Gauging the Educational Potential of Feminist Inroads into Science

Deepika Bansal*

Abstract

Feminists have a number of distinct appraisals of and perspectives on science. Beginning with documenting the near absence of women from conventional histories of science, to casting doubt over popular perception that associates reason, mind and objectivity with the male, and emotion, body and subjectivity with the female, feminists have identified sciences as both a source and a locus of other kinds of gender inequalities. The impact of such critiques, however limited, on certain disciplines cannot be ignored and that paves the way for questioning the nature of science as it presents itself and for putting forth viable alternatives. This paper maps the journey of this kind of a scholarship and discusses what has been its impact on three disciplines of archaeology, evolutionary biology, and primatology, and explores the educational role such feminist ideas play.

A Short History of Feminist Science Studies

Feminist scholarship in any discipline is motivated by a commitment to overcoming subordination and devaluation of women. Since the early 1970s, research has been getting published that reinterprets and 'profoundly illuminates' women's actions and experiences in a patriarchal setting. It has helped expose distortions in the way of how women were represented in much social science research; insisting that patriarchal biases get reflected in the way questions were posed about women, and that there was an absence of concepts that adequately tapped women's experiences. The researchers called for a social science which was not merely a catalogue of the past and present conditions

PhD Scholar, Department of Education, University of Delhi, Delhi 110 021, India; deebans.88@gmail.com

of women, was not just 'about' women, but was essentially 'for' them—a social science that did not exclude information about women but informed that knowledge with an intention to oppose various forms of patriarchy (Westkott, 1979).

Feminists turned their gaze onto science almost around the same time. Feminist reflection on the nature of science, stimulated and engulfed a scientist, 'deeply engaged' in her mathematical biology; and its urgency is best captured by her own words:

> Sometime in the mid-1970's overnight, as it were, another kind of question took precedence, upsetting my entire intellectual hierarchy: How much of the nature of science is bound up with the idea of masculinity, and what would it mean for science if it were otherwise? A lifelong training had labelled that question patently absurd; but once I actually heard it, I could not, either as a woman or as a scientist, any longer avoid it. (Keller, 1985, p. 3)

A stir in the minds of those who were involved in the conversations on gender, the *au courant* issue of the seventies, and 'knew something about the natural sciences' had been caused. It brought into view the hitherto hidden traditional naming of the scientific mind as masculine and the complementary naming of nature as woman. They began asking what these traditional and historical dichotomies meant and what their consequences were. The first book-length response was made by Carolyn Merchant in her work called *The Death of Nature* in 1980, which according to historians marks the origin of feminist science studies (Schiebinger, 2003). Merchant focussed on the significance of the metaphor of nature as woman for science, for women, for nature and for capitalism (Keller, 1985). She argued that modern science could be characterised by its espousal of the mechanistic worldview which turned nature into a machine. And it was this particular intellectual orientation that allowed for new ways to see order in nature that fostered an attitude of control and domination towards both nature and women (Fehr, 2004).

Soon after this headstart, scholarship began pouring in that investigated different aspects of science and their relationship to women. One thriving strand of these critiques was an obvious and 'visible' issue of absence of women in natural sciences. Historians and other scholars of science have documented historical patterns of exclusion of women from the academies and other formal bodies of scientists. At the same time, they have recovered significant number of women who were ignored by conventional histories of science, thereby producing evidence for women's participation in the sciences, often in the face of stiff resistance (Kohlstedt and Longino, 1997).

Along with this, historians have also turned their attention to the personal and external circumstances that empowered these women, and to those factors that inhibited their

achievement in science. The ways in which women's public and private activities intersected and how for some women, family relations were the source of both support and constraints for their advancement in science have been documented too (Kohlstedt and Longino, 1997). Case studies, biographies, and comprehensive histories are some examples of such kinds of work, amongst which, those of Nobel Prize winner Barbara McClintock and of Rosalind Franklin have garnered some public attention as well.

