HOW DOES GENDER MATTER IN THE PHYSICAL SCIENCES?

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Abstract

It is now well-established that the language and narratives embedded in the cognitive culture of several natural science disciplines reflect and reinforce existing social biases, shaping the knowledge, attitudes and practice of these disciplines. This may not, as yet, be so clear in the physical sciences, but the gender imbalance in the numbers of professional physicists and astrophysicists has been widely noted, with the ratio of men to women becoming increasingly skewed at the higher levels of scientific research and administration. There is an almost intuitive understanding that diversity in science professionals would enhance creativity and productivity. But because the reasons for the lack of diversity are complex and under-researched in India, responses tend to be short term and ad hoc. In order to develop a strategy to address gender issues in the physical sciences, there is urgent need for interdisciplinary dialogue and research on critical questions, such as:

- How is a person's identity as a scientist constructed?
- How is the public perception of a science developed?
- How does the number of women professionals in a science matter?
- How do implicit biases influence women's entry into and progress as scientists?
- How is the concept of merit/ competence in science shaped?
- How does the institutional structure become gendered?

In 1993, when science historian Abha Sur began her ground-breaking research on the first three women scientists in C.V. Raman's laboratory, she met physicist Anna Mani in Bengaluru. Mani who had risen to the position of the Deputy Director General of the Indian Meteorological Department was most amused. She asked: 'Why do you want to interview me? My being a woman has absolutely no bearing on what I chose to do with my life. What is this hoopla about women and science?' (Sur 2001: 95). In 2018, Donna Strickland, only the third woman ever to get a physics Nobel, does not see herself as a 'woman in science'. Cytogeneticist Barbara McClintock, who got the physiology Nobel in 1983, said science is not a matter of gender, for ideally 'gender drops away'. Theoretical physicist Evelyn Fox Keller, who worked at the interface with biology, says of McClintock 'her adamant rejection of female stereotypes seems to have been a pre-requisite for her becoming a scientist at all' (1995: 173).

Yet, there is ample evidence to show that gender does not drop away and is critical in determining educational and career choices. What would make a 15 or 16 year-old girl in the Indian education system opt for physics-chemistry-math, eschewing biology, or commerce, or history? In the 1930s, when Anna Mani entered university, when all the women physicists in India could be counted 'on one's fingertips', she said matter-of-factly that she chose physics not out of curiosity about the world or love for physics but simply 'because she happened to be good in the subject' (ibid. 111). Of course, being 'good' in the subject often simply translates into scoring well in the Class X examination.

In the early 1980s, half a century after Anna Mani had been a student in the University of Madras, Sagari Ramdas (2015: 185) recalls her days as a student in the Veterinary College at Hissar, in Haryana. There were only two women in a class of 80, some ten women in the entire college and only two women professors. She writes, 'We were "outsiders" in this traditional all-male preserve. Veterinary science after all was considered a very "male profession". So, each day for the next five years catcalls and whistles greeted us as we entered class. We survived and learnt to negotiate spaces for ourselves.' Today, as she says, the challenge is to 'analyse and understand' these gender dynamics, to grapple with internalised biases and world-views: What do we expect a woman to be, or a man; what do we expect a veterinary scientist to be, or indeed a livestock farmer? (Ibid. 207).

Science is an institutionalised system of knowledge production, a part of society and also its product; science is 'socially constructed'[1]. Scientists, like other professionals, view the world both through their social experience and their disciplinary training. Gender operates at the individual, structural and symbolic levels – in terms of identity, roles and systems of meaning (Harding 1986) – which create power relations between men and women. These gender dynamics are intermeshed with the dynamics of class, caste, ethnicity, religion, language and so on. And each of these is also socially constructed and impacts on gender relations. A gender lens alone may not do justice to other axes around which our lives revolve. Keeping the focus on gender, however, has advanced both the academic and the political project of uncovering and understanding the persistence of gender inequity.

Since the 1970s, socio-cultural and feminist critiques of the humanities and the social sciences have revealed how gender is written into various disciplines, how this shapes our conception of nature and women's nature. (For instance, Gerda Lerner (1979) viewed history through a feminist lens, leading to changes in the way history and women's history were taught in the US.) By the 1980s, feminist analysis was being extended to the natural sciences, medicine, engineering and technology. Cross-disciplinary analyses unpacked the gendered epistemologies of paleo-archaeology and anthropology, anatomy and physiology in medicine, botanical and zoological taxonomy and evolutionary biology in the life sciences. Most notably, primatology was transformed by feminist perspectives[2]. Looking back, Keller (2004) says she had sought to extend the kind of analysis that feminists were using in the humanities and social sciences to the natural sciences. She hoped that identifying 'traces of masculinist ideology in the natural sciences would lead to their purging, for surely, here of all places, they ought not to be tolerated'. Her aim had not been to change the world but 'merely to change science'!

