

**Defining Equity Indicators for Benchmarking Women's Participation in Science and Engineering
Faculties across Canada**

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This paper demonstrates the use of national and regional data sets to address the multidimensional question of equity for women in Canadian science and engineering faculties. Unbalanced representation of women in science and engineering fields has been described as a “pipeline problem” reflecting both insufficient flow of women into science and engineering positions and leakage or attrition of women from the field. This research explores the problem by comparing male and female science and engineering faculty with respect to the following equity indicators: representation among full-time faculty at Canadian universities, financial compensation, recruitment into full-time faculty positions, career progress in terms of tenure and promotion, and attrition from full-time faculty positions.

The Natural Sciences and Engineering Research Council of Canada (NSERC) supports a program of five regional Chairs for Women in Science and Engineering (CWSE). The goal of the CWSE program is to increase the participation of women in science and engineering and to provide role models for women active in, and considering, careers in these fields. The regional CWSEs collaborate on research that supports our common interests, including increased representation of women in academic careers. We have undertaken this research project to develop equity measures and benchmarks by which Canadian universities can assess progress within their particular institutions. Ideally these benchmarks will be used as catalysts for institutional change. This paper adds to the field by providing previously unavailable information about women in science and engineering at Canadian universities. Additionally the case is made for extending this research using individual institutional surveys as a multi-pronged approach to addressing this social problem.

Background

There is evidence of improvements in the overall number of women who hold faculty positions in Canada; however a review of data for all disciplines combined shows that women continue to make up a smaller proportion of tenured or tenure-track positions, with representation decreasing as academic rank rises. Additionally, women continue to be under-represented in Engineering and Applied Sciences (12.3% of all full-time faculty in 2006-07) and Mathematics and Physical Sciences (15.8% in 2006-07) (Canadian Association of University Teachers, 2009; Sussman & Yssaad, 2005). There is evidence to suggest that systemic problems such as lack of research support and institutional policies and practices impact tenure and retention of women (Callister, 2006; Perna, 2005; Xu, 2008). Low representation of female faculty in science and engineering programs is problematic because, as locations of education and employment, universities play a pivotal role in attracting, training, and retraining women as professional scientists and engineers. Female faculty are important role models for women studying in science and engineering disciplines.

There may also be differing patterns of attrition from academic positions for men and women. A study from Ontario, Canada found that 77% of those who left academic positions across all disciplines were men; 78% were tenured or tenure-track, and the most frequent single reason for leaving was retirement (46%) (Council of Ontario Universities, 2002). This information is interesting for two reasons, the first is that higher proportional attrition by men (because they tend to be older and more advanced in their careers) combined with increased hiring of female faculty will help over time to achieve more balanced representation of men and women in faculty positions. The second point is that more than half of faculty (54%) left for non-retirement reasons. More information is needed to identify differences in

patterns and reasons for pre-retirement departures for men and women in science and engineering faculties.

The goal of this research is to create benchmarks to assess science and engineering academic climates in Canada. Our hope is that these benchmarks will provide necessary information to improve representation and retention of women faculty in science and engineering fields. This study expands on existing research and explores equity issues by comparing Canadian men's and women's experiences in science and engineering faculties with respect to representation, career progression, and retention or attrition.

Specifically this study will:

1. Compare male and female full-time faculty at Canadian universities by rank¹ and major discipline² within science and engineering in terms of representation, demographic characteristics (age), and equity measures (salary).
2. Compare recruitment into science and engineering faculties for men and women by describing doctoral graduates (the hiring pool) and new full-time faculty appointments to universities.
3. Compare career progress of men and women by describing tenure status and promotion timelines.
4. Compare attrition of men and women from science and engineering faculty positions.