This sort of historical research on women in science has helped establish that exclusion of women from natural sciences was not due to their inherent weakness or inferiority, as was claimed earlier. Studies on 18th and 19th century culture in Britain and France have elucidated how sciences came to take on a distinct masculine profile (Crasnow, 2015). Ann Shteir shows in her work how women gained considerable expertise as herbalists and horticulturists about 300 years ago in Britain (Shteir, 1997). But in due course of time, certain rules were instituted that circumscribed their participation in botanical science. Becoming a member of some professional organisation was an important aspect of those prescriptions, and those organisations gradually began to take on markedly masculine identities. Professional codes of ethics, particularly those involving competition and social behaviour, were the traditional, aristocratic codes of honour that got translated into professional lives of middle class peoples. As a result, these behavioural norms, along with established rules that determined who could be a member of certain medical and scientific societies, played an elusive but effective role in gendering certain (scientific) activities (Kohlstedt and Longino, 1997).

These inquiries into human actors and their contexts in science have been accompanied, and followed in some cases, by more general analyses of scientific work. The insight that unites different critiques of this latter kind is that science is a social, political, and more specifically, a gendered institution (Wylie, Okruhlik, Thielen-Wilson and Morton, 1989). Feminist scholars have exposed ways in which gender ideologies get incorporated and expressed while deciding on researchable topics and framing research questions. A key example comes from medical sciences wherein women (their ailments and bodies) were not regarded as subjects worth systematic investigations, and male bodies and disease profiles were taken as the norm for medical diagnosis and treatment. The drugs which were very confidently prescribed to women, were in fact, never tested for their efficacy on them as women were never included as human subjects for clinical testing and trials of drugs even up to early- to mid-1980s (Schiebinger, 2000). A well-organised women's movement was required in changing

the relationship that women had, both with their doctors and with their own bodies. Another striking example worth mentioning, comes from the field of research in contraception, in which much greater emphasis has always been on finding procedures and techniques that temporarily or permanently alter female reproductive abilities as opposed to males' (Bal, 2002). Bal reports that despite the fact that both male and female anatomy and physiology offer more or less similar number of ways to prevent fertilisation, more funding and hence, subsequent research has gone into devising strategies that control women's bodies.

A related area of work for scholars of science has been the study of gendered images and metaphors in scientific theorising about non-gendered subjects like the interactions between nucleus (controlling, central, active) and cytoplasm (submissive, peripheral-around the nucleus, passive) in the cell. As Kohlstedt and Longino put it.

> Feminist scholars have drawn attention to the ways in which cultural gender constructs are naturalised and the natural world sexually dichotomised by such linguistic practices. They have also shown how alternative theoretical accounts are marginalised or silenced by the salience of gender, with its attendant metaphors of domination and subordination, attack, and defeat. (Kohlstedt and Longino, 1997, p. 5)

The usage of phrases, and hence, the concepts, of attack and defeat abounds in chemistry wherever reaction mechanisms are discussed. 'Attack by the nucleophile', 'electrophilic effect is dominant in this step' are few instances to testify that use of s uch linguistic categories cuts across disciplinary boundaries indicating pervasiveness of a particular gender ideology.

Critiques of the kind mentioned up till here have been considered as methodologically and epistemically conservative, that is, all that they aim for, is to show masculine distortions, in the content of science, such as how males, females, sex, and sexual difference have been represented in contemporary scientific theories; how collection, organisation, and interpretation of data gets skewed by gender bias; how research priorities are decided and, what goes into determining the standards of good research. They make use of the established research tools of modern scientific disciplines to critique the same disciplines, and believe that their stricter and reflexive application would serve feminist ends. However, Crasnow (2015) contends that these small scale efforts have resulted in the generation of more deeply challenging questions as well. She states that 'framework assumptions like ontological commitments, explanatory repertoire, conventional categories of description and analysis' have indeed been affected by omission and distortion of women in different aspects of science. So, another thread of conceptual feminist inquiry

has looked into methodological and epistemological features of science. Questions like, how has gender affected our conceptions of knowledge; what does it mean to call one aspect of human experience male and another female, have been asked (Kohlstedt and Longino, 1997). Few scholars have also taken the issue to 'popular mythology that casts objectivity, reason, and mind as male, and subjectivity, feeling, and nature as female' (Keller, 1985, pp. 47–48).

In this division of emotional and intellectual labour, women have been the guarantors and protectors of the personal, the emotional, the particular, whereas science, the province par excellence of the impersonal, the rational, and the general has been the preserve of men.