These critiques have had very little impact among natural scientists in India. In the late 1990s, I taught a social science component to MSc. students of environmental biology at the University of Delhi. They were very bright students but completely unaware of the critique of their own disciplines and they struggled to apply the logical processes of science to matters of gender. Similarly, in my experience over many years of working mainly with young male conservation and life scientists in field projects in coastal and southern India, I found that there was almost no awareness of critiques of science and that gender biases regularly crept into observations and analysis. The scientists would start with descriptions of what some women and men were observed to be doing. This was assumed to have cross-cultural, historical and universal applicability. The next assumption was that what was seemingly 'universal' reflected the essential natures of women and men. Other assumptions followed: that the division of labour, roles and responsibilities in the family and community are natural, and governed by hormones and genes. By this line of thought, male and female differences were perceived to be biologically fixed and determined by evolution and genetics. (Krishna 2009)

In order to understand how these perceptions developed, I began a more systematic examination, seeking to understand whether and how gender bias in the attitudes of scientists is influenced by the cognitive culture of science in India and the narratives embedded in the life science disciplines in which they are trained (for a more detailed account of the gendered critique of what I have called 'keystone stories' see Krishna, 2015 and 2009: 89-102). Here, I will first give a very brief glimpse of how bias is embedded within disciplines, with examples of metaphor, classification and theory from the history of the life sciences. And then I will take up a few critical questions, in relation to the physical sciences.

The anthropologist Emily Martin's (1996) now classic study shows how metaphors of the egg and the sperm in both popular and scientific accounts of reproductive biology are shaped by the cultural stereotypes of female and male. The egg is most commonly pictured as a passive, fragile, 'damsel in distress' (Schatten and Schatten 1984), protected by sacred 'vestments' till the heroic warrior knight, the sperm, attacks and accomplishes the 'mission' of rescuing her. Despite the new understanding of the biophysics of egg and sperm that shows that these are mutually active partners, researchers continue to conceptualise the story through the old imagery of the aggressive sperm. Martin argues that these are not 'dead' metaphors and the challenge is 'to wake up the sleeping metaphors of science.'

The passive female image has also shaped the organisation of particular disciplines. This is vividly revealed in science historian Londa Shienbinger's (1991) historical analysis of the emergence of botanical taxonomy. Both Carl Linnaeus and Erasmus Darwin introduced human sexual metaphors into botanical description. In the Linnaean system of classification, based on the sexual morphology of plants, 'classes' depend on the numbers, relative proportions and the positions of the male parts (stamens). Classes were subdivided into 'orders', similarly based on female parts (pistils) reflecting the gender hierarchy of 18th century Europe. Linnaeus used the Greek words *andria* (husband) and *gynia* (wife); in the order of *polygamia*, he envisaged polygamous plant husbands living with wives and harlots in marriage beds. (Today, these classes and orders of plants are not used but the lower rungs of the Linnaean classification continues.) Unlike the conservative Linnaeus, his contemporary Erasmus Darwin was a democrat and materialist. He saw the female character as mild and retiring; women's education was to be directed to enhancing the home life of prospective husbands. This was in line with broader political trends of that period that emphasised sexual complimentarity between unequals; this helped to maintain gender hierarchies and make inequality seem natural.

A hundred years later, the concept of sexual complimentarity between unequals had a deeper imprint on theories of human evolution, including that of Charles Darwin who saw women as more nurturant, reclusive and altruistic than men because in their case, he said, nature does not work to select the aggressive male traits. In a now infamous passage in *The Descent of Man,* Darwin (1871:874) simply mapped upper class Victorian culture onto nature:

> Thus man has ultimately become superior to woman. It is indeed fortunate that the law of equal transmission of characters to both sexes prevails with mammals. Otherwise it is probable that man would have become as superior in mental endowment to woman as the peacock is in ornamental plumage to the peahen.

In the 20th century, the notion of 'equal transmission of characters' was succeeded by new understanding of human genetics but the model of social relations between the sexes continued to prevail in the scientific imagination through the narrative of 'Man the Hunter'. Despite evidence from primatology, archaeology and anthropology that women are not necessarily dependent on men for household provisioning and may even be economically more productive, the passive-female/ active-male stereotypes in conjunction with Man the Hunter have had wide influence in different fields.

