Women in science and technology: an Indian scenario

*Akanksha Swarup and Tuli Dey**

Historically, the presence of women in the fields of science, technology, engineering and mathematics (STEM) remains mostly marginal. Despite the infrastructural and financial support availed from the government and non-governmental bodies, under-representation of women in the field of education has not changed over the years. Also, no information about the current status of women in STEM is available in the public domain. In this article, we address this lack of information by collecting data from eminent institutions throughout India. The under-representation of women in the science and technology community is depicted, primarily highlighting the male-dominated technology-driven Indian institutions. The probable causes for such inequality need to be analysed and addressed for remedial purposes.

Keywords: Gender inequality, higher education, science and technology, women's participation.

WITH the emergence of 'rational thinking', ideas like 'freedom from religion', 'abolition of slavery', 'constitutional government' and 'equal rights to women' become central to the political debates during the 'Age of Enlightenment'. The period also known as the 'Century of Philosophy' started in the 1620s with the scientific revolution in Europe and paved the way for different political revolutions of the 18th and the 19th centuries[1]. With the advent of 19th century, the 'right to vote' movement was quickly followed by the 'rights to equal employment and education' for the women workforce. However, a brief glance at the higher education and employment history shows marginal participation of women, not just in India but throughout the world, with an example of women Nobel laureates (2.94%) in the field of science and technology (S&T) along with the Field's medal (1.66%) in mathematics. Such glaring inequity can be explained by many social prejudices and stereotypes, e.g. the age-old concept of 'women being the intellectually weaker section' is often purported by many socio-economical factors along with psychological stereotypes, such as gender stereotypes[2,3], gender stereotyping of subjects[4–6] and social stereotypes[7].

Historically, the draconian concept of assuming women as the intellectually inferior class was profoundly fostered throughout the world[8,9]. However, a brief analysis of the Indian history indicates that in early Vedic period (2000–1000 BC), women used to enjoy a prestigious status in science and education. For example, Gargi Vachaknavi[10,11], Lilavati[12], Maitreyi[13] were mentioned as experts in their respective fields. The trend of women suppression in India started with the onset of the late Vedic period (1000–600 BC)[14] and continued during the Mughal era and British rule. In Western civilization, prominent philosophers such as Aristotle were found to advocate the inferiority of women[15]. The documented history of Hypatia, the first female mathematician and astronomer of Alexandria, Egypt, has only survived till date[16]. These early concepts are further strengthened by Charles Darwin, in his treatise *The Descent of Man* and Francis Galton's, *The Father of Eugenics*[17]. The World War I changed the scene for women in scientific research and a small, but substantial number of women joined the laboratories and engaged in science[17]. India, however, under the rule of the East India Company, witnessed several social reformers such as Raja Ram Mohan Roy, Ishwarchandara Vidyasagar, Jyotiba Phule and his wife Savitribai Phule, struggling to propagate literacy of women. Inclusion of women in the mainstream education and workforce became more visible after independence. The concept of women empowerment had materialized in post-independent India. However, the complete absence of any substantial data in the public domain except a few lone observations[18], provides no support regarding the 'actual empowerment' of women in India. The present study was undertaken to understand the real scenario in terms of women's representation in eminent educational institutions throughout the country.

Result and discussion

In the present study, we observed the recruitment pattern of various prestigious and prominent Indian

Akanksha Swarup and Tuli Dey are in the Institute of Bioinformatics and Biotechnology, Savitribai Phule Pune University, Pune 411 007, India. *For correspondence. (e-mail: tulidey@unipune.ac.in)