The consequence of such a division is not simply the exclusion of women from the practice of science. That exclusion itself is a symptom of a wider and deeper rift between feminine and masculine, subjective and objective, indeed between love and power, a rending of the human fabric that affects all of us, as women and men, as members of a society, and even as scientists. (Keller, 1985, pp. 6–7)

Keller and other scholars have focussed explicitly on the language of scientific knowledge generation and communication. They claim how even the ubiquitous and seemingly harmless concept of 'laws of nature' are marked by its political and theological origins.

> The philosophical distinction between descriptive and prescriptive laws is invoked to underline the neutrality of scientific description. But nonetheless, laws of nature, like laws of the state, are historically imposed from above and obeyed from below... The extreme case of the desire to turn observed regularity into law is of course the search for the one 'unified' law of nature that embodies all other laws, and that hence will be immune to revision; in Bacon's language, the 'summary law in which nature centres and which is subject and subordinate to God'. (Keller, 1985, p. 132)

She goes on to suggest that though the belief in the laws (or law) of nature is deeply ingrained, and hence seems irreplaceable, the concept of order is an apt alternative. It is wider than law and free from its coercive, hierarchical, and centralising assumptions. She is hopeful that an interest in order rather than law would entail a shift in the focus of scientific inquiry from 'the pursuit of the unified laws of nature to an interest in the multiple and varied kinds of order actually expressed in nature'. And such a shift would imply corresponding changes even in the role of a scientist. The scientist would not be the discoverer of authoritative and deterministic laws that govern the unfolding of a submissive and meek nature, rather the new 'order' would allow nature to be resourceful, generative, and more abundant; an active partner in a more reciprocal relation to the observer, thereby

marking a shift in the relationship of the knower and the known.

Other scholars have attempted to delineate what should be an appropriate feminist epistemological attitude (alternative in few cases) too. Sandra Harding (1989) has been championing the idea of a feminist standpoint on nature and redressing the absence of unique feminine values that should be a part of science. For her, science should be appropriated by each community as its own; should be free from its western, white, middle class origins and different ways of knowing and learning should become a part of what that science is. Others like Helen Longino (1989) have advocated for a kind of objectivity in science that is not the responsibility of individual scientists but of a community of scientists which would allow for a thorough scrutiny of assumptions and values in the knowledge being generated. As a corollary, such an arrangement must have practitioners from a different race, class, gender, in order to provide the lens of difference that would help filter the taken-for-granteds of a particular group.

Thus, we can acknowledge that over the past forty some years, a great deal of work has been done on women's exclusion from science, how gender has been one potent factor structuring scientific institutions and practices, and how gender hierarchies have shaped scientific priorities, theories, values and a good part of its philosophy. In areas like medical research, these critiques and the ever so strong women's movement have had profound effects in the United States of America the hub of feminist scholarship in the sciences (Subramaniam, 2009). There are regulations now from the apex funding body of research in medicine that mandates inclusion of women in clinical trials of drugs. Separate grants have been instituted to promote investigation of women specific diseases like breast cancer and female reproductive ailments. This approach has not only increased the number of women (of many backgrounds) in the medical sciences but has also brought significant improvement in U.S. biomedical research and healthcare (Schiebinger, 2003). Likewise, disciplines of 'pure science' have been influenced in varying degrees by the feminist appraisals. Those with humans as their objects of inquiry have been the target of most feminist scrutiny and hence, have incorporated insights offered to the largest extent (the social and human sciences). Next are those that inquire about other living organism-subjects that are projectively gendered, and quite expectedly, the physical or the 'hard' sciences have remained most impervious to feminist critiques.

In the next section, I discuss the impact that feminist science studies have been able to make in three different disciplines of science, namely archaeology, evolutionary biology, and primatology.

Impact on Different Disciplines

Archaeology

Though the widespread view of archaeologists is that they dig in the ground for artefacts, some and not all of them indulge in this kind of work. Many studies surface evidence, pottery, paintings, and sculptures, and still others perform chemical studies of stone and clay objects and other geological source materials. A good number of archaeologists work in laboratories making and breaking pottery or studying pollen, bones, and seeds (Hays-Gilpin, 2000). Thus, it would be safe to say that most archaeology practiced is in the intellectual heritage that considers archaeology to be a scientific enterprise strongly linked to empirical phenomena (Conkey, 2003).