In the mid-1970s, the entomologist E.O.Wilson (1975) contended that biology favours patriarchy – men continue to hunt game, he said, now represented by 'money' – and that denying this would lead to loss of efficiency. He claimed that 'Even with identical education and equal access to all professions, men are likely to continue to play a disproportionate role in political life, business and science'. This sociobiological thesis provides an invidious justification for all manner of hierarchies – of ethnicity, class and gender. This was swiftly and comprehensively refuted by numerous scientists and feminists[3]. In recent decades, sociobiology has fed into evolutionary psychology, which has also been persuasively critiqued (see Hilary Rose and Steven Rose, eds., 2001). Yet, in the minds of students and practitioners of science in India, the Wilsonian argument continues to prevail.

Parallel to the critiques of the natural science disciplines, since the early 1980s, there has been a lively debate on the relationship between technology and society and the social shaping of technology (MacKenzie and Wajcman, eds., [1985] 1999). The popular conception of technology is that it is applied science. But technological developments may be independent of science. Technology uses science and science uses technology. Furthermore, both technical and scientific advances are often incremental. And the many who contribute to this incremental process, women in particular, remain unknown.

Studies of the gendering of technology have interrogated the projection of technology as masculine, and the idea of technical competence as being integral to male identity (Grint and Gill 1995; Cockburn 1992; 1983). Cynthia Cockburn (1999: 130-131) has argued that power lies in the ownership and deployment of technology, with women either being at the 'receiving end' (as of military and medical technologies), or being 'manipulated and exploited operators' (e.g. of typewriters, washing machines). Even when women are technically competent, they often do not perceive this as a valuable attribute. The reasons for this are complex. She says:

> When you see a woman take a set of spanners and approach a car, you suddenly become aware of the manifold informal pressures against women in public spaces using their bodies in the way men do: getting dirty and sweaty, climbing up things, lying on the floor, spreading their legs, exerting muscular force. (ibid. 131)

Till 10 or 15 years ago, in India, very few were interested in the kind of gendered analysis of natural science disciplines and technology that I have outlined. There were activist critiques of gender and health emerging from the women's movement in India and essentialist critiques of western science by ecofeminists[4]. But these scarcely touched the basic disciplines. Therefore, when the Indian Association for Women's Studies (IAWS) – during my tenure as President (2005-2008) – began a dialogue on various aspects of feminist knowledge production, we included science. First, we held a Southern Regional Workshop (Bengaluru, 2007) on the struggle to transform the disciplines (Krishna 2007). Many of the papers were on psychology, medicine, veterinary science etc. My own interest was especially in the approach and methodology of the science disciplines in India and we followed this up at the IAWS National Conference (Lucknow, 2008), inviting Gita Chadha and Riddhi Shah to coordinate a sub-theme on 'Gender, Science and Technology'. Having identified a group of scattered researchers working in this area, we held another workshop (Mumbai 2011) leading to the two-volume *Feminists and Science,* which I co-edited (Krishna and Chadha, eds., 2017, 2015).

During the process of putting these volumes together, it became apparent that, curiously, the physical sciences are not being critiqued in the same way as the biological sciences. I wonder whether this is because those sciences which are underpinned by mathematics are relatively free from the socio-cultural embedded-ness of the social and biological sciences, of engineering and technology. Or whether this is because those who are interested in uncovering bias are located outside of these disciplines, which are not easily self-taught? To critique a discipline, to unravel its language and culture, its metaphors, systems of classification, and narratives, a researcher has to 'enter' the cognitive space of the discipline. This does not seem to be happening for the physical sciences, globally and in India.

Instead, what we do have are qualitative and quantitative analyses of gender imbalance in the physical sciences. According to a survey of 36 million authors of academic papers in STEM (science, technology, engineering and math) and medicine, over a 20 year period, physics has the largest gender gap[6]. A global 'head count' of researchers in STEM from 110 countries show that, in 2014, women constituted 29 per cent (UNESCO 2017). Among physical scientists, the ratio of women to men is often estimated to be a fifth but this depends on which disciplines and professional occupations are included. In India, although the gender gap in the sciences is declining, the physical sciences continue to lag behind. The ratio of women to men becomes increasingly skewed at the higher levels of research and administration, and especially so in the 'elite institutions' (Shastri 2015a). This has led to questions about girls' motivation to do physics, about implicit biases that prevent their entry and progress in the discipline, about perceptions of merit and competence.

