FEEDBACK LOOPS AND CRITICAL MASS: THE FLOW OF WOMEN INTO SCIENCE AND ENGINEERING

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CURRENT MASS AND CRITICAL MASS. After more than a decade of active promotion in Canada of women in science, technology, engineering, and mathematics (STEM), the persistently low ratios of women in some sectors and institutions indicate the need for a fresh analysis of the processes and mechanisms. The analysis in this paper, carried out with an engineering perspective, considers a mass flow process acted upon by two feedback loops.

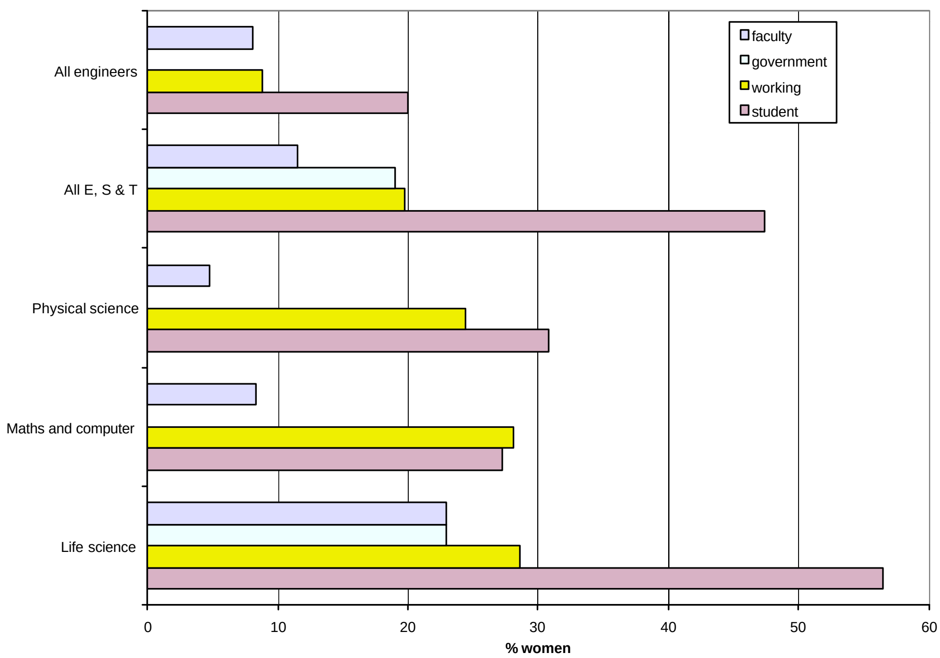


Figure 1: Average ratios of women in STEM in Canada, undergraduate university students, in the workplace, and university faculty.

Figure 1 shows Canadian data on the participation of women in representative sectors. The ratios here and throughout this paper refer to the number of women divided by the total number in the group, expressed as a percentage. Throughout Canada, as in other countries, the highest ratios are in the life sciences and at the undergraduate level; the lowest ratios are in engineering and computer science, and in university faculties.

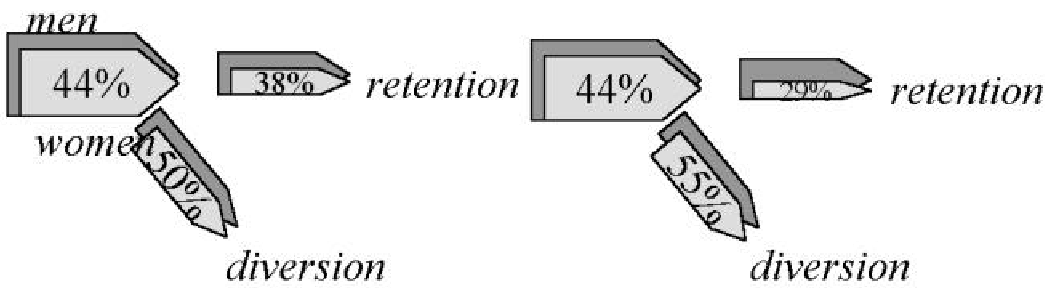
An objective of increasing the participation of women in STEM should be specific. Allowing for a dynamic diversity of interest, ability, and opportunity over time, culture, and sector, what proportion of women is enough to meet the objective? One is not enough. A token representation in any situation fails to achieve any of the benefits of gender diversity. At best, it results in an isolated individual habitually identified by her gender, a characteristic which not in her job description. At worst, it results in a skewing of the gender patterns and assumptions held by the organization towards the characteristics of one individual.

Valian [1] calls these gender patterns ‘gender schemas,’ and defines them as a set of implicit and unconscious hypotheses about sex differences which all of us (women and men) share, and which play a central role in our expectations of men and women and our evaluations of their work. Valian reports that gender schemas will fade and women will be more fairly evaluated if women are at least 25% of the group.

The benefits of diversity will not engage until women’s ideas are consistently brought forward and women’s interests are considered normal. A simple calculation shows that if 33% of any group are women, then whenever two or more of that group work together, there is a 0.5 probability that at least one will be a woman.

The 33% level has been proposed by other authors, citing a variety of reasons, as the level at which the behaviour of the group accommodates fairly the differences of the minority [2], and the point at which non-traditional work becomes the tradition. For university faculty, Etzkowitz [3] said that the discrete point at which change is accelerated is at least 15%, but then observed that the desired change may be impeded by a bifurcation of views among the women faculty. Hence we adopt 33% as the ‘critical mass’, or proportional representation which meets the objective.