Establishment of 'scientificity' of the discipline would unsurprisingly be followed by a note on its male character. As Margaret Conkey, one of the foremost practitioners of the discipline, writes:

The practice of archaeological fieldwork has long been male dominated and much has been written about this with accompanying statistics to show how the 'big digs' have been primarily male led—'the practicing field archaeologist who himself conquers the landscape, brings home the goodies, and takes his data raw!'—and how males have received more funding for such excavation than have females. Not only has fieldwork, and excavation at that, been gendered male, doing excavation (as opposed to other kinds of research such as survey research or the analysis of museum collections) and having one's 'own site' have been privileged as central to the crucial emphasis on fieldwork, as to what defines a 'real' archaeologist. (Conkey, 2003, p. 868)

Not surprisingly then, one of the first and major concerns of feminist inspired archaeology has been to make the women of the past visible. This got accomplished only when archaeologists began to 'see' the androcentric currents in the accounts of the human past that had been prevailing. Motivated by a rejection of the equation of human behaviour with the behaviour of men, the primary task in this case was to identify and assert the presence and activities of women on prehistoric sites (Conkey and Gero, 1997). These studies gained their value from the recognition of female labour in a wide variety of activities, most of which were earlier considered as exclusive male domains. Evidence for the presence and active participation of women were found in the making of cave art, animal husbandry, and mortuary rituals at different sites all over the globe. Equally noteworthy is the increasing literature that takes a gender-sensitive approach to 'the sociology of the field'. A number of journal volumes and issues have dealt with the 'hidden voices' of practising archaeologists—women whose contributions were not

acknowledged or who were underappreciated (Conkey and Gero, 1997).

Another related, significant contribution has been that this interest in women and gender has led to innovations and new directions in research. The historical and traditional concern in archaeology has been research at the macro scale —'big systems' aspects of lives thousands of years ago such as trading networks, socio-political alliances, and demographic trends. But research into past situations where women were more likely to have been present is being done with more intensity, scrutiny and methodological innovation than before. More work at the 'microscale', at the level of the household or daily practices, structured space, local knowledge, and local production, for example, has been taken up with new vigour and success (Conkey, 2003). Highly sophisticated scientific techniques such as micromorphology (study of components, features of soil at microscopic level), bone chemical analysis of skeletal remains, advanced soil chemistry of deposits on house floors have been developed to infer microscale practices. Learning about detailed architectural histories that look at 'life-cycle' of a house or its structure not just in terms of a static form at any one time has been made possible only because of this increased attention to concerns of women and gender. In other words, another major contribution of feminist inspired archaeologies has been to bring to fore a more explicit multiscalar archaeology (Conkey, 2003).

Another arena which has shed light not only on women and females but also on masculinity, males and varied ways of engendering in ancient societies is visual representations (art, imagery, iconography) in archaeology. Since women are more 'visible' owing to their depictions in murals, figurines and rock art, renewed interest and increasing sophistication in their study has promoted analyses of what these visual artefacts might mean. These analyses have drawn theoretical insights from topics as varied as art history and theories of representation, offering another instance of working with the feminist idea of bringing in multiple perspectives to construct knowledge (Conkey, 2003).

Also to feminism's credit are the efforts to try and understand the manifestations of concepts such as personhood, sexuality, homoeroticism, gendered statuses and symbolic capital in past human societies which may not have presented themselves as areas worth investigating earlier. For example, some archaeologists have scrutinised the sex-gender dichotomy. They call for decoupling the two in order to avoid ruling out all kinds of possibilities that prevailed in the past cultures. Gender, they assert, should be viewed as multidimensional and continuous; archaeologists, instead

of emphasising delineation of gender identities, should focus on individuals and their experiences (Kohlstedt and Longino, 1997).

Similar to this have been feminist interventions in archaeologists' use of visual images while presenting archaeological knowledge. As noted earlier, popular views of 'scenes of the past' majorly comprise men. Be it making tools or sculptures, the 'visual language of archaeology' such as maps, charts and artistic reconstructions of past scenes have been analysed to be not neutral, especially in regard to representations of males, females and gender. A 2013 study that analysed 204 images from 1936 to 2007 in a popular science magazine concluded that gender bias was pervasive and persistent in pictorial representations of the past (Solomento and Moss, 2013). They observe:

> That the scenes most frequently chosen for illustration—hunting, combat, construction, as well as the artists' close attention to male musculature, communicates that men's strength and men's work underwrite the division of tasks, and are responsible for human evolution and the making of civilisation… women's physiques were not emphasised, apart from their breasts… have no place in scenes demanding physical labour, but appear primarily in domestic and market scenes… (Solomento and Moss, 2013, p. 139)

The impact of scenes which convey that men were more responsible for creating our revered cultural artefacts, effecting technological advances and governing civilisations has been legitimation of contemporary gender roles and other patriarchal notions of authority, hierarchy and value.

