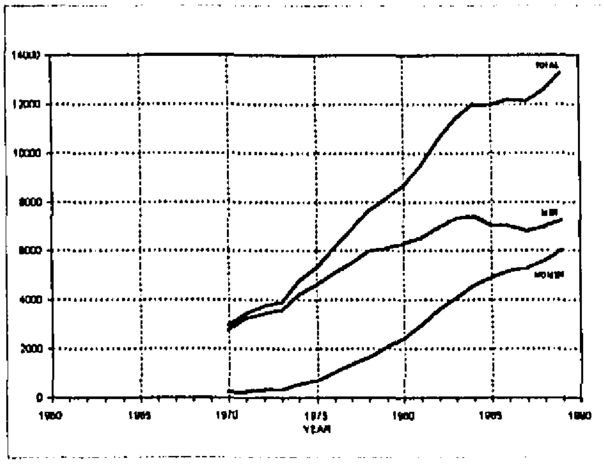


Fig. 12Y

Environmental Studies

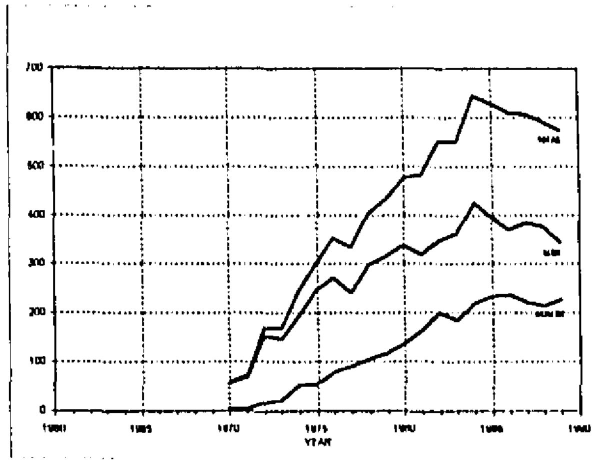


Fig. 12Z

Economics

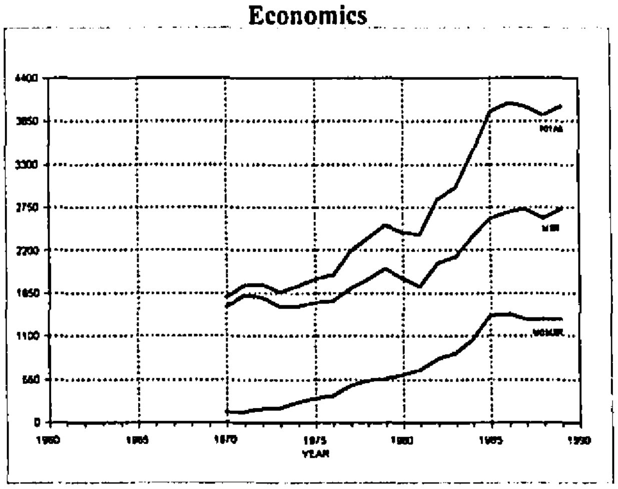


Fig. 12AA

Geography

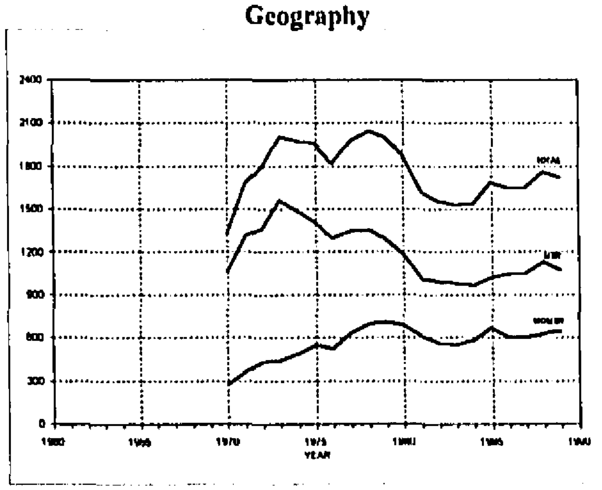


Fig. 12BB

Political Science

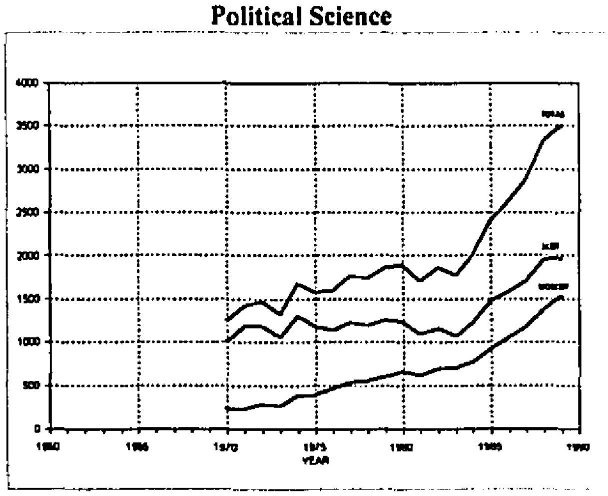