Methods

This study employs two Canadian national data sets to obtain information about women's representation in science and engineering faculties across Canada: the Survey of Earned Doctorates (SED 2003-05, 2004-5, and 2006-07) and the University and College Academic Staff System (UCASS 2004-5, 2005-6, and 2006-7). Both surveys are conducted and owned by Statistics Canada, Canada's national statistics agency. Additionally, summaries of the UCASS data provided by the Canadian Association of University Teachers (CAUT) provided historical data for comparison.

The Survey of Earned Doctorates is an annual questionnaire given to all graduates earning a doctorate degree in one of the academic institutions granting doctorates throughout Canada. The survey collects data about graduates' field of study, their funding sources while studying, and their immediate postgraduate plans (Statistics Canada, 2009). The response rate varies from year to year but is approximately 55 to 60%.

UCASS provides annual information on the number and socio-economic characteristics of full-time faculty in degree-granting institutions in Canada. Institutions (colleges and universities) submit information for each individual full-time teaching staff member employed by the institution as of October 1st of the academic year (Statistics Canada, 2009). Statistics Canada provides public access files of summarized UCASS data to educational institutions, additionally the Canadian Association of University Teachers (CAUT) publishes an annual summary of UCASS data which is available online (<http://www.caut.ca/pages.asp?page=442>). In this study, research questions related to career progress and attrition were addressed with custom tables from the UCASS data requested from Statistics Canada.

There are limitations to using these data sources. All variables and in some cases full data were not publicly available for all of the years between 2000 and 2007. UCASS data provides information about individuals at their current institution of employment. While it is technically possible to combine files to obtain longitudinal data, analyses of this sort were beyond the scope of this study. UCASS data accuracy

¹ Full, associate and assistant professors and instructors below the rank of assistant professor with minimum 12 month contracts.

² 1 Agricultural and Biological Sciences, 2 Engineering and Applied Sciences, 3 Mathematics and Physical Sciences.

is dependent on individual institution's submissions to Statistics Canada. UCASS data is also rounded for counts of three or less which may impact on some analyses (e.g., attrition from specific disciplines).

The CWSE for Quebec has completed two related studies based on regional data sources: a longitudinal statistical analysis of data from the Quebec Ministry of Education, Recreation and Sports for undergraduate and graduate students (Boiteau & Ghazzali, 2008) and a study of CREPUQ³ data for academic staff in science and engineering faculties in Quebec universities for the period 1997-2007 (Émond & Ghazzali, 2009). Data from both regional studies is included for comparison with national data from Statistics Canada. In the Quebec-based studies, the major disciplines were defined as Engineering, Applied Sciences⁴ and Pure Sciences.

Results

Representation of Women in Science and Engineering

Despite improvement over the last several years, women continue to be under-represented as teaching faculty in mathematics, science, and engineering fields (see Figure 1). Women are slowly moving into higher academic ranks however they are still better represented at the assistant professor and "other" (other includes instructors with a minimum 12 month contract and visiting faculty) categories than as associate or full professors.

- In 2005-06 women made up 33% of all full-time faculty across disciplines, an increase from 29% in 2000-01.
- Under-representation of women was particularly evident in Engineering and Applied Sciences where only 12% were women and in Mathematics and Physical Sciences where 16% were women in 2005-06. In Quebec universities, the proportion of women academic staff in engineering disciplines increased from 6.9% in 1997 to 10.8%, in 2007.
- There are significant differences in rank by gender in all major disciplines in science and engineering [Chi Square significant at $p < 0.001$ for all major disciplines]. Almost half of male faculty members are full professors (49% in Agricultural and Biological Sciences, 44% in Engineering and Applied Sciences, and 47% in Mathematics and Physical Sciences). The proportions of women in these disciplines who are full professors are closer to one quarter (31%, 26%, and 27%, respectively).

Profile of Male and Female Faculty in Science and Engineering

Female faculty in mathematics, science, and engineering fields are younger and of lower ranks than their male counterparts, which, in part, accounts for receipt of lower salaries. However salary differences are still noted at the full professor level.