I now turn to six over-lapping and interrelated questions, which I will discuss two at a time.

How is a person's identity as a scientist constructed? And how is this related to the public perception of a science?

Identity, like character, is not cut in marble. It is shaped by many influences: by reading and exposure, by how one is perceived in childhood by one's parents, teachers and peers, by recognition and achievements, by how one's professional interests develop in adulthood, through opportunities and setbacks. What makes one a 'maths person' or a 'physics person', or a 'biology person'? Or even a 'disciplinary anarchist' as I was once called by a university vice chancellor? The biologist Richard Lewontin (1993:3) says, 'Scientists do not begin life as scientists, after all, but as social beings immersed in a family, a state, a productive structure, and they view nature through a lens that has been molded by their social experience.' How does the social experience of gender, and of caste in the Indian context, shape one's identity?

In I993, the monthly journal *Seminar* had an issue called 'Our Scientists', seven autobiographical essays by distinguished, liberal and progressive scientists, all male. The scientists had been invited 'to interrelate individual biographies to the wider issues of knowledge and organisation, politics and culture'; it was hoped that each scientist would become 'his own case study', reflecting on what it meant 'to be a foot soldier or even a sergeant in the grand march of science' (Vishwanathan 1993). In keeping with the male-centric metaphors of marching soldiers and sergeants, the essays reveal a consistent *gender blankness.* (Educated by my disability-rights friends, I no longer use the term 'gender-blindness'). Women appear in passing as mothers and wives; one person mentions a daughter. Only one scientist mentions a woman mentor, a university teacher. In that collective story of the making of 'our scientists' women are recognised as helpmates and inspirers and occasionally as providing valuable professional support to the male scientist. Uniformly, there is a lack of self-reflection on matters of social location. (Even in *Lilavati's Daughters* (Godbole and Ramaswamy 2008), the more recent collection of autobiographical stories of distinguished women scientists, one can discern a certain distancing from their social locations.)

Abha Sur (2011) has analysed the 'confluence' of science vis-à-vis caste, nationalism and gender in modern science in India. Her work focuses on C.V.Raman, who was from an educated, upper class Tamil Brahmin family, and Meghnad Saha, who belonged to an uneducated rural family of modest means and an underprivileged caste (OBC) in Bengal. In a talk at the Tata Institute of Social Sciences, Mumbai, in 2011, Sur sketched the possible linkages between Saha's approach and his social location. This sparked an email conversation among a group of women researchers including some scientists, which was later included as the first chapter in *Feminists and Science, Vol 1.* In that conversation physicist Anita Mehta (Mehta et.al. 2015: 3) said: 'in their mature work, most of India's scientists seems to have spoken the universal language of science, rather than one derived from their individual backgrounds'. In Indian science, she felt, caste was irrelevant in comparison to gender. Is this really so?

Consider the autobiography of nuclear scientist Raja Ramanna (1991). At one level this is a straightforward narrative about his life and career. But unpacking the text, Sankaran

Krishna (2006) (no relative), says it reveals the anchoring of Ramanna's identity in caste, deep-rooted discomfort with the masses and a reading of 'politics' as something that thwarts 'merit'. This runs as a counter current to the democratic, egalitarian outlook that Ramanna also professes. The critique highlights this 'unself-reflexive majoritarianism' as one of the realities of being an upper caste, middle class Indian.

To understand how one's identity as a modern Indian has been shaped by gender and caste requires a degree of self-reflection that most professionals, scientists and others, lack. It is a rare scientist who can bring self-reflection into a technical discipline. In her doctoral study of soil, agricultural scientist Meghana Kelkar (2017: 47) is keenly aware of and openly discusses the 'social markers' that delineate her as she traces the epistemological roots of her research and her own path. She describes this as a 'journey through an alien terrain', a journey which is 'an essential and conscious exercise'. Kelkar's work also shows how one's sense of identity and public perceptions are intertwined.

The lay perception of science is mediated through the public perception of individual successful scientists, rather than through an understanding of science or through developing a 'scientific temper'. The old image of the famous, lone scientist, usually male, continues to persist. There is, of course, romance in this view – in the popular figure of an elderly Einstein or more recently that of Stephen Hawking, or even a pioneering woman scientist like Marie Curie stirring pitchblende in a make-shift laboratory. As in any professional field, the 'star' renders invisible the large numbers in the background – in this case, women scientists and technicians. In India, casual observation shows that women technicians are swiftly increasing - pharmacists, opticians, lab-technicians etc. – but we have no information on this trend.