Feminists have also taken issue with heretofore assumeds and taken-for-granteds in archaeology, for example, categorisation of the human past periods by technologies or economies (for example, the Stone Age, the Iron Age, hunter gatherers, village agriculturalists); the centrality of tools and technologies in explaining our evolutionary success ('man the toolmaker'). These assumed centralities and objects of knowledge are being questioned in line with contemporary views on gender that accuse this fascination with tools and warfare as highly masculine. These feminists are trying to find out other factors and processes that must have happened over the course of human social and cultural life which will help bring alternative understanding of processes like establishment of social alliances and social relations of production, importance of gathering and hunting in primeval societies to the fore (Conkey, 2003).

Evolutionary Biology

It is a subfield of biology that studies the evolutionary processes that produced the diversity of life on earth, starting from a single origin of all life. These processes include the descent of species, and the origin of new species. One of the most influential theories in the discipline

that attempts to explain causes and consequences of sexual behaviour is the Parental Investment Theory. Robert L. Trivers, in his landmark paper titled 'Parental Investment and Sexual Selection' in 1972, put forth his thesis on the relation between typical natures associated with the two sexes and (Darwinian) selection of traits, in evolutionary terms. This theory argues that the supposed natures of males and females originated in most sexual species with ancient selection pressures that favoured more parental care by mothers than by fathers, which in turn favoured discriminating, passive females and competitive, profligate, and aggressive males. The logic is based on the fact that females usually have more to lose than males through poor reproductive decisions, so that selection favoured careful, choosy females (Gowaty, 2003).

This theory also explained the Darwinian assertion that the dual mechanisms of male–male competition ('as the male is generally eager to pair with any female and competition among them is for the possession of the other sex') and female mate choice ('females tend to choose the most attractive partner') are the two most prevalent mechanisms of sexual selection (Fehr, 2011). The fact that females of 99 per cent or more of sexual species have bigger sex cells or gametes than males is consistent with the Parental Investment Theory— larger gamete size translates to more investment, which has allowed it to achieve axiomatic status in disciplines like sociobiology and evolutionary psychology. Because of the tremendous intuitive appeal of the theory, it is an ubiquitous feature in elementary animal behaviour, behavioural ecology, and evolutionary ecology texts as well.

Patricia Adair Gowaty, feminist practitioner of evolutionary biology, alleges that perhaps it is this 'intuitive appeal' of this model that has prevented investigators to test how this theory is associated with sex roles in 'typical species' — species with mother-biased offspring care patterns or in which females invest more time, energy and resources in bringing up their children (Gowaty, 2003). Feminist biologists like Ruth Hubbard have expressed concerns over wholesale application of this model of sexual selection without empirically testing its underlying assumptions. She has also pointed out the close parallels of this Darwin inspired account of eager males competing with one another for access to reticent, choosy females with victorian gender values of the time (Fehr, 2011).

Parental Investment Theory has indeed been a flash point of controversy within and outside evolutionary biology. It has been accused of being just a story that reinforces the *status quo* notions about sex roles; notions that are often used to confine women to their 'natural' roles as mothers and

as subordinates to men. Some have also alleged that this model provides a basis for arguments that rape is 'natural', and is rather an evolutionary given. This model indeed spells doom for any critical feminist aims as, 'even with identical education for men and women and equal access to all professions, men are likely to maintain disproportionate representation in political life, business, and science' (Fehr, 2011).