MASS FLOW. Having set 'critical mass' as an objective, this paper uses, instead of the frequently cited pipeline, a mass flow analogy. At any stage in the flow, there are processes which either conserve mass, or divert it to some other form. Mass conservation, in human resource terms, is retention. Mass diversion may be positive for the process it feeds, but is considered a loss for the STEM workforce. Figure 2a illustrates how small differences in diversion rates for men and women can have a significant effect on ratios. The widths of the block arrows represent relative numbers of men and women. In the first pair of arrows, women comprise 44% of the total. This pair could represent the group of students leaving high school with the qualifications to begin a university science or engineering degree program. These students have other options. They might choose some other university program, or the workplace. These are all positive choices, made by about half the students, and taken equally by women and men. The pair of block arrows representing diversion shows 50% women. In the retained group, women now comprise 38% of the total. Figure 2b is similar to Figure 2a, but with a slightly higher ratio for women diverting, 55%. In the retained group, women are now 29%, below critical mass.



These simplified examples illustrate two important properties of the process which produces the qualified workforce. First, if women are a minority ratio in the input, and if the diversions are gender neutral, then women are a smaller ratio in the output. Second, if women are more than 50% of the diversions, then the ratio of women in the retained group diminishes drastically.

Studies for many different groups where women are a minority, for example university students [4], university faculty [5], and the federal government science and engineering workers [6], show that even when the gender differences in experience were small, the ratio of women among the diversions (departures) was higher than their representation in the population. The higher ratio suggests biased reasons for women's departure. Unless the total population is expanding, with gender balanced intake, it is extremely difficult, with biased departure rates, to increase the ratios of women.

Human resource planners have tended to explain the low ratios of women in STEM as a ‘cohort effect’. The implication is that the ratios we currently see in undergraduate enrollments, 45% to 55%, depending on how the population is defined, will advance, and ratios in the workplace right up to senior levels will self correct once the current cohort of undergraduates arrives. The mass flow analysis explains the evident contradiction between the cohort effect and the enduring low ratios in the workplace, even after a decade of active promotion in Canada of women in STEM.

THE ROLE OF THE UNIVERSITY IN DIVERSIONS. Research on retention of women in STEM has shown that the decision factors evolve as the career progresses. In secondary school, there are small but consistent gender differences in the reasons for selecting, or not selecting, post-secondary education in STEM [7-9]. In the workforce, differences in job satisfaction for women and men vary with organization and culture of the workplace. Where there is a gender difference in the measures of job satisfaction, there is also a gender difference in the complement, that is the diversion rate.

At the university undergraduate level, teaching styles, subject matter relevance, and the culture of the discipline are diversion influences with gender bias [10, 11]. Extensive research on the culture of academic science demonstrates its persistence [12] and its bias against women [13]. The unique role of the university is that it sits on the supply line for its own workers, and for those of many other organizations.

TRADITIONS, SCHEMAS, AND NEW TRADITIONS. In a culture where there is a consistent gender correlation with certain roles, gender schemas will not change unless the individuals in that society gain credible experience with countervailing schemas, or until the individuals involved are brought to explicit awareness of the schemas they hold and how they invoke them [1]. The first mechanism requires a critical mass in the alternate gender roles. The second requires strong leadership, sensitivity, and organization-wide commitment.

Traditions are like schemas: they are ways of thinking or acting which have been useful to an organization in the past, which are self-reinforcing, and which will persist unless an outside influence, such as market forces or performance requirements, push the organization to new ways of thinking and acting. Traditions are not a priori based on gender, but may have gender implications.

In the dynamic economy of the past decade, information-based organizations in the science and technology sector have formed, transformed, and grown at a rapid pace. The forces propelling change are the complexity and volume of information, the rewards of innovation, the evaluation by investors, and the supply of skilled and talented workers. For these rapidly evolving organizations, all traditions are new. The demand for skilled and talented workers has provided rich opportunities for women in science and technology. At the same time, the bottom line benefits of diversity in innovation capacity and in market sensitivity have propelled organizations to place high value on qualified women. The new traditions evolving in response to these pressures are more fair to women. Not surprisingly, the representation of women in the new traditions organizations is relatively high.

The external forces have affected established organizations, to greater or lesser degree. Those which are making a conscious effort to increase their workforce diversity might be termed emerging workplaces. They include: Oil and Gas, Utilities, Technical Service and Financial Service. Internal change results when there is clear leadership, discriminating traditions are identified, managers are trained to recognize them, and there is targeted hiring to achieve critical mass. The representation of women in the emerging organizations is increasing, at a rate regulated by the organizational commitment.

The organizations which are least likely to change might be termed traditional institutions. They have a respected history, protected revenue stream, and internal performance standards and evaluations, and consequently are shielded from external forces. Examples are universities and government institutions. Figure 1 confirms that these organizations have relatively low representation of women.

CONCLUSIONS. A minority ratio of women in an area of STEM is sensitive to diversion, and hence tends to further diminish as the cohort advances through a career. The university experience has a strong influence on career decisions. Some university traditions are biased against women's participation in STEM, and hence universities continue to restrict the supply of women to STEM careers. Traditional institutions such as the university will not change spontaneously. Strong leadership and external pressures are required to achieve change in the university. Otherwise the efforts to achieve critical mass of women in many sectors of STEM will continue to fall short.

Every institution is accountable somewhere for its actions and its budget. The political, business, or academic leaders to whom an institution is accountable are the ultimate agents of influence. They can set diversity objectives for an organization, monitor progress, and specify the consequences of meeting or not meeting the objectives. They must also put in place processes and resources to achieve the objectives. Then diversity becomes a performance standard, for units and for individual managers. Effective leaders will present the objectives with a rationale and a commitment to success which reorients organization thinking and opens the way for viable new traditions.

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