$$\Theta_{\text{Tot-}k}(j) = \frac{\sum_{i=1}^{n_j} PQCn_{ik}\,\text{Add}_{ik}}{\sum_{i=1}^{n_j} \text{Add}_{ik}},$$

where $\Theta_{\text{Tot-}k}(j)$ is the publication intensity in disciplinary area j of university k; $PQCn_{ik}$ the publication intensity of university k in scientific discipline i (within area j), normalized to the average scientific discipline publication intensity in all of the universities; Add_{ik} the number of research staff associated with scientific discipline i (within area j) of university k and n_j the number of scientific disciplines encompassed in area j.

12. Because research activities are multi-input and multi-output, efficiency measures should take into account these characteristics. More appropriate parametric and non-parametric techniques to measure research efficiency have been developed and applied, and can be found in the relevant literature.
13. OECD, Main Science and Technology Indicators 2006/1 and EC, Key Figures 2005.
14. Not knowing the number of public sector publications of the other countries of the comparator group.
15. Dosi, G., Llerema, P. and Sylos Labini, M., *Res. Policy*, 2006, **35**, 1450–1464.
16. In Italy, for example, researchers in the government research laboratories are not grouped into scientific disciplines, unlike those in the universities.

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How critical is critical mass? Implications of the minority status of women in science in India

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A low representation of women in science is considered a serious limitation when the numbers fail to reach a 'critical mass'. In 1986, the physicist Dresselhaus suggested that women experience lower career obstacles once their numbers reach 10–15% of a particular group. Since then, the concept has been extensively used to analyse the effect of a skewed gender ratio on women in science. Attainment of critical mass has the potential to minimize socialization difficulties[1], to influence policy-making, tenure decisions[2], and to diminish the role of the 'gender schemas'[3].

Though there has been tremendous increase in the enrolment of women at all levels since independence, figures on women's education indicate their under-representation in science education. The proportion of girls increases from graduation (39.0%) to postgraduation in science (42.5%), and then declines again from postgraduation to Ph D (37.2%)[4].

The enrolment of women is greater in fields that have a higher job potential. However, women continue to be heavily under-represented in engineering. Two problems that remain despite increase in enrolment are: (a) fall in enrolment of women in undergraduate science and engineering in prestigious institutes, and (b) increase in enrolment not being reflected in careers in science and engineering.

According to the report[5] on the Joint Entrance Examination (JEE) 2004 for the IITs, only 14% of the registered candidates were girls, although university enrolment of women in science[4] in 2000–01 was 39.4%. Of the total number of the candidates who qualified in JEE 2004, only 7.03% (nearly 350) were girls[5].

While entry into science streams is encouraged, sending their girls to elite institutes is a matter of debate for parents. A science degree is seen to enhance the 'marriage value' and make women better mothers as it is considered useful for them to later teach their children at home[4]. However, sending girls to prestigious institutes entails sending them to another city to reside in hostels. Social dangers perceived in travelling and studying in an overwhelmingly male institute deter parents from sending girls to prestigious institutes[6]. Coupled with this is the fact that entry into such institutes requires expensive coaching and parents are less willing to expend resources in educating girls than educating boys, because benefits of education are seen to accrue to the husband's family in our 'patrifocal' society. The social system lowers the expectations of parents towards their daughters compared to their sons. A recent study[7] has shown that expectations from boys are in terms of professional career advancement, while girls are expected to use their education to become 'independent'. About 40% women scholars reported that their parents wanted them to be 'independent' and only about 22% male scholars reported similar expectations. About 61% male respondents reported that their parents wanted them to be 'highly successful' in their careers.

While the critical mass of women is lacking in the top institutes, it is also lacking at the level of research and faculty. The number of women faculty in science and engineering is a miniscule 7% at prestigious institutes[4,8] such as IISc, Bangalore and the IITs. The proportion of women in the national laboratories and prestigious universities is less than 15%, except in institutes related to biotechnology and medical research[4], where the percentage exceeds 25. These figures when compared with 42.5% women at the postgraduate level and 37.2% at the doctorate level, clearly show attrition from science education to science careers.

