

CONSTRAINTS TO CONTRIBUTIONS: EXPLORING WOMEN'S BREAKTHROUGHS IN STEM FIELDS IN INDIA

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STEM, an acronym for Science, Technology, Engineering, and Mathematics, encompasses a range of vital disciplines that are shaping the present and defining the future of the nation's development. Promoting STEM education fosters critical thinking, logical and analytical reasoning, and problem-solving skills, and paves the way for innovative and sustainable solutions. STEM education focuses on hands-on and problem-based learning methodology by integrating all four domains through an interdisciplinary approach. In the technologically enabled world we live in, the importance of STEM education cannot be stressed enough. In 2015, the United Nations earmarked 11 February every year as 'International Day for Women and Girls in Science'. National Science Day is observed annually in India on February 28 and in 2020 the focal theme was 'Women in Science'. It was also the year when 11 chairs were established in the names of women scientists from India at various institutes across the nation.

Globally the number of women in science and engineering is improving, yet men continue to outnumber women. Women's advances in the domains of STEM can be seen through the lens of the recognition they have received for their contributions. One aspect of disparity illustrates the vast gender gap in Nobel laureates. Since the inception of the Nobel Prizes in 1901 till 2023, only 65 women are Nobel laureates, as compared to 905 male Nobel laureates in all categories. In the categories of Physics and Chemistry, there are 13 female winners against 406 male laureates. (Richter) Women's limited representation in fields that emphasize rationality, particularly in the fields of Science, Technology, Engineering, and Mathematics (STEM), can be considered a consequence of men's and women's divergent skills, or it can be considered a consequence of the patriarchal constructs of society. As per an article ("India Climbs Eight Places to 127 in Global Gender Index, Says WEF Report"), India has ranked 127 out of 146 countries in terms of gender parity according to the World Economic Forum's annual Gender Gap Report, 2023. The male-to-female ratio in India's workforce stands at 78%-18%, women hold only 14% of the top executive functions across Fortune 500 companies, and women constitute only 36% of our technology workforce. Women's participation in STEM disciplines remains limited, especially in the domains of Engineering, Information and Communication Technology (ICT), and Physics. Globally, gender parity in the STEM ecosystem is also imbalanced with women constituting only 29% of the STEM workforce. The article goes on to say that in India, 43% of STEM graduates are women, yet, as of 2023, only 27% of women were part of the STEM workforce and only 16% of STEM faculty members in India are women. ("International Women's Day: Empowering Women in STEM Is Key to Bring about Gender Parity.")

The issue of women's participation in STEM fields in India is not as much about whether women have the required opportunities or skills to succeed but rather the loss to STEM that will occur without the full participation of all capable candidates, irrespective of their gender. Stereotypically women are represented as mentally lesser, weak, and relying on emotion, whereas men are represented as rational thinkers, mentally superior, and strong. Hilary Rose writes, Evelyn Fox Keller, writing of her experiences as a student physicist and later as a research worker, draws attention to subtle, and not-so-subtle exclusion mechanisms deployed against women scientists." (Rose 76) Feminist standpoint theory prioritizes thinking from women's or marginalized lives and the theory considers these lives as privileged sites of knowledge production.

...it is unequivocally clear that the elite of science—its managers and the constructors of its ideology—are men. Within science, as within all other aspects of production, women occupy subordinate positions, and the exceptional women who make it in this man's world only prove the rule. (Rose 73)

The All India Survey on Higher Education (AISHE) 2021-22 presents comprehensive statistics on the Higher Education scenario in the country in which data on various aspects is collected for analysis from the Higher Education Institutions of the country in online mode. According to the report, the enrolment in STEM (at U.G., P.G., M.Phil., and Ph.D. levels) is 98,49,488, out of which 56,56,488 are males and 41,93,000 are females. Engineering and Technology stream had 34.71 lakh students enrolled. The total number of male students enrolled in Engineering is 71.2%, whereas female participation in this sector is low. The number of students enrolled in the Science stream is 25.33 lakh and out of this 51.7% are male students and 48.3% are female students. The situation is a bit better in the case of Science degrees where the enrolment of females is lesser than male students but there is not a wide gap between their enrolments. The representation of women in Engineering studies hasn't seen much improvement from 28.8% in 2012-13 (as per AISHE 2012-13) to 29.14% in 2021-22 (as per AISHE 2021-22). ("Department of Higher Education") Many Indian students opt to pursue Engineering after their senior secondary education. the National Testing Agency conducts the highly competitive Joint Entrance Examination – Main, formerly All India Engineering Entrance Examination, a