Indeed, it has taken years for information to trickle out about the women who worked as 'computers' in Harvard in the 1880s (dismissively referred to as Pickering's harem), the 'kilogirls' of Britain in World War II, supposedly each with the energy equivalent to a thousand hours of computing labour. Or the black female mathematicians, the 'hidden figures', in the US space programme that put men on the moon; Margot Lee Shetterly (2017: 247) who told that story says, 'Most people are astonished that a history with such breadth and depth, involving so many women and linked directly to the 20th century's defining moment, has flown below the radar for so long'.

This image of the lone scientist, whether male or female, is fed by media and film, and even by the science establishment. It does not conform to the way most cutting-edge science is done today – by collaborations among many scientists within a discipline and across disciplines, across countries and continents. And it also does not conform to the way engineering projects for example are actually carried out through multi-disciplinary teams.

A *Situational Analysis of Women Water Professionals in South Asia*, the first study of this kind, led by Seema Kulkarni (compiled 2009) covered over a hundred professionals, including engineers and others. The low number of engineers in particular was determined both by the type of work women do, and the content and structure of engineering science itself (Kulkarni 2012: 224). The skills of irrigation engineers were underutilised in unchallenging desk-work, but the choice of work was beyond their control. Women were kept away from site-work, which was believed to require physical strength and 'hard' technical knowledge and competence, and women were also kept away from the financial management of projects[5]. It is not surprising then that, in the public perception, women engineers and technical experts do not exist in the water sector. Anecdotal evidence and some recent trends in engineering education show that the space for women is opening slowly because men are moving onto more lucrative sub-disciplines or out of engineering altogether. But the public perception of engineering science and scientists has not kept pace with these trends.

How does the number of women professionals in a science matter? And how does this relate to implicit biases that may affect women's entry into and progress as scientists?

Self-identity as a scientist and the public perception of science seem to impact the number of women professionals. And there is evidence that diversity can influence the way science is done, the questions that are asked, the methodologies that are adopted. The critique of fundamental concepts in history and sociology, for instance, is certainly related to the higher number of women from diverse backgrounds in these fields. From experience in other work spaces, we also know that a critical mass of women does result in more practical facilities – the availability of washrooms, the height of a lectern, provision of crèches and so on. A larger number of women may also serve as a support system against some forms of workplace harassment. Yet, it is likely that numbers alone do not matter.

In India, as in other countries there have been initiatives to encourage girls to opt for the physical sciences. There are many assumptions about why girls are not doing so – physics being seen as masculine, the lack of female role models etc. But such assumptions have rarely been tested through quantitative or qualitative studies. This is now beginning to change. In the US gender parity in the biological sciences was achieved in the late 1980s but sharp imbalances continued in the physical sciences. Zahra Hazari and her team have experimentally tested five factors that were commonly assumed would benefit the career interest of female students in the US (Hazari et. al. 2018):

- Having a single sex physics class
- Having a female physics teacher
- Getting a female scientist as a guest speaker in physics class
- Discussing the work of female scientists in physics class
- Discussing the under-representation of women in physics, in physics class

The data show that the single most-important factor that could make a change is: Discussing in class the under-representation of women in physics and the kind of career problems they could face. The students' relation to their physics teacher was also of some significance, but this was not specific to a female teacher. A single-sex class or a female scientist guest speaker had no impact.

Another study by an interdisciplinary team of US scientists expressly addressed the biological and physical science faculty's possible gender bias (Corinne A Moss-Racusin et. al. 2012). The results were clear – the faculty, male and female, subtly favoured male students. The study concluded that 'faculty gender bias impeded women's full participation in science.'

Therefore, they suggest that interventions that address faculty gender bias could further the goal of increasing women's participation in science. A recent study from Austria (Thomas 2017) looks at gender differences in students' motivation for the physical sciences and whether this is linked to the teachers' implicit cognitions. The study found that there was a positive correlation in gender differences in motivation and a possible correlation with educational aspiration.

An interesting qualitative study from Canada follows two female doctoral students in observational astrophysics (Gonsalves 2018). The detailed case studies show how the two students cope with the prevailing discourse of physics as a gender neutral discipline. The research indicates that cultural models of the discipline did not fit with the female students' experience and at times interfered with their careers. Although the career trajectories of the two were very different, both continued to identify as physicists but repositioned themselves as teachers rather than researchers. This is a phenomenon that is well-known in India too.