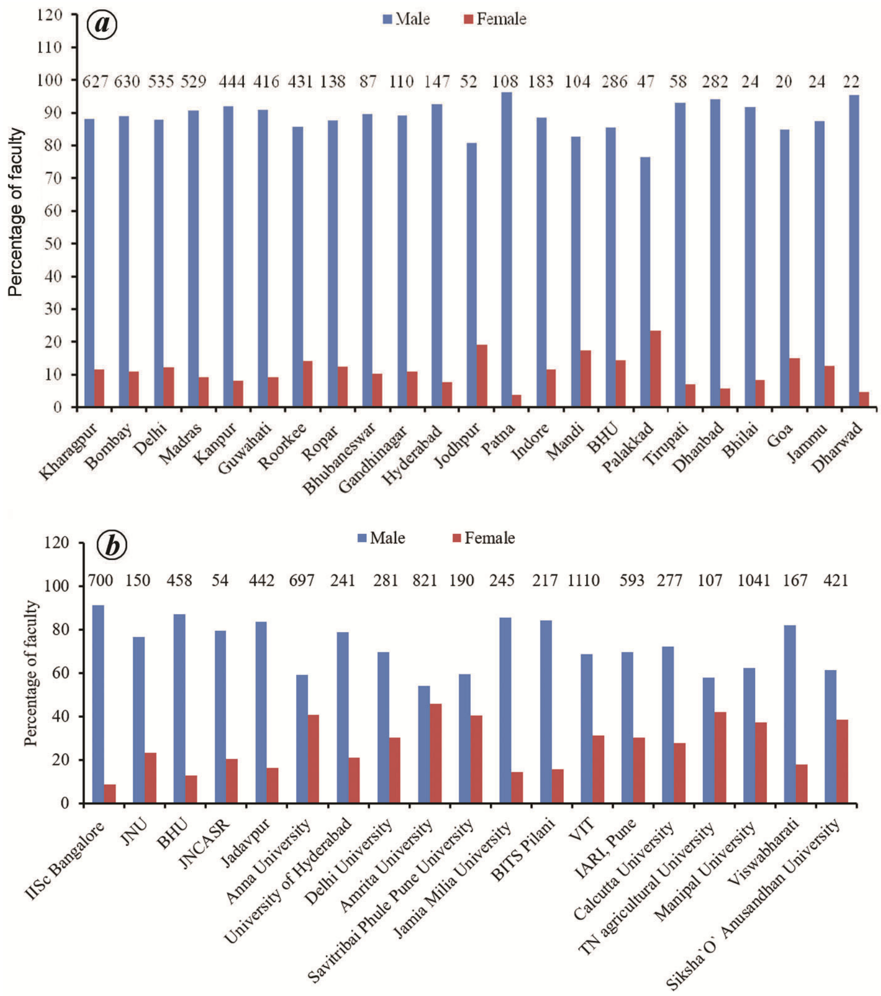

Figure 1. Comparative analysis of faculty distribution in the Indian Institutes of Technology (IITs) and universities in 2018. The situation in 23 IITs (***a***) and top 19 universities (***b***) is presented as percentage values. The *Y*-axis represents percentage of each gender and the figures above each bar exhibit the total number of faculty/scientists in the respective institution.

institutions/universities over the years. A comparative analysis of male and female faculty in the various science-related streams taking into account the major institute types in India was done to show the disparity in the numbers. These categories include – institutes of national importance (IITs, NITs, IISERs), universities and colleges (top 20 colleges of India according to NIRF rankings and the top 10 universities in the world according to the Times Higher Education Ranking), Council of Scientific and Industrial Research (CSIR) institutions such as Advanced Materials and Processes Research Institute (AMPRI), Centre for Cellular and Molecular Biology (CCMB), etc. and others (other institutions not covered in above categories, but making significant contributions to research). The reason for categorizing them in this manner is due to their different mandates. Assuming that a complete and successful scientific career might span over 25–30 years, we considered a group of faculty who had been recruited in 1988–90. Analysis of IITs, the most prominent engineering colleges in the country, showed the wide gap in gender equality (Figure 1 *a*) with the average number of women faculty being 11.24% (±4.65). The first group of seven IITs established between 1951 and 2001 showed an average of 10.74% women faculty in the S&T stream, followed by 11.6% in the second set (2008–09; eight IITs) and 11.33% in the third set (2012–16; eight IITs). It can be assumed that the dearth of qualified women candidates remained the same from 1951 to 2018. However, the profile of faculty in the top 20 universities of the country (Figure 1 *b*) differed significantly, as the average number of women faculty was 27.11% (±11.12). This can be probably explained by the fact that these universities handle teaching and research mostly related to basic sciences rather than technical subjects. Among the universities, Indian Institute of Sciences, Bengaluru was mostly male-dominated (with 8.6% female faculty), while Amritha Vishwa Vidyapeetham (45.8%) and Savitribai Phule Pune University, Pune (40.53%) stood out with most balanced distribution of gender within India. The NITs

