Gender Disparities in STEM Education and Patterns of Female Participation in India

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KEYWORDS
STEM education, gender disparities, Becker's D coefficient, engineering education, science education, higher education, doctoral research, India

ABSTRACT
This study explores the gender disparities in Science, Technology, Engineering, and Mathematics (STEM) education in India over ten years, spanning from 2012 to 2022, using data from the All India Survey on Higher Education (AISHE) for the academic year 2021-22. The focus is on engineering and science disciplines across different levels of education—undergraduate (UG), postgraduate (PG), MPhil, and PhD. Using Becker's D coefficient to measure the degree of gender imbalance, the analysis reveals that male students consistently dominate engineering programs, especially at the UG and PhD levels, where the D coefficient regularly exceeds 1, indicating a significant overrepresentation of males. While there are some positive trends at the MPhil level, where female participation occasionally surpasses male enrollment, the data suggests that women continue to face challenges advancing into doctoral research in engineering. In science fields, the gender dynamics are more balanced. Female students outnumber males at the PG and MPhil levels, as reflected by negative D coefficients. The UG level shows a relatively equal distribution between genders, with a slight female majority in recent years, which mirrors broader national trends of increasing female participation in science. However, male dominance returns at the PhD level, highlighting the structural obstacles that women encounter in pursuing advanced research careers in science. These findings underscore the importance of targeted policy interventions to address these disparities and promote gender equity in STEM education, particularly in engineering and at the doctoral level.

1. Introduction

In recent years, female enrolment in higher education in India has shown a steady upward trend, reflecting significant progress in gender inclusion at the tertiary level. According to data from the All India Survey on Higher Education (AISHE), the Female Gross Enrollment Ratio (FGER) increased by 32% between 2014 and 2022. For five consecutive years, the FGER has surpassed the Male Gross Enrolment Ratio (MGER), highlighting a positive shift towards greater female participation in higher education. However, despite these overall gains, female enrolment in Science, Technology, Engineering, and Mathematics (STEM) courses has not kept pace with the broader trends in higher education. This disparity points to persistent challenges in gender equity within STEM fields, which are critical for fostering innovation, economic growth, and social progress in India. STEM education equips individuals with the skills required to thrive in emerging fields such as artificial intelligence, biotechnology, and renewable energy, making it essential for the country's development.

The present study aims to examine the trends and patterns of female participation in STEM courses across India from 2012 to 2022, using data published by the Ministry of Education in various

AISHE reports. Becker's D coefficient (D) is applied to detect and analyse the presence of gender-based patterns in enrolment, providing insights into the extent and evolution of the gender gap in STEM education. This research seeks to offer evidence-based recommendations to promote gender equality and improve female representation in STEM fields, ensuring more inclusive access to opportunities in India's rapidly evolving knowledge economy.

2. Literature and Evidence on Gender Disparities in STEM Education

Achieving gender parity in education has been a key objective in global frameworks such as the Millennium Development Goals (MDGs, UN 2015)), the World Declaration on Education for All (EFA, 1990), and the Dakar Framework for Action (The World Education Forum, 2000). Despite these efforts, gender equality remains elusive, particularly in STEM education and careers. Male dominance continues to define STEM fields, restricting women's access to high-growth and lucrative careers while also reducing the potential for diverse and innovative contributions within the workforce. The persistent gender gap in STEM reflects the need for targeted interventions to dismantle cultural stereotypes and structural barriers that limit female participation (UNESCO, 2017).

Research shows that long-standing stereotypes still link abilities in mathematics and science with males, despite growing efforts to challenge these biases. The Field-Specific Ability Beliefs (FAB) hypothesis suggests that women are less likely to enter fields where success is believed to depend on raw, innate talent, a trait that women are stereotyped to lack. (Leslie et al., 2015). These ingrained beliefs shape how society perceives talent, often influencing how young girls view their abilities and potential in these fields. As a result, many girls grow up doubting their skills in subjects like maths, often feeling anxious or lacking the confidence to pursue STEM fields (Correll, 2001). Even when they perform just as well as their male peers, they tend to lean toward careers that involve working with people, believing that STEM fields might not align with their interests or goals (Miller et al., 2015). These subtle yet powerful influences often push many girls away from pursuing opportunities in STEM. Equal opportunities in these fields are essential so that both men and women contribute meaningfully to economic growth, technological advancement, and societal progress (UNESCO, 2017).