It cannot, of course, be assumed that the results of these recent studies from North America and Europe would hold for female students in India. As Carol Mukhopadhyay (2009) argued, girls' educational choices in India are often not individual choices but the outcome of a familial decision. Economic factors – the sheer expense of higher education in science and technology – could deter families from choosing disciplines that are not perceived as having job potential. This is especially so, she says, given the 'patrifocal' structure of society and strong restrictions on women's sexuality, mobility and so on.

How is the concept of merit/ competence in science shaped? And how does this impact institutional structures?

The concept of merit is the most contentious issue in the science academy. 'Merit' is often the reason given for exclusions of any kind. In her pioneering work on unravelling the gender-merit conundrum, mathematician Jayasree Subramanian (2015) had the advantage of being seen as a fellow scientist, an insider. Nevertheless, women scientists did not want the issues that they shared to be discussed 'outside'. (At a training seminar attended by many women space scientists, I was heckled for raising issues of gender bias and exclusion. But later in the tea break, some of the women came to me and said, 'there is discrimination but none of us will speak of this in public, it will be detrimental to our careers'.) In spite of this wall of silence, Subramanian's research revealed the many ways in which merit was used to marginalize women and strengthen male domination in scientific institutions. As she says, under-representation of women in science is only the most 'visible aspect of the gender question in science in India' (ibid. 41).

Subramanian's data show that 'women's competence and commitment to pursue science are doubted' by male scientists. Their progress is invariably attributed to 'hard work' rather than 'talent for science'. As with women in many other professions, women are too easily excluded by the presumption that they will leave science to care for their families. The 'blatant and subtle exclusions' are aggravated by the way science institutions function, she says, under the control of a few powerful scientists, mainly men: 'Personal connections make a difference to what a scientist can achieve. So to succeed it is important for scientists not only to do good work but also to lobby. For more than one reason, women do not find it possible to make personal connections as men do'. (ibid. 41-42)

Ajita Chakraborty (2010), India's first practising woman psychiatrist, joined the West Bengal Government Health Service in 1960 and her career was contiguous with the formation and growth of the discipline of psychiatry in India. Chakraborty was an uncompromising woman with strong views that ran counter to the discipline that was being established. She had to fight marginalization at every step. She argued that academic psychiatry was so strongly biological and medical that it is 'almost devoid of social and human dimensions'. For a new orientation to emerge, she felt, there had to be greater awareness of the local experience and cultural context – this was especially important for women. Mental illness may be caused by biological factors but was manifested through language and non-verbally in a particular social context (ibid. 150). 'When does a woman's contribution gain recognition as knowledge or as being significant in building up a profession?' asks Mandira Sen (2015: 132), writing of Chakraborty's work, which remains largely unrecognised. Although she did not see herself as a feminist but her ideas are at the core of women's critiques of medical and mental health practice today.

If gender and science is a conundrum, caste and science is even more so. Educationist Mina Swaminathan (Mehta et.al.2015) has been forthright in drawing attention to how merit is used to mask the caste prejudice of 'many leading scientists'. In the email conversation, referred to earlier, she says (ibid.3): 'They do not even try to cover it up or make excuses, because surprisingly they do not yet think it is embarrassing ... Most of them are strong believers in the 'merit' theory, which they are unable to define, because they do not have the vocabulary, the 'cultural capital' to talk about it rationally (may I say sarcastically, 'scientifically'.) Defence of the 'holy cow' of merit is a regular item of all convocation lectures and such occasions. She points out that 'people who are convinced of their intellectual superiority' are 'unaware of what has produced it' (ibid. 12) and often claim in all sincerity to be casteless.

> Many upper-caste, upper-class male scientists … talk with pride of their lineage and family with a long tradition of scholarship, but fail to see the other side of the coin – that those without these (caste-class) credentials cannot be expected to catch up in one generation, even with support, which they rarely get. One rarely comes across such responses from women scientists, because they have had to struggle against their own problems (gender) and are too busy confronting them, having no time to boast … they are not unsympathetic to the deprived castes but they tend to stand shoulder-to-shoulder with their men on issues of merit and reservation. (ibid.13)

The success of increasing numbers of upper class and upper caste women scientists, and professional women as a whole, is fraught with a contradiction. While women struggle to enter and survive in male dominated professions, there has also to be the awareness that both men and women who do not have their class and caste privileges continue to remain excluded.