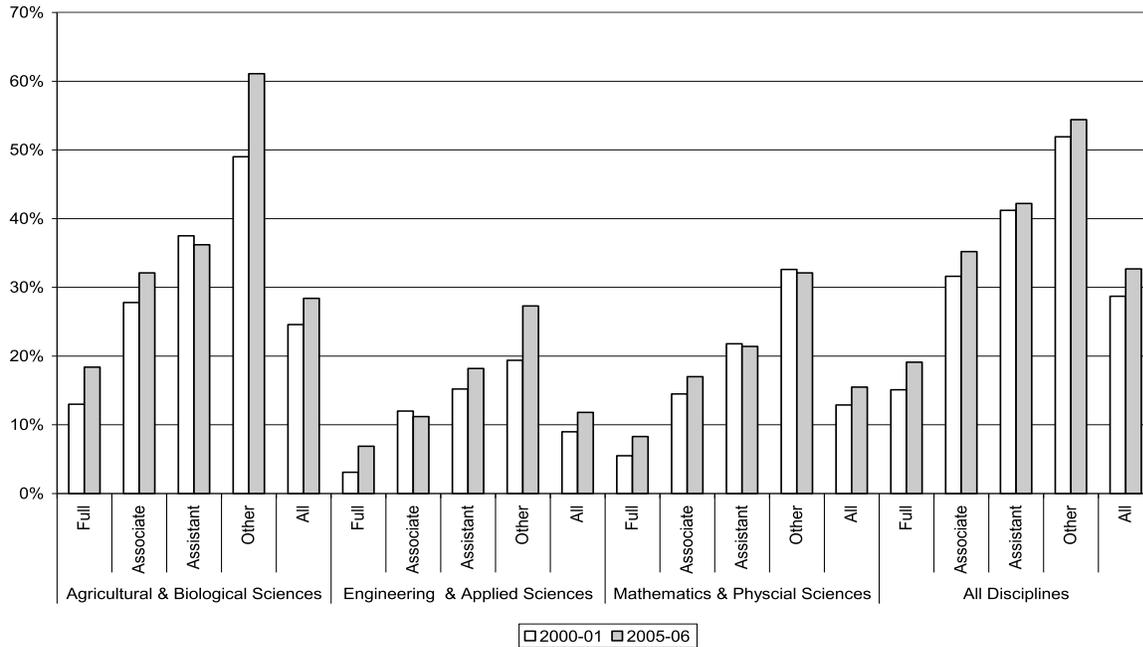
- Overall, female faculty members are younger than male faculty. In the 2006-07 academic year, the median age of male faculty in Agricultural and Biological Sciences was 50 compared to 46 for women, in Engineering and Applied Sciences median male age was 47 compared to 44 for women, and in Mathematics and Physical Sciences median age for male faculty was 48 compared to 43 for women. Age discrepancy is most apparent at the full professor rank.

³ Conférence des recteurs et principaux des universités du Québec

⁴ Quebec Ministry of Education, Recreation and Sports defines Applied Sciences as agriculture, land resource science, crop science, animal science, architecture, landscape architecture, urban architecture, industrial design, environmental sciences, natural resources, surveying, soil science, computer and information science, food science and technology, human kinetics and urban planning.

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Figure 1: Women as a percent of faculty by major discipline and rank 2000-01 and 2005-06



Source: UCASS 2000-01 and 2005-06

- Representation in age categories is significantly related to gender for all major disciplines [Chi Square significant at $p < 0.001$ for all major disciplines]. Women are over-represented in the 25-44 years category and under-represented in the 60+ years category (UCASS 2006-07).
- Overall, in 2005-06 female faculty members in mathematics, science and engineering earned between 87% and 90% of men's salaries. A large part of this discrepancy is related to the higher concentration of women at lower academic ranks than men. Even so, greater earning gaps are evident at the full professor level than at lower ranks. In 2005-06, female full professors in Engineering and Applied Sciences earned 92.3% of their male counterparts and female full professors in Mathematics and Physical Sciences, earned 93% of a man's salary. It is important to note that full professor positions can span many years and that earning discrepancies may reflect female full professors at earlier stages in their careers.
- For the province of Quebec in 2007, female professors in Engineering, Applied Sciences and Pure Sciences earned respectively 91.66%, 91.76% and 90.10% of men's salaries and the largest gaps were at the full professor rank.