There is empirical evidence for significant differences in gender representation across various STEM fields as well. A study conducted in the USA shows that while women earn a large share of undergraduate degrees in biology, chemistry, and mathematics, they remain significantly underrepresented in fields like computer science, engineering, and physics, where they account for less than 20% of graduates (Cheryan, et.al., 2017). The authors critically examine traditional explanations for these gender disparities, such as differences in math performance and discrimination, and find that these factors do not fully explain the variations across different STEM disciplines. Instead, they propose that the larger gender gaps in certain fields are driven by three key factors: masculine cultures in fields like computer science and engineering, which create a lower sense of belonging for women; lack of early exposure to these disciplines; and gender differences in self-efficacy, with women often underestimating their abilities. They suggested that increasing female participation in these underrepresented fields will require changing the cultural norms that discourage women and providing early, inclusive experiences that foster a sense of belonging and capability for both genders.

The underrepresentation of women in STEM is also evident in India. Amirtham & Kumar (2023) examined the underrepresentation of women in STEM fields, focusing on elite institutions like the Indian Institutes of Technology (IITs). Their study highlights the significant gender disparity in these institutions, where male students and faculty overwhelmingly outnumber their female counterparts. Drawing on data from the All India Survey on Higher Education (AISHE) and reports from the Council of Indian Institute of Technology, they reveal that the gap is particularly evident at higher academic levels, such as PhD programs and faculty positions. Amirtham and Kumar's findings emphasise that systemic barriers continue to impede women's participation in STEM fields at these institutions. They argue that addressing these challenges requires intersectional reservations, which take into account not only gender but also factors like caste and class.

Previous research on gender disparities in STEM education has predominantly focused on global trends or specific regions such as the U.S. or Europe, often overlooking the unique challenges faced by women in India. While these studies emphasise the role of gender stereotypes and self-assessments as key barriers to women's participation in STEM, they do not adequately address the systemic factors specific to India's socio-cultural and institutional contexts. Furthermore, existing research tends to focus more on undergraduate enrollments and less on higher levels of education, such as MPhil and PhD programs, which are crucial stages where gender disparities become more pronounced.

In India, AISHE data provides comprehensive information on educational trends, but few studies have utilized this data to quantitatively analyze gender disparities in STEM fields over time. The Becker's D coefficient offers a unique approach to measuring these disparities, yet it remains underutilized in Indian studies. One available Indian study sheds light on these gaps, using AISHE data to highlight the significant underrepresentation of women in elite STEM institutions like the IITs. However, this research still leaves a gap in understanding broader trends in STEM participation across various educational levels and disciplines. This study seeks to address these gaps by providing a comprehensive analysis of gender disparities in STEM education in India, focusing on the period from 2012 to 2022. Using AISHE data and Becker's D coefficient, this research will identify key trends, barriers, and opportunities for promoting gender equity in STEM education across different educational levels. This analysis is crucial in the Indian context, where intersectional factors such as caste, class, and geography play a significant role in shaping educational opportunities for women. By examining these dynamics and offering insights into systemic challenges, this study will contribute to designing inclusive policies aimed at creating a more equitable STEM environment in India.

3. Data and Methodology

This study examines gender disparities in STEM education in India using data from the All India Survey on Higher Education (AISHE), spanning ten years from 2012 to 2022. The data provides detailed information on enrollment trends for male and female students across Undergraduate (UG), Postgraduate (PG), MPhil, and PhD programs in STEM fields, including disciplines like engineering, technology, and physical sciences. This dataset serves as the foundation for understanding gender patterns across multiple education levels and identifying trends in male and female participation.

To measure the disparities between male and female students, the Becker D coefficient is used. This statistical measure captures the degree of disparity by comparing the average enrollments of both genders over the years while accounting for the variability within each group. The D coefficient allows us to quantify how much male enrollment exceeds or falls below female enrollment, with positive values indicating higher male participation and negative values suggesting female dominance. This approach ensures a nuanced understanding of the disparities by considering not only the enrollment counts but also the variability in the data. The analysis focuses on how these gender disparities evolve over time and vary across different academic levels. By applying the Becker D coefficient to UG, PG, MPhil, and PhD enrollments, the study provides insights into the areas where gender imbalances are most significant.