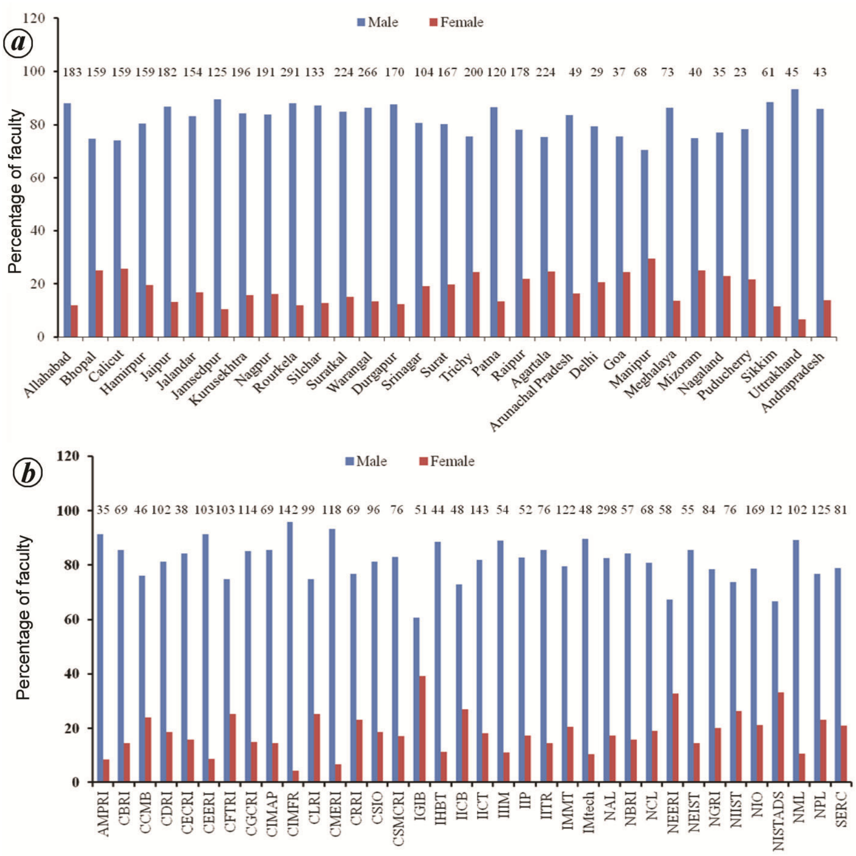

Figure 2. Faculty/scientist distribution in the National Institutes of Technology (NITs) and Council of Scientific and Industrial Research (CSIR) institutions during 2018. Gender distribution in 31 NITs (***a***) and 36 CSIR institutes (***b***) is presented as percentage. The *Y*-axis represents percentage of each gender and the figures above each bar exhibit the total number of faculty/scientists in the respective institution.

showed an average of 17.75% (±5.65) women faculty, with NIT Uttrakhand having the lowest (6.67) and NIT Manipur having the highest percentage (29.41) of women faculty (Figure 2 *a*). CSIR had 4600 active scientists, of which only 18.48% (±7.62) were women (Figure 2 *b*). The gender-wise distribution in IISERs throughout the country was 15.47% (± 6.50; female) and 84.52% (male; Figure 3 *a*), which is comparable to IITs and NITs. Different research institutions (mainly focused on biological sciences), such as National Centre for Biological Sciences (NCBS), Institute of Life Sciences (ILS), Indian Institute of Chemical Biology (IICB), etc. exhibited a similar profile with 23.12% (±9.74) women scientists compared to 77.49% (±8.88) male scientists (Figure 3 *b*). Thus it is clear that irrespective of the year of establishment, eminence and geographical distribution, all research and teaching institutions in India show a similar pattern in employing women faculty/researchers (merely 10–20% of the total strength), with very few exceptions. The distribution of women scientists/faculty among the top ten ranked institutions throughout world showed an average participation of 20.34% (± 3.45), which is marginally better than the Indian scenario (18.86%) (Figure 4 *a*).