Increased Representation through Recruitment and Hiring

Women continue to be under-represented both as graduate students and new faculty appointments in science and engineering disciplines. This suggests ongoing challenges to attract and retain female graduate students. It also suggests that relying on affirmative hiring practices alone may not be sufficient to balance historic inequities.

- In all disciplines combined, the proportion of all new faculty appointments who are women increased between 2000-01 and 2005-06 by four percentage points from 37% to 41%.
- The proportion of new full-time Engineering and Applied Sciences faculty appointments who were female more than doubled between 2000-01 and 2005-06 from 10% to 22%; however the proportion fell to 13% in 2006-07. There was also a significant decline in the representation of women as new appointments in Agricultural and Biological Sciences in 2006-07. Across all major

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disciplines in science and engineering, the levels still fell well below representation for all disciplines (41%)

The Hiring Pool: Graduates from Science and Engineering

The proportion of women in all doctoral programs has been increasing steadily in the last decade. Recent doctoral graduates form the hiring pool for new faculty appointments. Therefore, it is useful to consider the numbers of women who graduate from mathematics, science, and engineering programs in relation to the number of new faculty hired. Women remain a relatively small proportion of doctoral graduates in Engineering and in Computer Science and Mathematics disciplines. While women comprised 44.3% of doctoral graduates from all fields of study combined in 2006-07, they were under-represented as a proportion of 2006-07 doctoral graduates in Engineering (17%), Computer Science and Mathematics (24%), and Physical Sciences (34%). A similar situation was observed in Quebec and detailed statistics are available on the website for the CWSE for the Quebec region (www.chaire-crsng-inal.fsg.ulaval.ca/recherches/statistiques).

- Women graduate from Science and Engineering doctoral programs at the same or a younger age than men but may take slightly longer to complete their degrees.
- No significant differences were noted in the time from receiving a Ph.D. to hire at assistant rank for men and women. However there were discipline differences: the mean time for Engineering and Applied Sciences was 3 years compared to 5 years for Agricultural and Biological Sciences.
- The proportion of doctorates earned by women is compared with the proportion of new faculty appointments to women from 2004 to 2007 (see Table 1). Using the three-year average as a benchmark, hiring in Engineering and Applied Sciences was somewhat higher than the proportion of women in the pool of recent earned doctorates whereas hirings in Agricultural and Biological as well as Physical Sciences were somewhat lower than representation in their respective pools.
- The decline in the percentages of new faculty appointments awarded to women in 2006-2007 is alarming across all science and engineering disciplines. In terms of absolute numbers, 48 women were appointed as faculty members in Engineering and Applied Science in 2004-2005 compared to 21 women in 2006-2007.

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Table 1: Women as a percentage of new doctorates and new faculty appointments

Women as a percent of new faculty appointments	2003-2004 2004-2005 2005-2006 2006-2007				3 year average
	Agricultural and Biological Sciences		32.7%	37.0%	29.8%
Engineering and Applied Sciences		21.3%	22.4%	13.0%	19.2%
Computer Science and Mathematics		23.1%	26.8%	21.0%	23.7%
Physical Sciences		17.9%	22.4%	20.4%	20.1%
All Disciplines		39.4%	41.0%	40.6%	40.3%

Women as a percent of earned doctorates	2003-2004 2004-2005 2005-2006 2006-2007			
	Agricultural Sciences	33.8%	39.6%	
Engineering	15.2%	15.5%		16.8%
Computer Science and Mathematics	20.2%	30.0%		23.7%
Physical Sciences	22.9%	28.7%		34.4%
All Disciplines				44.3%