4. Interpretation of Becker's D Coefficient

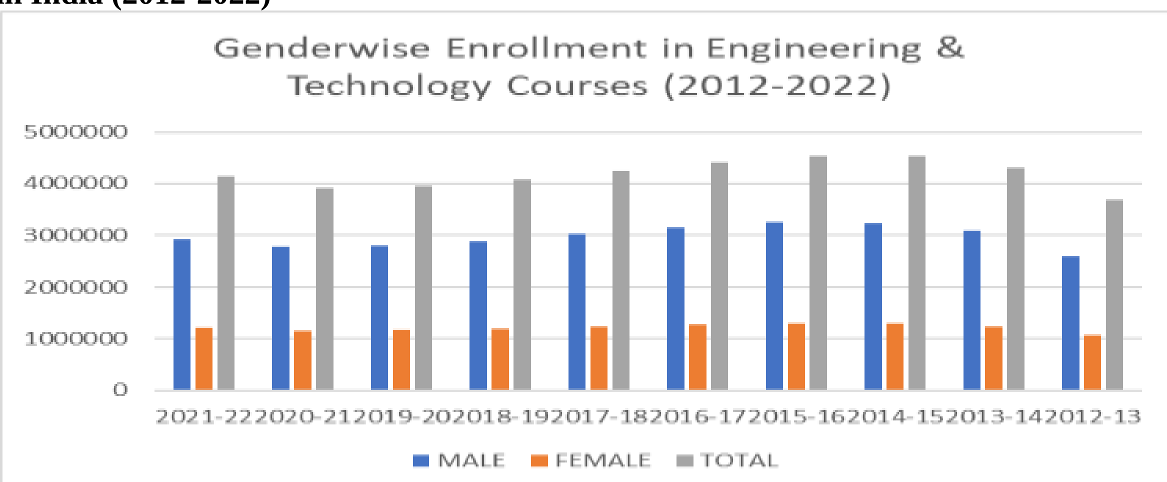
The Becker D coefficient is a valuable statistical tool for measuring disparities between two groups, such as male and female enrollments in education while accounting for the variability within each group. This measure allows for a clear assessment of how much one group differs from the other in terms of representation or participation, providing important insights into gender imbalances.

- When the D coefficient is 0, it signifies perfect equality between the two groups, indicating no disparity in participation or representation.
- A positive D value (D > 0) indicates that the first group (typically males) has a higher representation than the second group (females). The larger the D value, the greater the disparity favouring males.
- A negative D value (D < 0) suggests that the second group (females) has a higher representation. Negative values highlight greater female participation.
- A D value around ±1 is interpreted as indicating a moderate disparity between the two groups, while values beyond ±2 suggest a significant disparity, reflecting substantial overrepresentation of one group over the other.
- D values exceeding ±5 point to a large disparity, signalling a strong imbalance that likely stems from underlying structural or cultural factors.

5. Gender Trends in STEM Enrollment in India (2012–2022)

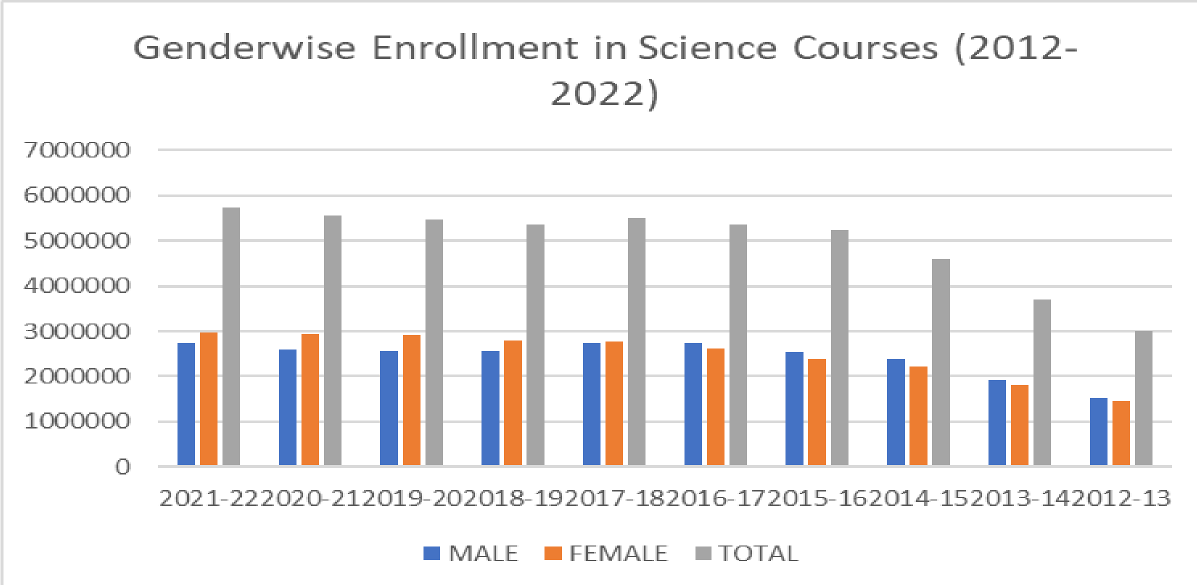
The gender-wise percentage distribution of STEM enrollment over the period from 2012 to 2022 reveals contrasting trends across Engineering & Technology and Science (including Mathematics) disciplines. In Engineering & Technology, male enrollment has consistently dominated, accounting for approximately 70-71% of the total enrollment each year, with female participation remaining relatively low at around 29-30%. For instance, in the academic year 2021-22, males constituted 70.67% of the total enrollment, while females made up only 29.33%. This persistent male dominance in technical fields suggests significant structural barriers and cultural stereotypes that limit female participation in these programs, indicating the need for policies that encourage greater female involvement.