Fig. 12CC

Psychology

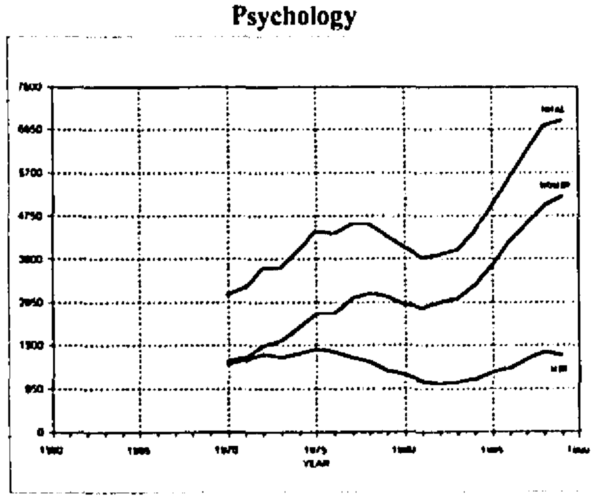


Fig. 12DD

Social Work

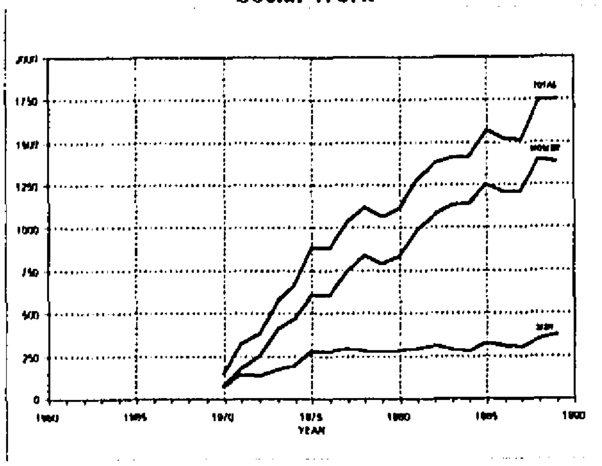


Fig. 12EE

Sociology

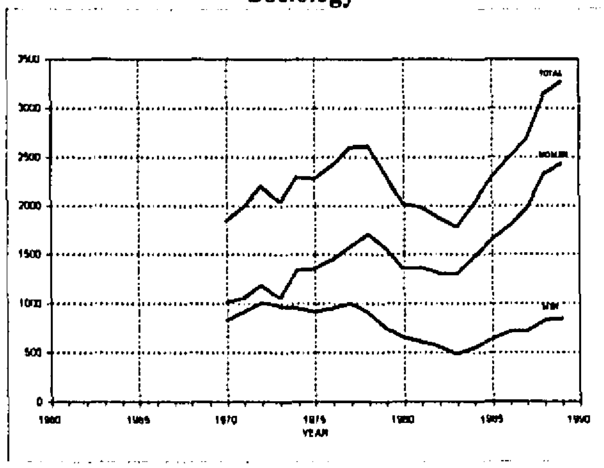


Fig. 12FF

Medicine

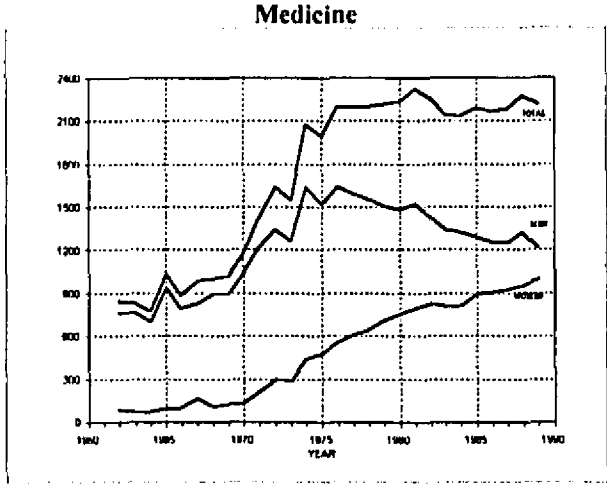


Fig. 12GG

Dentistry