standardized computer-based test for admission to various technical undergraduate programs like engineering and architecture in India. The gender-wise distribution of candidates registered in both sessions of JEE Main in 2023 indicates that out of the total of 1162398 registered candidates, 357545 are females (30.7%). While the enrollment ratio of girls in higher education has been steadily increasing over the years, there is still a gaping difference prevalent in the number of boys and girls who end up in engineering and technology courses. (“Press Release.”)

Deliberating on the constraints and challenges that women in STEM face in India, Nandana Sengupta talked about the stereotypes and gender divide prevailing in educational and professional settings. (“Women in STEM in India”) She shared her observations on how women’s roles even in liberal institutions are often limited to “academic housekeeping” wherein relatively lesser significant tasks are assigned to women at academic institutions. There is also the issue of the leaky pipeline phenomenon in STEM which sees a clear gap between the enrollment of female students, their actual employment, and taking on leadership roles. Stereotypes, such as the belief that technical fields are more suitable for boys, emerge in early schooling and play a role in influencing women’s career choices and participation in STEM disciplines. Gender disparities in household chores and domestic commitments, and constraints on mobility to pursue advancements in career often hinder women’s progression in STEM fields.

Former CEO of Pepsico Indra Nooyi weighs in on the topic of work-life balance in her book *My Life in Full: Work, Family, and Our Future* (2021). Writing of the dilemma of the gendered term ‘working women’, Nooyi considers there is no such thing as balancing work and family, which she feels is a constant juggling act. Nooyi spoke of the unrealistic expectations placed on women executives who are also caregivers with expectations on them to excel at their workplaces as well as the pressure of proving themselves as a good wife and a good mother. In her interaction with the conversation with David Bradley, she shares that a woman ‘having it all’ is just an illusion that comes with painful sacrifices and tradeoffs that are accompanied by constant feelings of guilt. She says, “I don’t think women can have it all. I just don’t think so. We pretend we *have* it all. We pretend we *can* have it all.” Nooyi’s observations on starting a family were:

“...the biological clock and the career clock are in total conflict with each other. Total, complete conflict. When you have to have kids you have to build your career. Just as you’re rising to middle management your kids need you because they’re teenagers...And as you grow even more, your parents need you because they’re aging. So we’re screwed... stay at home mothering was a full-time job. Being a CEO for a company is three full-time jobs rolled into one. How can you do justice to all? You can’t.” (Forbes)

Feminist theorist Sandra Harding coined the term ‘standpoint theory’ to categorize epistemologies that emphasize women’s knowledge. Dorothy Smith in *The Everyday World as Problematic: A Feminist Sociology* (1989) argued that because women have been traditionally taking on the roles of the caregivers of society, men have been able to focus on abstract concepts that are viewed as more valuable and important. (“Standpoint Theory”)

Considering the contributions of women in STEM in India, Savitribai Phule, the pioneer for women’s education merits first mention. The first female schoolteacher in India was an influential social reformer and trailblazer in providing education for girls and ostracized sections of society. She opened a school for girls in Pune with her husband Jyotirao Phule in 1848 wherein the curriculum included mathematics, science, and social studies and was based on Western education. As a tribute to this strong lady who stood firm for the cause of women’s education in India, Pune University is named after Savitribai Phule. The couple went on to establish 17 more schools. Savitribai Phule challenged the conventional gender roles prevalent in her times by breaking social norms and actively working to emancipate women through education. Her life is heralded as a beacon of women’s rights in India and she is often referred to as the mother of Indian feminism. (“Savitribai”)