Figure 1: Gender Wise Enrolment in Engineering and Technology Courses Across all Levels in India (2012-2022)



Source: Compiled from various AISHE Reports (2012-22)

Figure 2: Gender Wise Enrolment in Science (Including Mathematics) Courses Across all Levels in India (2012-2022)



Source: Compiled from various AISHE Reports (2012-22)

In contrast, Science (including Mathematics) shows a more balanced gender distribution, with female enrollment surpassing male enrollment in recent years. By 2021-22, 52.14% of the total science enrollments were female, compared to 47.86% male, indicating a shift towards gender equity in these fields. This pattern has remained relatively consistent, with females maintaining a slight majority in science-related disciplines throughout the decade. The data reflects different gender dynamics within STEM, suggesting that while women are gaining ground in science, engineering fields still lag in achieving gender parity. These contrasting trends reveal gendered patterns within STEM education. While males continue to dominate technical fields like engineering, science disciplines have become more inclusive of female students. However, achieving gender equity requires sustained efforts, particularly in engineering and technology, where female participation remains disproportionately low.

6. Trends in D Coefficient

Table 1 shows Becker's D coefficients for Engineering enrollments at various academic levels (UG, PG, MPhil, and PhD) across 10 years from 2012-13 to 2021-22. These coefficients reflect the gender disparity between male and female students at each level of study.

Table 1: Trends in D Coefficient in Engineering Courses

YEAR	UG Engineering	PG Engineering	Mphil Engineering	PhD Engineering	Total Engineering
2012-13	1.48	0.72	-0.3	1.56	1.409
2013-14	1.52	0.62	-0.5	1.6	1.417
2014-15	1.56	0.57	-0.8	1.51	1.387
2015-16	1.58	0.56	-0.7	1.39	1.416
2016-17	1.53	0.61	-0.7	1.23	1.446
2017-18	1.5	0.68	-0.8	1.24	1.464
2018-19	1.46	0.7	-0.9	1.16	1.499
2019-20	1.42	-0.81	-0.5	1.16	1.476
2020-21	1.45	0.99	0	1	1.506
2021-22	1.43	1.11	-1	0.94	1.425

Source: Compiled from various AISHE Reports (2012-22)

1. Undergraduate (UG) Engineering:
    - The D coefficient remains consistently above 1 across all years, indicating a persistent disparity in favour of male students.
    - For example, in 2021-22, the UG D coefficient is 1.43, showing a substantial overrepresentation of males. While there is slight fluctuation across the years, the gap remains significant.
2. Postgraduate (PG) Engineering:
    - The PG D coefficient ranges from 0.56 to 1.11 over the years. These values are moderate but still show a consistent bias toward male enrollment.
    - A notable negative value (-0.81) in 2019-20 suggests a rare moment where female enrollment surpassed male enrollment. However, by 2021-22, the D coefficient rebounds to 1.11, again reflecting male dominance.
3. MPhil Engineering:
    - The negative D coefficients (ranging from -0.3 to -1) suggest that in many years, female students outnumbered males in MPhil programs. This reversal may indicate a shift in enrollment trends at this specific level, although participation in MPhil programs is generally low compared to UG or PG levels.
4. PhD Engineering:
    - The D coefficient for PhD enrollment hovers around 1.16 to 1.6, indicating a strong male dominance at the doctoral level. This suggests that barriers remain in place for women pursuing advanced research and academic careers in engineering.
5. Total Engineering Enrollment:
    - The total D coefficient for engineering fluctuates between 1.387 and 1.506, reflecting a persistent gender imbalance across all levels, with male enrollment dominating over the years.