While the proportion of women in engineering education continues to be low, the existing pool of women engineers is not translated into a national resource. Parikh and Sukhatme[9] found about 30% unemployment among women engineers, and that gender bias in the process of selection limits the job prospects for women engineers.

In most organizations, including academia, women engineers are lacking at the decision-making level. In the elite science

and technology institutes, there are no women deans and few women on committees at the institute level[8]. A break in career for women due to family reasons also implies losing out on career advancement. Several problems related to women in doctoral research and to faculty in science disciplines are similar to those in engineering disciplines. Some of these problems are discussed below.

Based on a study of research students at two IITs[7], it was observed that women doctoral students get lesser help than their male counterparts in most of the departments. This is due to lack of women colleagues and lack of interaction between men and women researchers. This lack of interaction is due to both 'tokenism'[10] and traditional stereotypes. Female doctoral students, being tokens, are treated as social out-groups by their male colleagues. Since men are larger in number, they do not need the help of women. This coupled with gender-based groupings inhibits interaction between men and women researchers, which affects the capacity of the latter to acquire help in academic matters. Another effect of tokenism is 'heightened visibility'. Female students, being few, are also more easily noticed. Their performance is under constant scrutiny. Hence, many women scholars feel that they have to work harder than their male counterparts (and work in isolation) in order to gain acceptability into the system and to prove themselves[7].

Attainment of critical mass helps in providing a greater circle of women to rely upon for support and advice. As some women research scholars from both the institutes remarked, an increase in the number of women researchers will provide 'more interaction and discussion', and 'it will make men realize that women can work without difficulty and that they are as intelligent as men'. However, a large number of women in a department does not imply greater informal interaction between men and women scholars (mainly due to gender-based groupings).

Lack of interaction not only diminishes the help available to women researchers for academic purposes, it also affects exchange of extra-academic information (e.g. information about postdoctoral and job opportunities) and to establishment of contacts and networks. The example of women research scholars indicates that negative tokenism outcomes due to lack of critical mass cannot be understood in isolation. Gender status and gender stereotyping are essential ingredients in the research environment, which are intertwined with a lack of critical mass.

That lack of numbers alone is not responsible for obstacles in the professional growth of women in male-dominated professions is proved by the reverse results for men in female-dominated professions. For example, studies of male nurses and female physicians indicate that gender interacts with tokenism and results in more positive outcomes for men and more negative outcomes for women[11]. For many men, their token status works to their advantage in terms of hiring and promotions. As opposed to the 'glass ceiling' encountered by women – the set of invisible obstacles that prevents women from moving up in a company, many men in female-dominated occupations encounter a 'glass escalator' – invisible pressures to move up in their professions[12].

Absence of critical mass becomes particularly significant when it is studied along with gender stereotypes. Stereotypical assumptions about what tokens (women) 'must be like' seem to conflict with the notion of a 'scientist'. In the study on women faculty[8,13] many respondents remarked that their colleagues expect them to be submissive (a common expectation from women as a part of the patrifocal ideology); women who speak out their minds or those who are assertive are not considered as 'normal'. The social belief that women should look after the house, and career should be secondary was brought out in several ways by the respondents.

While women faculty lack critical mass in an institute and hence may not have a group of women colleagues, they usually lack interaction with the male faculty of the institute and thereby lack contacts compared to male faculty. Women also travel less and have less time for informal interactions with professionals within and outside the institute. A lack of interactions leads to a lack of social capital, which is essential to obtain professional information, to form networks and collaborations, and to obtain visibility through contacts. In the absence of social capital, women are essentially isolated and depend exclusively on merit to obtain recognition[13].