Feminist critics have repeatedly questioned the Parental Investment Theory on the grounds that observation often fails to match the predictions made. Females have been found to be aggressive and enthusiastic about sex not only in species which have male biased parental investment (like seahorses and pipefish) but also in species with typical mother biased parental investment too. In addition to this, certain feminists have postulated that male manipulation of female behaviour, sexuality and reproduction related decisions may also cause restraining of female sexuality. It is argued, 'if female sexuality is biologically muted by ancient selection pressures, why must men and their families go to extreme lengths to control and contain it?' An evidence for this hypothesis was provided by a study on fruitflies that identified certain ejaculated peptides from males, the exposure to which decreased the lifespan of females. Thus, the male 'chemical weapons' have been shown to prove significant for understanding the origin of female natures as well (Gowaty, 2003).

Apart from the presence of alternative theories that have tried to dissociate sex specific differences in reproductive success variance from universal sex roles, there have been attempts to test the Parental Investment Theory in other species of fruitfly than Drosophila *melanogaster*. In her paper, *'Sexual Natures: How Feminism Changed Evolutionary Biology'*, (2003), Patricia Adair Gowaty reports working with two different species of fruitflies—Drosophila *hydei* and Drosophila *pseudoobscura* in order to find experimental evidence against this model. The thorough scientist opines that ultimately it is the accumulation of data inconsistent with the current dominant hypotheses that changed science. She ended up finding results which were not consistent with those predicted by parental investment theory in D. *pseudoobscura*. She found that both females and males showed no difference in interest in mating or their 'basic nature.' In the other species, D. *hydei*, males showed statistically significant, higher interest in females than females in males. This observation, too, was in contrast with the predictions of the Parental Investment Theory for this particular species as the gamete sizes are comparable and so allegiance to PTI should have caused the males to be more discriminating and less aggressive.

Primatology

Studies on primate societies like those of baboons, chimpanzees and other apes have been a cornerstone of most biology departments. Although primatology proper is the study of the behaviour, evolution and biology of primates in their own regard, the knowledge gleaned from such works has been used to draw conclusions about human behavioural evolution as well. Historically, the studies were done on savannah baboons which had social structures that seemed similar to humans. Echoing popular ideological currents, the knowledge generated was such that further 'naturalised' the promiscuous male, passive female stereotypes by providing evidence of such traits in our ancestral predecessors as well. But it was the entry of feminist women in the discipline that instigated, what Donna Haraway calls, a 'powerful methodological revolution'. She credits feminist primatologist Jeanne Altmann who developed a method called focal-animal sampling that undermined previous research that generated sexist accounts of leadership and control in baboons; her method enabled research on female primates and on novel topics such as mothering (Haraway, 1989). Significance of female bonding through matrilineal networks was studied and an analysis of female sexual assertiveness, female social strategies, female cognitive skills, and female competition was done. Conventional wisdom on baboons now recognises that females provide social stability, while males move from group to group (Schiebinger, 2000); and females actively solicit sexual favours from their male counterparts even when mating and collection of sperm for reproduction is not a real agenda. These changes in perspectives happened because a lot of female scientists were entering the profession of primatology and began paying attention to females (Fehr, 2011).

Here a reorientation of field observation practices brought into focus the central role played by females in primate societies, and the importance of 'tactics other than aggression (particularly those that rely on social finesse and the management of relationships),' making it clear that 'hierarchy may or may not have a place in primate society, but that males and females are equally capable of competition' (Strum and Fedigan, 2000; cited in Crasnow, 2015, section 3.1).

A Word on Physics

It is a well acknowledged fact in feminist science circles that most work has been done on biology to the exclusion of all other sciences. In fact, many find it curious that despite the lack of attention to the physical sciences in feminist critiques, at the level of autobiography or experience, it is physics that gets 'over-represented' (Hammonds and Subramaniam, 2003).

Demography, quite overwhelmingly, seems to be the major feminist issue

relevant to physics. Near absence of women in this discipline that valorises abstract thought and imagination has been a concern ever since feminists steered their critiquing forces toward the natural sciences. It is a no-brainer that women are seriously under represented in physics. Although percentage total enrolment of women has grown from 10.9 per cent in 1950–1951 to a healthy 39.4 per cent in 2000–2001 in India. In 2000–2001, 39.4 per cent of all university science students were women (a slight increase over 37 per cent in 1995–1996), yet, the most serious problems for Indian women in the sciences, above all in physics, start at the post PhD level. The number of women faculty members in the physics departments of Indian universities and research institutes is found to be dismal, rarely crossing even 10 per cent. A survey of eight premier research institutes found 20 of the 245 physics faculty were women, while in the seven Indian Institutes of Technology 16 of 201 physics faculty were women. The universities fared little better: 11 university physics departments surveyed had only 30 women faculty members out of 258. In many cases, this fraction has remained roughly constant over more than a decade (Chandra, Godbole, Gupte, Mehta, Narsimhan, Rao, Sharma and Surya, 2009). The authors of this study provide several recommendations that aim to increase the participation of and retain more women in physics. They include measures such as forming support system for women, such as science camps for girls, for inclusion of underrepresented categories; offering incentives to institutions to hire women and make it possible for their spouses to work at the same place; making workplaces more amenable to women with household responsibilities by providing childcare facilities and flexitime and part time options.