A reason for the vastly different representation of women faculty may be due to the different mandates of the educational institutions. At university/college level, faculty are expected to play a dual role of researcher and a teacher. Naturally, such infrastructure does not promote a cut-throat competition of research and publication pressure, which probably plays a critical role in nurturing high female participation. This might be because women scientists in India are burdened with the expectations of marriage and family, and would invariably choose a less competitive setting provided by the universities. The other Institutions of National Importance such as IISERs, IITs, etc. receive huge amounts of funding from the union and state governments, which puts them under constant pressure to perform. Under these circumstances, the authorities of these institutions may perhaps be inclined to believe that women are fragile and may not be able to handle the workload at the cost of their family, despite their qualifications.

The minimal number of women candidates pursuing a career in science, technology, engineering and mathematics (STEM) can be explained by a model called the 'leaky pipeline effect'[19,20], where the leaking happens at primary school, secondary school, undergraduate, postgraduate, doctorate, postdoctoral and faculty-level positions (Figure 5). This phenomenon is further supported by data (Figure 4 *b*) on different research/re-entry fellowships/ faculty positions awarded in India over the last five years, which showed a similar representation of women (21.88%). Participation of women in STEM-related jobs in USA also showed minimal increment from 22% (1993) to 25% (2010)[21]. It is, however, important to note that there is no conscious decision to filter out women in this system. However, the continuous loss of female workforce can be assumed to be a cumulative effect of several factors[2] including social responsibility[22], glass ceiling at workplace[23], lack of recognition and the Matilda effect[24]. Multiple examples of this effect include renowned women scientists not duly credited for their ground-breaking experiments, such as Agnes Pockels, Nettie Stevens[25], Frieda Robscit-Robbins[26], Rosalind Franklin[27], C. S. Wu, Jocelyn Bell, and Lise Meitner[24]. Additionally, low participation in networking by women faculty might negatively impact scientific recognition[28].

Probable solutions

General improvement in the social and financial fronts, especially in developing countries like India is paramount for further inclusion of women in mainstream education, which can be expected to trickle down further in STEM. Inclusion of women role models specifically from STEM in the popular media and scientific literature, particularly in school textbooks, might have a positive impact.

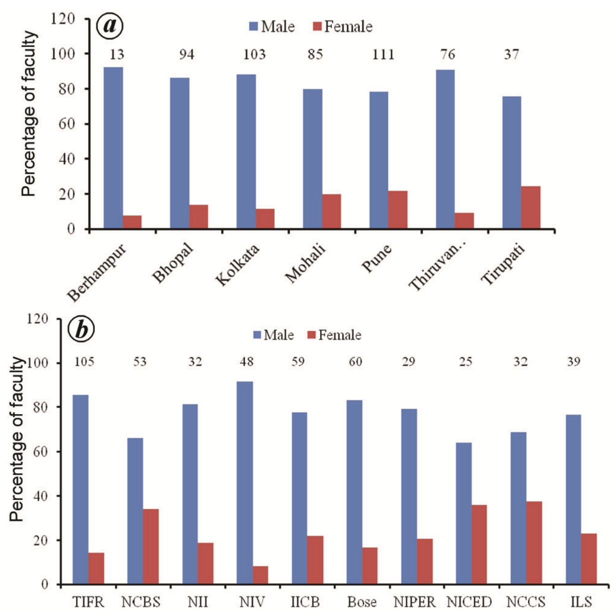

Figure 3. Gender-wise distribution of total faculties in Indian Institute of Science Education and Research (IISERs) and nationally significant institutes in 2018. Faculty distribution in seven IISERs (***a***) and 10 biological science research institutions (***b***) in India is presented. The *Y*-axis represents percentage of each gender and the figures above each bar exhibit the total number of faculties/scientists in the respective institution.

Scholarships, comfortable workplace, flexible working hours, crèches and daycare facilities can be included to the current infrastructure to support the existing women workforce.