Indeed, the success of aspiring scientists from conventionally excluded backgrounds who clear the merit gateway and forge a scientific career lies in their ability to negotiate spaces in the institutional structure and culture of science. Their presence does not necessarily change the culture of the institution or of the science. As Keller (1989) argued, 'for women scientists as *scientists*, the principal point is that measures of scientific performance admitted of only a single scale, according to which to be different was to be lesser. Under such circumstances, the hope of equity, indeed the very concept of equity, appeared – as it still appears – to depend on the disavowal of difference.' Keller is particularly perceptive in saying that gender-based difference is the basis both for women being excluded from science and for women scientists being viewed as 'not women'. This is evident across many upper class/caste and male dominated disciplinary fields in India. It is not surprising then that Anna Mani, Donna Strickland and even Barbara McClintock should believe that their being women has nothing to do with their science, that gender simply 'drops away'.

We in India have a tradition of collecting statistics, even if often confusing and contradictory. In keeping with the substantial increase in girls' access to education in the last decades of the 20th century, the enrolment of women in scientific disciplines also increased (UGC 2001). Comparing the enrolment figures across different disciplines shows that the ratio of women in science (40 per cent) was higher than in commerce (37 per cent) but less than in medicine (44 per cent) and in the 'arts' (humanities and social sciences, 44 per cent). In the science-based professions the ratio was about one in five: engineering 21 per cent, veterinary science 21 per cent, agriculture 17 per cent (Krishna 2015: xv-xvii). The Mehtab S. Bamji Committee on women in science of the Indian National Science Academy (INSA) and the Research Centre for Women's Studies of the SNDT University, Mumbai (INSA 2004, Poonacha and Gopal 2004) analysed the data. They point out that in a few states, Goa, Kerala, Punjab and Puducherry, more women than men were studying science; and that there was very little attrition from the undergraduate to the postgraduate levels although there was horizontal segregation by discipline. The INSA study (2004:65) notes that the 'majority of respondents were from Hindu forward cast [sic] families, from English medium schools. Poonacha (2005:246) argues that 'While overtly claiming to extend access and outreach, the implicit policy motivation is the maintenance of an exclusive social order'.

There is also considerable data available from the regular All India Higher Education Surveys on trends in women's enrolment: in 2015-16 the percentage of women pursuing science is 19.1% but this is a fraction of total women's enrolment, not a fraction of men and women in science (HRD 2017). Rohini Godbole and R. Ramaswamy calculated that in 2008, 19.5% of women were in government laboratories and teaching institutions, of which 10-12% were in the premier institutions (TAASSA 2015). A recent study commissioned by Niti Aayog (SSESS 2018) aimed 'to understand the reasons for the loss of trained female scientists from scientific manpower in India,' and identify policies and 'best practices' for retention. None of this, however, seems to lead to a coherent understanding and evidence-based strategy to address gender imbalances. Initiatives for female students or scientists are ad hoc and piecemeal – the kind of 'special considerations' that someone like Anna Mani so disdained[7].

As astrophysicist Prajval Shastri (2015a; 2015b) has pointed out, schemes for women scientists, such as DST's Career Break Fellowships operate in a climate of hostility and backlash, without denting the deep structures of gender bias in institutions. She suggests that career breaks, flexitimes and so on should be gender-neutral, available for women and men. This would be seen as fair within the scientific academy and hopefully nudge men into taking on some of the caring responsibilities in the family, necessary for a more gender balanced society.

The single-most important obstacle to strategies that impact deep institutional and organisation structures is unrecognised automatic bias among science educators, practising scientists, science administrators and policy makers. Because implicit bias is *implicit*, it is difficult for most people to recognise that this exists. But one can test oneself with the 'Project Implicit' (undated) attitude tests that are available on the Harvard education website. Based on speed of association, the tests cover many different ingrained binary concepts; they are well-designed and can be taken online in just 10 minutes for each set. While I was preparing this talk, I took four of these tests. My results: Slight automatic association for Male with Career and Female with Family; Moderate automatic association for Male with Science and Female with Liberal Arts; No automatic preference between young and old people; Slight automatic preference for abled persons over disabled persons. Does this surprise you? It should not. One can consciously strive to minimise bias; that does not mean that one is entirely free of socialized automatic associations. This kind of testing could be taken further by using inter-disciplinary methods and tools to study and uncover the implicit gender (and caste) biases of individuals and institutions but also preferences that seep into day-to-day practices. This would be the first step in the process of addressing persisting gender imbalances in both female and male dominated professions, including the physical sciences.