Some of the pioneers who paved the path for women scientists to follow are Anandibai Gopalrao Joshi, the first Indian woman to study and graduate with a degree in Western medicine from the United States in 1886; Kadambini Ganguly (1861-1923), India’s first female doctor and practitioner (1886) of western medicine in South Asia; Mary Poonen Lukose is India’s first female Surgeon General. Rupa Bai Furdoonji is the world’s first female anesthetist (1888). Bibha Chowdhary was India’s first woman high energy physicist and the first woman scientist at the TIFR (1948); Asima Chatterjee was the first woman to be awarded a Doctor of Science by an Indian University (Calcutta University) and was also the first female recipient of Shanti Swarup Bhatnagar Prize in Chemical Science Category in 1961; renowned botanist and plant cytologist Edavaleth Kakkat Janaki Ammal, was the first Director of the Central Botanical Laboratory at Allahabad, 1952 and was also the first Indian scientist to be awarded the Padma Shri in 1977; Kamala Sohoni, the first Indian woman to receive a Ph.D. in a scientific discipline; Iravati Karve India’s first female anthropologist; Debala Mitra, the first Indian archaeologist to have served as Director General of the Archaeological Survey of India in 1981; Indian physicist Purnima Sinha who received a doctorate in Physics under the guidance of Prof. Satyendra Nath Bose. Her contributions were tremendous in the field of x-ray crystallography of clay minerals; Ayyalasomayajula

Lalitha is India's first woman engineer in 1943; Rajeshwari Chatterjee, who pioneered research in microwave engineering and the first woman engineer at IISc who joined the Department of Electrical Communication Engineering in 1952; Anna Mani, the first woman to join the Meteorological department in Pune, 1948. Her major contributions are in the field of solar radiation, ozone, and wind energy instrumentation; Kamal Ranadive established India's first tissue culture research laboratory at the Indian Cancer Research Centre in Mumbai, in 1960. Hiriyakkanavar Ila was the First woman to receive a Ph.D. from the Indian Institute of Technology (IIT), Kanpur; Archana Sharma was the first female to be awarded the prestigious Shanti Swarup Bhatnagar Prize in the Biological Sciences category in 1975; Sudipta Sengupta and Aditi Pant are the first Indian women to visit Antarctica in 1983. Tessy Thomas is the first woman scientist to head a missile project in India; Sanghamitra Bandopadhyay is the nation's first woman Computer Scientist and Director of the Indian Statistical Institute (2015); Soumya Swaminathan is the first Indian to become WHO's Deputy Director General, and also its first chief scientist; GC Anupama is the first woman President of the Astronomical Society of India (2019). ("Indian Women Scientists")

A significant step in furthering India's space ambitions, India's maiden mission to Mars (Mars Orbiter Mission) Mangalyaan was launched on 5 November 2013 by the Indian Space Research Organization (ISRO). The mission had a team of about 500 people working to make it a success, and about 27% of the key executive positions in the mission were held by women. Minnie Vaid's *Those Magnificent Women and Their Flying Machines* highlights the efforts of women scientists towards the success of Mangalyaan. Ritu Karidhal, Nandini Harinath, Anuradha TK, Moumita Dutta, and Minal Rohit were some of the scientists who were given critical tasks in the execution of the mission. Nandini Harinath shares her observation, "Many times I wonder about all the attention that we women scientists are getting...my male colleagues who work equally hard also deserve it, right? But sometimes I also feel that women need that kind of example so that they know it [success in science] is possible and they should not give up." (Vaid)

Speaking of women who have successfully shattered the proverbial glass ceiling, and made outstanding contributions to sciences and research, Kiran Mazumdar-Shaw is the first Woman Science Entrepreneur who founded Biocon (1978) - an innovation-led global biopharmaceuticals enterprise. A pioneering biotech entrepreneur and global influencer, she has many international and national recognitions to her credit. In 2023, she was conferred with Fortune India's Most Powerful Women Award for the year 2022, EY World Entrepreneur of the Year in 2020, ranked at the sixty-eighth position on Forbes list of World's 100 Most Powerful Women in 2020 and was the recipient of Australia's and France's highest civilian awards, in addition to Padma Bhushan (2005) and Padma Shri (1989). ("Kiran Mazumdar-Shaw")