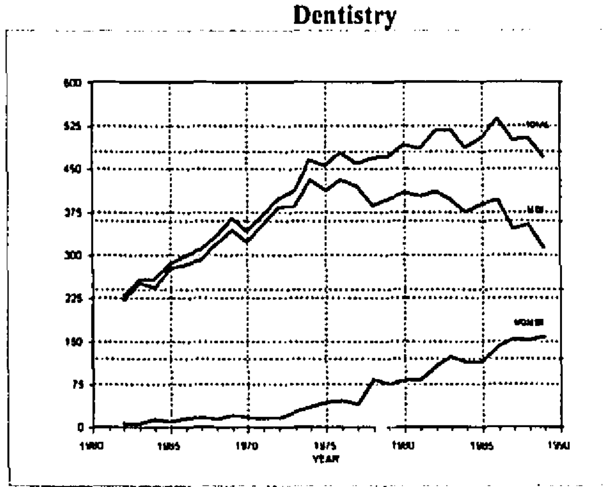


Fig. 12HH

Pharmacy

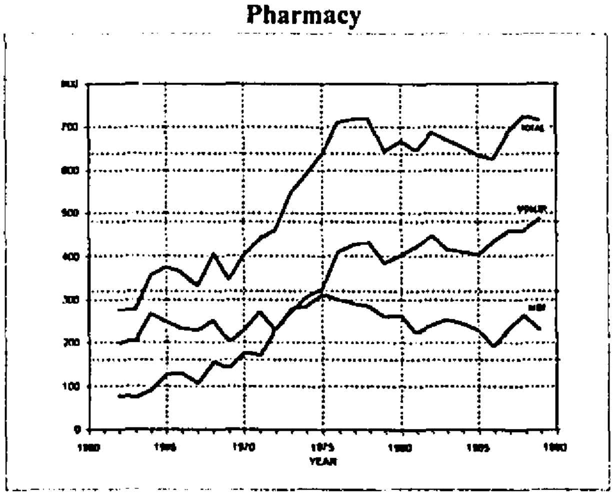


Fig. 12II

Veterinary Medicine

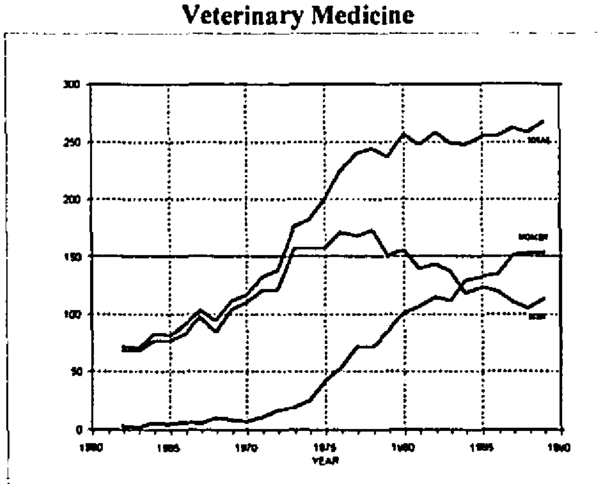


Fig. 12JJ

Law

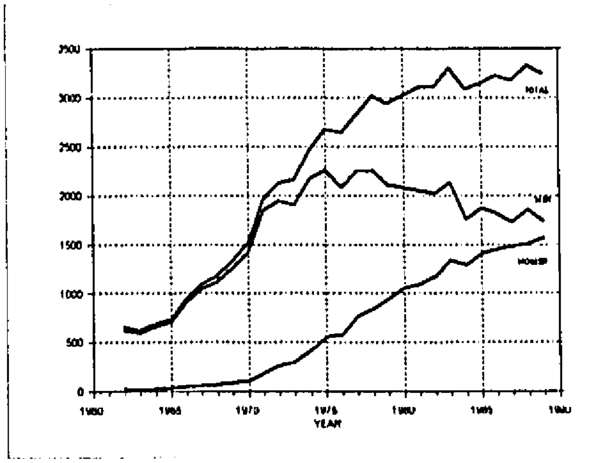


Fig. 12KK

Architecture

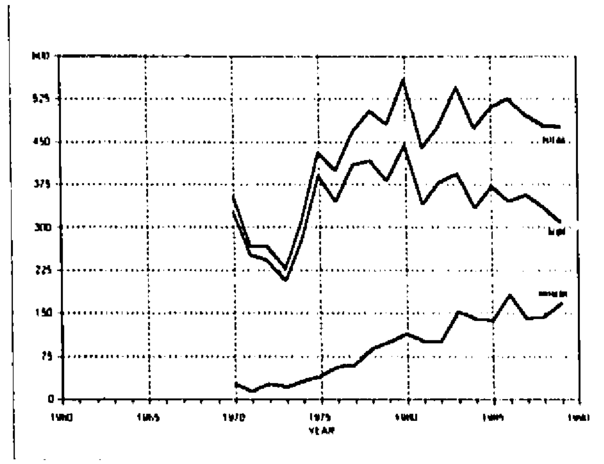


Fig. 12LL