Sources: CAUT Almanac 2007-2008, 2008-2009, 2009-2010 and SED 2003-04, 2004-05 and 2006-07

Career Progress

Investigation of career progress is at a preliminary stage because information in the UCASS database is limited to the current institution of employment and thus does not capture an entire career for a faculty member who moves between institutions. As an initial indicator of career progress, we analysed three specific time periods: number of years from time of hire to promotion to associate professor, number of years from time of hire to promotion to full professor and, for the 2006-2007 cohort of assistant professors, number of years spent at current rank. Few differences were seen in time from hire to promotion between women and men. Differences were noted in tenure status, women were more likely to be untenured compared to men.

- Differences in time from hire to promotion to **associate professor** are seen at the $p < 0.05$ level only in the Agricultural and Biological Sciences with women appearing to take longer to receive promotion to associate professor compared to men (UCASS, 2006-07). In many institutions, promotion to associate professor coincides with the granting of tenure.
- Differences in time from hire to promotion to **full professor** are seen at the $p < 0.05$ level only in the Agricultural and Biological Sciences and in Mathematics and Physical Sciences with women under-represented in the 0-4 year category and over-represented in the 10-14 year category. Women in Engineering and Applied Sciences did not take significantly longer to be promoted to full professor compared to men (UCASS, 2006-07). Ornstein *et al* (2007) reported gender differences in median times for promotion to full professor based on a longitudinal study of Canadian institutions from 1984 to 1999. For women as compared to men, median times were 1.30 years longer in Biological Science, 1.10 years longer in Science, 0.11 years longer in Mathematics and 0.87 years longer in Engineering.

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- There is a relationship between gender and time spent at the current institution at the assistant professor rank at the $p < 0.05$ level only for Agricultural and Biological Sciences. Women are under-represented in the 0-2 years category and over-represented in the 8+ years category (UCASS, 2006-07).
- There is a significant relationship between type of appointment (i.e., tenured, leading to tenure and other types) and gender for all major disciplines. “Other” types of appointment include those that are visiting, contractually limited or indefinite terms. Women are under-represented as tenured faculty and over-represented in the “leading to tenure” and “other” types of appointment (UCASS, 2006-07).

Attrition from Academic Positions

The UCASS database no longer tracks the “Year of termination” for academic appointments so we estimated the number of leavers by comparing institutional records for the last two academic years (2005-06 and 2006-07). The numbers of “leavers” (see definition at bottom of Table 2) were analysed by gender, rank and major discipline.

- Numbers of faculty members who left their current institution in 2006-07 were significantly related to academic rank and gender for all major disciplines. In Table 2, the data are normalized by the total number in each rank/gender category; major disciplines in science and engineering are compared to all other disciplines. Of concern are the higher attrition rates for females at the assistant professor rank for Agricultural and Biological Sciences as well as Mathematics and the Physical Sciences. Recognizing that these observations are based on one year of data only, further investigation is needed to determine if these differences continue over time and to better understand the reasons for leaving an institution.
- Note that small cell sizes for women “leavers” in the Engineering and Applied Science discipline mean that comparisons in this discipline are made with caution.

Table 2: 2006-2007 Leavers¹ by Rank, Gender and Discipline (% of total number in rank/gender category)

Discipline	Full Professor		Associate		Assistant	
	Male	Female	Male	Female	Male	Female
Agricultural and Biological Sciences	6.69%	6.17%	8.78%	11.22%	4.61%	12.50%
Engineering and Applied Sciences	4.89%	0.00%	4.82%	2.27%	3.46%	5.45%
Mathematics and the Physical Sciences	7.88%	7.94%	8.40%	7.14%	7.23%	8.99%
All other disciplines	6.72%	5.84%	6.72%	7.70%	6.80%	8.23%