Implications for Science and Education

There is evidence that working scientists either do not take feminist (or other sociological) criticisms of science seriously enough to influence their own work or they dismiss them as inconsequential and ill-founded. Even women scientists interpret these concerns as threatening beyond a certain point; they fear all their gains in science would be disregarded by focusing on their identity as a woman scientist or on their gender (Keller, 1993). Such perspectives stem from a lack of awareness of the concept of gender. Most people, scientists included, conflate gender with women, their concerns and challenges. But gender is a much larger category that encompasses men and women, their experiences and identities, the social and cultural division of labour and activities that produce their differential experiences, and the political and intellectual import of such categorisation.

Such an explication of the concept of gender shows a way forward on how to bring science, science education and feminist criticisms of science closer. Scientists spend nearly a decade of their adult lives in their scientific training, under which they acquire not only the most advanced knowledge of their fields, but the ways of thinking and reasoning about nature and their work, larger methodological and epistemological frameworks that guide their scientific contributions and constitute their worldviews. Expecting a thorough socialisation in a scientific culture to be changed by exposure to feminist ideas much later in their professional lives is a bit far-fetched if not completely untenable. And here comes the value of assimilating feminist perspectives of science with science education.

Research in the field of science education has established that nature of science instruction in schools ought to have an explicit character (McComas, Almazroa and Clough, 1998). Experiments in which students were expected to implicitly reach an understanding of how science proceeds did not show any positive gains in students' understanding of the nature of science issues. Given such a context, a categorical instruction and systematic exposure to feminist perspectives on science holds tremendous potential for improving not just science education but also the practice of science and the products that result from that practice when students educated thus would go onto become scientists in the future.

We can appreciate from the foregoing discussion that over the four decades of feminist scholarship in the sciences, the internal logic of feminist criticism in the sciences has shifted along a spectrum from liberal to radical (Rolin, 2004). Early feminists were mostly concerned with the issue of fewer women in science, channelising their efforts to understand the particular institutional and social barriers to their participation and uncovering the forgotten contributions of women to science in the past. They examined the historical conditions in which science was institutionalised and the dynamics that led to women's and femininity's exclusion from what counted as science.

Gradually, feminist attention shifted to the 'scientific' or intellectual consequences of historical under-representation of women, and scholars began asking how that under-representation affected the choice of problems, how (inadvertent) bias crept into design of experiments, and interpretation of data and formulation of theories (Keller, 1985). This kind of knowledge also led to an examination of western philosophical structures that legitimated the kind of science produced, and was followed by an affirmation of the roles of philosophical ideas such as reductionism, atomism and

individualism played in forming the basic character of modern science.

We are aware of the many dangers that have befallen us due to this reductive and violent way of generating knowledge about the natural world. The issues are not just 'feminist' but concern the humankind on the whole. Destruction and eradication of forest cover that endangers survival of many bird and animal species, indiscriminate mining for natural resources that adversely affects populations of people around the world, development of monocultures and 'scientific forestry' which reduces plant varieties and thus, contributes to dangers of severe food shortage and disturbance of ecological balance, and increasing global warming that spells doom for the entire planet—the challenges that modern science has given rise to are immense.

I believe that weaving feminist appraisals of science in the teaching of science can serve as one corrective initiative. The preceding discussion on feminist impact on subjects of archaeology, evolutionary biology and primatology has tremendous educational value not just with respect to science, but also social sciences and the larger goals of education. A pervasive theme in feminist analysis of scientific knowledge involves a strong challenge to the masculine-feminine or male-female dichotomy and other oppositional pairings that structure our theoretical world such as reason-emotion, mind-matter, nurture-nature, objective-subjective and mind-body, among others, which map onto the male-female dichotomy directly. Acknowledging the constructed nature of this set of oppositions and the ways in which they serve sexist interpretation of the world can help weaken their power over us.