On 08 March 2024, India's Prime Minister Shri. Narendra Modi announced that philanthropist Sudha Murthy has been nominated to Rajya Sabha by President Smt. Draupadi Murmu. The PM hailed her nomination to the Rajya Sabha as a powerful testament to 'Nari Shakti' (women's power), exemplifying the strength and potential of women in shaping the nation's destiny. Sudha Murthy is a Padma Bhushan awardee (2023), and Global Indian Awardee (2023) bestowed by the Canada Indian Foundation to honor a distinguished Indian individual who has made a significant impact in their respective field. She is the former chairperson of the Infosys Foundation which she spearheaded for 25 years (1996-2021). Her husband Narayan Murthy is the founder of the IT giant Infosys, and the current Prime Minister of the United Kingdom Rishi Sunak is her son-in-law. While pursuing her engineering education, Sudha Murthy secured the first rank across all engineering branches, and she earned a gold medal from the Institute of Engineers. She became the first woman engineer hired at India's largest auto manufacturer TATA Engineering and Locomotive Company (TELCO). She joined the company as a Development Engineer in Pune at a time when women were not employed. On finding out that only men could apply for the job vacancy, she wrote a postcard to JRD Tata complaining about gender discrimination at TELCO. She shared about her experience in a television show during which she stated her point that "women work better than men and if they are not given the chance, they won't be able to prove themselves." This communication led JRD Tata to change the prevalent 'only male employees' policy and order for interviews and examinations to be conducted for female applicants. ("Throwback") Murthy is also a prolific writer in English and Kannada with 30 books and over 200 titles to her credit which have sold more than 26 lakh copies. Her love for her mother tongue Kannada led her to establish more than 60,000 libraries in Karnataka. In 2010 Harvard University and Harvard University Press (HUP) announced that Sudha Murthy and her husband have established a new publication series, the Murthy Classical Library of India to make the rich classical heritage of India accessible worldwide, with a donation of \$5.2 million. (Harvardgazette)

In the field of Mathematics, Shakuntala Devi was an internationally renowned mathematical prodigy who was gifted with an exceptional ability to carry out highly complex mathematical calculations in her mind at a speed faster than the available computers, which earned her the sobriquet of Human-Computer. She was also skilled in calendar calculation where she could identify the day of any date in the last century. A psychologist from the University of California-Berkeley, Arthur Jensen, conducted several tests on her skills and published the findings in the journal *Intelligence* in 1990, but there was no conclusive evidence of how she was able to perform incredible numerical feats. A parallel can be drawn between his hypothesis regarding Shakuntala Devi and Sandra Harding's standpoint theory when he mentions in his report "Devi 'perceives' large numbers differently from the way most of us ordinarily do. When she takes in a large number (and she must do this

visually), it undergoes some transformation, almost instantly — usually some kind of simplification of the number.” (Ed, Team Leverage) Shakuntala Devi was a prolific writer who authored several books on calculations, and mathematical puzzles, grooming children in mathematical skills, astrology, cookbooks, and novels. Her exceptional mathematical abilities earned her a place in the Guinness Book of World Records in 1982, the Ramanujan Mathematical Genius Award in 1988, and the Lifetime Achievement Award in 2013 conferred by the Indian National Mathematical Olympiad.

On the policy front, corporates, and academic institutions have undertaken many strategic and collaborative initiatives to promote STEM in India. Gender Advancement for Transforming Institutions (GATI) and Women in Science and Engineering-KIRAN (WISE-KIRAN) are specially designed schemes to promote gender equality. India’s Science and Engineering Research Board’s (SERB) initiative of POWER (Promoting Opportunities for Women in Exploratory Research) is working towards increasing the participation of women scientists in research by offering grants and fellowships and aims to mitigate gender disparity in science and engineering research funding. Academic institutions are augmenting their curriculums and embedding STEM-focused skilling. Many organizations are focusing on Diversity, Equality, and Inclusion (DEI) initiatives to enhance and support the involvement of women in STEM. Efforts are being taken to bridge the gender disparity by promoting STEM education for girl children, supporting upskilling of women and research in STEM, and supporting startups in science domains that are led by women. Some studies indicate that when reviewing the same resume but with a female versus a male name, the female prospect was rated lower than the male. Removing an applicant’s name in the application process could be a step in the right direction for equality in evaluation as STEM skills are not gender specific.

The way ahead to encourage more women to participate in STEM fields is to address barriers, challenge societal perceptions, and foster inclusivity, promote mentorship to create an environment conducive to women’s advancement in STEM fields. On a general note, pay parity, more structured childcare systems, and offering flexible working hours, adapting inclusive terminology would enable women in the workplace to give time to their families in their roles of caregivers as well as contribute to creating more positive workplaces. Encouragement by family and teachers to girls and young women to pursue STEM fields, as well as providing successful female role models in STEM, may result in creating a lasting impact for a more inclusive work culture and harnessing the full potential of the nation’s women in STEM fields.

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