¹Leavers are staff who were employed at an institution in 2005-2006 and were not employed at this institution in 2006-07

Conclusions

Modest increases in the representation of women in Engineering and Applied Sciences and Mathematics and Physical Sciences have been realized over the last decade in Canadian universities. However, slow growth from an initial small number means that women are still drastically under-represented in these fields especially at higher academic ranks. Recognising that women are under-represented as a percentage of earned doctorates in Engineering and in Computer Science and Mathematics, the regional CWSEs offer a number of programs at national and regional levels to support women in graduate programs in science and engineering and to encourage doctoral students to consider academic careers. The decline in representation of women as new appointments in 2006-07 raises an alarm bell because it reduces the rate of a significant change process from slow to a snail’s pace. Finally, while beneficial, programs focused on equitable hiring practices may not be sufficient to build representation.

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Analyses of available data do not give a complete picture of career paths for men and women in mathematics, science, and engineering careers. Information derived from national and regional data sets is useful to provide information about representation of full-time and newly appointed faculty. However, Statistics Canada data sets do not provide information about the nuances of career paths of men and women. For example, time from hire to promotion is used as a proxy for career progress but does not capture time spent at other institutions, and may not accurately account for parental leaves, or reduced employment agreements. Additionally, in 2006-07 for certain science disciplines, a larger proportion of women were found to leave academic positions at the assistant professor rank compared to men, which suggests that there may be a problem with retention of female faculty. Further investigation is needed to understand the reasons for these departures, how career paths may differ between men and women and how women can be supported in this process.

The regional CWSEs wish to address the need for more comprehensive assessment of hiring practices and career progress of men and women in mathematics, science, and engineering disciplines at Canadian institutions. We recognize that this requires cooperation with individual institutions in order to obtain information about efforts to recruit, and about hiring practices and career progress (tenure and promotion). A few Canadian institutions and progressive faculties have started to conduct working climate and gender equity self-studies (e.g. Armour, 2008; Joldersma, 2005; Kuske *et al.*, 2008). Furthermore most Canadian universities comply with the Federal Contractors Program⁵ which requires a written commitment to an employment equity plan as a condition for bidding on contracts with the federal government, including funding from the national research councils. As evidence of their commitment, a number of institutions produce public reports on workforce representation but aggregate their data across all academic staff so it is not possible to extract discipline-specific information. We propose to work with some progressive faculties and institutions to gather equity indicators for major disciplines within science and engineering. The intent is not to identify individual institutions but to amalgamate the findings to provide national level information about the processes of hiring and promotion for men and women in science and engineering faculties. The research questions to be addressed with this follow-up study include:

- With respect to the hiring process for major disciplines in science and engineering:
 - What percent of annual new appointments are women?
 - What percent of applicants for faculty positions are women?
 - What percent of short-listed applicants are women?
 - What are institutional policies on partner hires?
- With respect to the tenure and promotion process for major disciplines in science and engineering:
 - What is the time from appointment to the institution to achieving tenure for men and women?
 - What percent of men and women who are eligible to apply for tenure receive tenure?
 - To what degree do men and women make use of academic and employment leaves and extended tenure clocks?

A sound strategy to improve the representation of women in science and engineering requires attracting and retaining women at all levels of academia from graduate programs to hiring of new faculty and to achieving tenure and promotions. This research aims to develop equity measures and benchmarks by which institutions can assess their progress toward equity for female students and faculty members.

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⁵ The Federal Contractors Program was initiated by a Cabinet Decision in 1986 and applies to provincially regulated employers which receive federal government goods or services contracts of \$200,000 or more.

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Engineering – British Columbia and Yukon region from 2004 to 2009. Anne was a key contributor to the national network and she will continue to collaborate on this project in her role as Associate Dean, Faculty Affairs and Strategic Initiatives for the Faculty of Science, University of British Columbia.

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