In spite of such hardships and obstacles, the scenario is changing worldwide, as 130% increase in enrollment of girl students was observed in male dominated subjects such as physics, technology, engineering, mathematics,

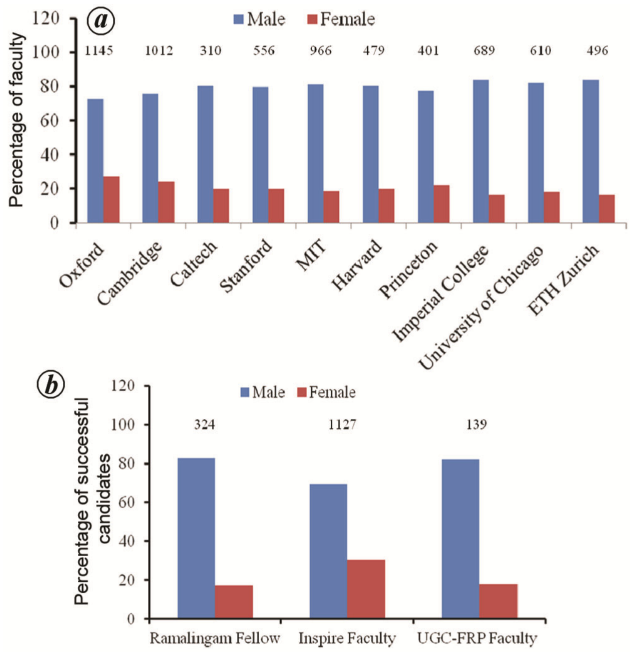

Figure 4. Comparative analysis of male and female faculty in international institutions and re-entry fellowships. ***a***, Distribution in the top ten institutions worldwide in 2018 is presented in percentage. The *Y*-axis represents percentage of each gender and the figures above each bar exhibit the total number of faculty/scientists in the respective institution. ***b***, The fellowship/faculty positions offered by different funding agency in India in the last five years plotted as percentage.

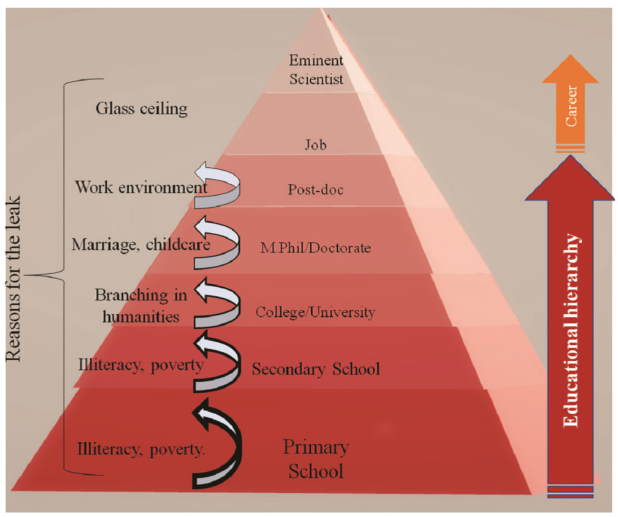

Figure 5. Schematic diagram of the concept of 'leaky pipeline' in the education system. (Right) Different stages of education. (Left) Probable causes of losing girl students over time.

statistics and computer science during the period 1990–2013 in USA[29]. In India, long-term analysis is needed to understand the repercussions of previous policy changes and their impact on the social structure.

To conclude, this long-lasting problem needs more discussion and debate at the national and policy-making level, which might sensitize the current generation and support the next one.

Methods

To analyse the scenario of faculty distribution in Indian institutions and universities, we have done a stratified random sampling where all the IITs, CSIR national laboratories, NITs and top ten institutions were established as individual strata. Many established universities were not included in this study as they do not have the information publicly available. The data were collected primarily from websites of the respective institutions, under the sub-page titled 'Faculty' and 'Scientists'. The departments covered in this study were all STEM-related departments, such as physics, chemistry, mathematics and biological sciences (not including medicine). Departments not related to STEM, such as management and humanities, while offered by the IITs and NITs, were not included in the study. The data were collected during May to August 2018. The collected data represent the cumulative values of recruitment over the last 30 years (1988–2018), as a regular faculty has 25–30 working years. We can assume that our data indicate the problem in recruitment during the last 30 years. To understand the bias against the recruitment of women scientist in highly reputed institutions, research fellowships/re-entry fellowships/faculty positions awarded by the DST/Ramalingam/UGC in the last five years (2013–18) were collected from the published results available on the official sites.

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