The gendered evaluations of 'merit' add further to the problem of recognition of women scientists. Several women faculty members reported inequities in day-to-day aspects of their profession[8]. Becoming a fellow of the national science academies requires getting nominated and then elected. However, knowing the members of the decision-making committees personally is one of the unwritten factors in such operations[14]. Hence, it is not surprising that, in India, few women (only 6.7% between 1994 and 2004) are elected as fellows of science academies or receive awards open to both the sexes (e.g. Women Bhatnagar awardees form only 2.07% of the total). Further, there is no fixed criterion for being nominated to the prestigious advisory bodies constituted by the government[14]. Such subjective criteria leave the door open for bias and unfair nominations.

Thus, there are various issues intertwined with a lack of critical mass at all levels. Gender bias in the society affects the entry and progress of women in science. A science institute, though based on the principles of merit and rationality, is peopled by those who are a part of that society. Hence, biases infiltrate the institutes. In our patrifocal society, women continue to be under-represented, particularly in the field of engineering, and at higher levels of research and faculty positions in both science and engineering. Attaining a critical mass in these fields may increase the acceptability of women in the traditionally male domains and may help bring about a more women-friendly work environment.

While attitudes and gender stereotyping may take generations to change, measures could be taken up to attract more women towards a career in science and to address the concerns of women in science, so that they could utilize their potential fully. This is an important task because an efficient utilization of human resources is seen as the key to national development. Scientific knowledge is an essential ingredient for economic growth and development. In this context, nations, the world over, are vigorously pursuing the agenda of harnessing the available scientific talent. Women in science are considered to be one of the vital resources that cannot be allowed to go waste. In India, there is a similar concern, voiced by different government agencies. According to the National Resource Centre for Women, India has produced some outstanding women scientists, 'however, the number is not large enough, so efforts must be made to attract and retain women in the sciences'. Encouraging more women to take up careers in scientific research and development is one of the stated objectives of the government policy.

Indian scientists (men and women) themselves have launched efforts to unearth the issues facing women in science, to redress them and to bring greater representation of women in science. In January 2003, the Council of the Indian Academy of Sciences, Bangalore constituted a committee on 'Women in Science' to address the issue of women underrepresentation in science[15]. In 2004, the Indian National Science Academy, New Delhi brought out a report on women's access to and retention in a career in science[16]. Meetings and conferences have been held in collaboration with social scientists to discuss these issues and to come up with concrete solutions.

Various solutions have been proposed to attract and retain meritorious women, such as on-campus crèches and allocating funds to pay for the salary for replacement of a woman faculty who need to take a break for child-bearing and rearing. The logic for the above measures stems from the realization that if women scientists use their potential fully, it is also in the best interest of science. The Department of Science and Technology (DST), New Delhi has two schemes to encourage women to take up research after a break in career. The report of the Steering Committee on Science and Technology[17] proposes schemes for study and practice of science and engineering by women. It includes 'relocation fellowship' for women scientists who are forced to give up their jobs due to relocation of their husbands and families. However, this scheme seems to miss out those women who get married and migrate immediately after their Ph D. Married women scientists unable to find positions in the institutes where their husbands work, should be encouraged to pursue independent research through separate projects and grants through DST.

Universities should institute awards for meritorious women and Ph D scholars, and provide opportunities for them to attend conferences and seminars. The Steering Committee report mentions creation of a website for women scientists. However, there is a need to have a dedicated website which includes details not only on active women scientists, but also on women research scholars, so that mentoring and networking could develop among them.

Measures for enhancement of the status of women scientists taken up in other countries may be examined for India. For instance, as in many US schools, women and men faculty members joining the institute should be assigned to a senior faculty member who introduces them to the rules, informal norms and other faculty members. This will help women faculty members as they are often isolated in the overwhelming male environment. Another example is that of the revamped NIH (National Institutes of Health) Pioneer Award of the US, which demonstrates how a few small changes can make a significant difference in outcome. By simply changing the procedure, so that anyone can self-nominate and by ensuring a highly diverse selection committee, the number of women and minority winners went up to more than 50% from zero[18]. We can take lessons from these and make the system of awards to scientists more fair and credible by introducing self-nomination and appointing more than one independent committee to look at the applications for awards, with active and well-known researchers as members.

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