Feminist archaeologists have been warning their colleagues against superimposing present cultural categories on the narratives weaved about lives of antiquity. There have been studies that illustrate that roles in past societies were not as strictly divided as they are in the present day and age, that both men and women had access to exotic objects and sources of wealth. In fact, it has also been pointed out that wealth or control of material resources was not the sole source of power in those societies (Hays-Gilpin, 2000). Similar counsel has been provided by feminists in primatology. They are wary of capturing and confining the world of primates in concepts that structure human society and thus distort the knowledge that is generated about them.

Another serious issue raises itself when we look to nature for ways of organising our societies and social relations. Feminists have brought to our notice that once animal behaviour or behaviour of humans in prehistory is understood to follow gender norms of modern times, such instances are taken to establish the 'naturalness' of prevalent gender norms. As a result, scientific knowledge ends up

playing a role in the legitimisation of social inequalities. At the same time, emerging feminist scholarship has shown that gender is complicated and multifaceted. Taking it (gender and its complicatedness) into account makes a difference in how we interpret past ways of life and experiences.

Feminist contributions in the field of evolutionary biology have alerted us to the limitation of the scientific method to root out sexist and androcentric biases of the best of our theories. The intuitive appeal of parental investment theory which led to its uncritical acceptance by the scientific community challenges the objectivity and assumed neutrality of science. This can be used as an example to illustrate to students that adequate empirical tests are necessary to prove or disapprove a scientific theory despite its 'natural' appeal. Many a times, the best of scientific minds fall victims to the powerful forces of ideology which sneak into their scientific works.

Extending these criticisms can help teachers and students question other taken-for-granted dichotomies such as public-domestic and sacred-profane which structure the lives and experiences of men and women differently. Making space in our curriculum for a discussion on women from the past whose work was ignored or not duly acknowledged and highlighting the presence and value of women's work in scientific and other public activities are a few steps towards reclaiming science for young girls and women. Such kinds of discussion have liberatory potential for both students and teachers. Becoming aware of the ways in which science both promotes and limits our thinking is valuable for any human being, and feminist critiques of science are a handy tool to achieve such an understanding.

Conclusion

Feminists have a number of distinct perspectives on science. They have articulated positions that reveal a variety of gender-based forms of oppression that have characterised science since its ancient origins and its modern reincarnation. Feminist critiques have challenged the soundness of knowledge that is produced in scientific disciplines by exposing how gender ideologies of scientists had crept into different stages of their rational, objective scientific work—from selecting a portion of reality to study, to describing it in certain acceptable terms, to framing testable hypotheses, and to describing the evidence called on to support a particular hypothesis. An increasing feminist consciousness has resulted in increased instances of feminist research ethics being followed, such as democratising research, fostering views on nature from different vantage points, being open to continuous revision in theory, evidence, and interpretation, and favouring theories that do not mask complexity and heterogeneity.

Unfortunately, such revisions to scientific practices and knowledge are few and sporadic. At the same time, the conceptual and fundamental critiques have had the most profound effects on the disciplines which are labelled as 'soft' and in which women are present in comparable numbers to men—social and life sciences. Realising the analytical and political force of feminism requires that similar criticisms be directed against physical sciences too. Weaving feminist criticisms of science with current science education until we have a formal space in curriculum for them is a good strategy to remedy the situation.

The way forward from here seems to involve ourselves in the act of 'reconstruction' (Subramaniam, 2009). Armed with the knowledge of ways in which sexist and androcentric distortions occur in science, we, as actors in the field of (science) education, should make use of this knowledge to convey the truly human character of science to our students. Our pedagogies should incorporate feminist learnings. They should include methods and strategies such as peer instruction, just-in-time teaching, inquiry-based science and physics workshop that have been shown to attract girls and students from other marginalised backgrounds. We should bring to our classrooms the discussion that despite popular opinion, science is not a certain, absolute truth about the world. Scientific knowledge is generated by human actors in very human settings and thus is vulnerable to values scientists hold. But once we stay open to constructive criticism of our work from feminists or other social critics, we have the opportunity to reinvent and improve our own science and along with it our own society.

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