The death in October 2018 of the British moral philosopher and public intellectual Mary Midgeley, at the age of 99, brought renewed attention to her consistent attempt to question the 'myths' of science. Myths, not as falsehoods, but as patterns of symbols that we absorb from society. Midgeley (2003; 1992) argued that automatic associations and ingrained patterns of thought shape our world views and seep into the professional work of scientists. The problem is that these myths then seep back into society having acquired scientific authority[8]. The narratives inscribed into the scientific disciplines and the automatic associations and preferences embedded in the culture of scientific institutions are difficult to recognise and overcome. But unless we consciously work towards doing this, all the well-meant initiatives to address imbalances in education and career paths will remain superficial measures. Increasing the numbers of women in science education and research is an important goal but our academic and political purpose has to move beyond numbers to addressing the gender, caste and other exclusions in the deep structure of scientific institutions and the practice of science.

Notes

I thank the Working Group for Gender Equity of the Astronomical Society of India for the invitation to deliver the Anna Mani Lecture at the National Centre for Radio Astrophysics, Pune: 30th October, 2018, which provided the impetus to write this essay. Some sections are based on my earlier work (Krishna 2009; 2015a; 2015b). Thanks also to Sandeep Krishna, Thomas Abraham and Vatsala da Cunha for useful comments.

1. The positivist approach to knowledge production, which characterises much of modern science, sees 'reality' as being discovered, rather than being created or constructed. The alternative social constructionist approach sees 'realities' as being shaped by how we choose to seek and interpret the evidence, which is specific to a historical and locational context. In this approach, science is also a socially-situated construction of reality. This does not mean that nothing is real or that the real is ignored but that different processes of socialization produce different perspectives.
2. For socio-cultural studies of the natural sciences, see, for instance: Evelyn Fox Keller (1984); Nancy Tuana (ed.) 1989; Sandra Harding 1991; Donna Harraway (1992); Londa Shiebinger (1999); Reid and Trawick (2000).
3. See Krishna (2015b) for a more detailed discussion; comprehensive refutations by scientists such as: Lewontin (1978), Rose, Lewontin and Kamin (1990); Kitcher (1985); and by feminists such as: Haraway (1992; 1988); Kaplan and Rodgers (1990); Sperling (1991).
4. Ecofeminist approaches speak of a 'feminine principle' in nature and see all women as essentially nurturant. German sociologist Maria Mies and Indian environmentalist Vandana Shiva (Mies and Shiva 1993) link European colonization of other lands, the scientific 'colonization' of nature and male 'colonization' of women's bodies. This thesis has been critiqued as tending to essentialism - the belief that biology determines social divisions and that monopolies of knowledge derive from male and female reproductive capacities - by those (including myself) who seek a more contextual and gendered approach to the environment and to women. (Krishna [1995] 2009)
5. This study was followed up by a project on South Asian women water professionals – irrigation engineers, administrators, scientists, researchers, journalists and community organisers (Krishna and De, eds., 2012). One of these women, Chief Engineer Badra Kamaladasa, who set up and oversaw the Sri Lankan department of dam safety, said she took up engineering 'simply because she got the best marks in mathematics in school'; of the 150 students in her civil engineering class, only ten were women (Shedde 2012: 105).
6. The study, by researchers at the University of Melbourne, Australia, covered last named authors of papers assuming that the senior-most author would be the last named. The assumption is questionable because in some disciplines authors' names may be listed alphabetically; the broad conclusion, however, that it will take two centuries before there are an equal number of senior male and female researchers in physics points to the extent of the gender gap (Holman, Stuart-Fox and Hauser 2018)
7. For instance, in 2018, the Government of India's Department of Science and Technology allocated Rs.20 million to 15 premier institutions as part of a programme, Vigyan Jyoti (literally light of science) to encourage rural girls to opt for science. One such Vigyan Jyoti scheme, organised by the Indian Institute of Technology in Guwahati, had some 30 school girls from the north eastern states interacting with scientists from NASA and the Indian army (DST 2018).
8. Midgeley (1983, 1979) was particularly exasperated by biologist Richard Dawkins' (1976) striking image of the 'selfish gene'. She argued that this was not simply a metaphor that Dawkins used but structured his science. And because of its popularity it influenced people's moral outlook and social and economic behaviour. She has also drawn attention to how the metaphor of nature as a machine influences science and society.

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