- The slight decline to 1.425 in 2021-22 shows some narrowing of the gap, though the overall disparity remains substantial.

The analysis reveals a consistent pattern of male dominance across most levels of engineering education, with the exception of MPhil programs, where female participation occasionally exceeds male enrollment. The UG and PhD levels show the highest disparities, indicating that female students face barriers not only in entering engineering fields but also in advancing to doctoral research and academia.

Table 2: Trends in D Coefficient in Science Courses

YEAR	UG Science	PG Science	Mphil Science	PhD Science	Total Science
2012-13	0.07	-0.17	-0.3	0.36	-0.082
2013-14	0.11	-0.21	-0.3	0.36	-0.117
2014-15	0.14	-0.28	-0.3	0.29	-0.117
2015-16	0.12	-0.32	-0.4	0.32	-0.09
2016-17	0.1	-0.36	-0.5	0.24	-0.002
2017-18	0.06	-0.37	-0.6	0.19	0.04
2018-19	-0.04	-0.42	-0.5	0.08	0.065
2019-20	-0.07	-0.42	-0.6	0.06	0.088
2020-21	-0.08	-0.37	-0.6	0.05	0.065
2021-22	-0.03	-0.94	-0.7	0	0.038

Source: Compiled from various AISHE Reports (2012-22)

1. Undergraduate (UG) Science:
    - The D coefficients for UG science fluctuate between 0.07 and -0.08, indicating a relatively balanced gender distribution.
    - In recent years, the values tend to dip into the negative range, suggesting a slight female majority in UG science programs. This aligns with national trends showing more women pursuing science fields at the undergraduate level.
2. Postgraduate (PG) Science:
    - The D coefficients for PG science remain consistently negative, ranging from -0.17 to -0.94.
    - This indicates that female students consistently outnumber male students in postgraduate science programs, suggesting that women are more likely to pursue advanced degrees in science.
3. MPhil Science:
    - The D coefficients for MPhil science are all negative, ranging from -0.3 to -0.7, indicating that female participation exceeds male participation at this level.
    - This pattern may reflect increased interest among women in research-oriented fields, although MPhil programs often have smaller enrollments compared to other levels.
4. PhD Science:
    - The D coefficients for PhD science are positive, ranging from 0.05 to 0.36, indicating a slight male dominance in doctoral-level science programs.

    - Despite balanced enrollment at the undergraduate and postgraduate levels, the male advantage at the PhD level highlights structural barriers for women in advanced research careers.
5. Total Science Enrollment:
    - The overall D coefficients for science enrollment fluctuate between -0.117 and 0.088, with most values close to zero.
    - This indicates that science fields are relatively gender-balanced when considering the aggregate across all levels of education, though specific levels (like PG and PhD) show variations in dominance.

The D coefficients for science enrollment (table 2) reveal complex gender dynamics. Female dominance is evident at the PG and MPhil levels, with consistently negative D coefficients. At the UG level, the gender distribution is close to balanced, with minor shifts favouring females. However, male dominance exists at the PhD level.

7. Results and Analysis

The analysis of gender disparities in engineering education reveals a consistent pattern of male dominance across most levels. At the undergraduate (UG) level, the D coefficient remains consistently above 1, indicating a significant overrepresentation of male students. For example, in 2021-22, the D coefficient for UG engineering was 1.43, showing a substantial gender gap. This trend persists at the postgraduate (PG) level, where D values range between 0.56 and 1.11, reflecting a moderate but consistent bias toward male enrollment. A notable exception occurred in 2019-20, when the D coefficient briefly dipped to -0.81, indicating that female enrollment surpassed male enrollment during that year. However, this reversed by 2021-22, with the D coefficient returning to 1.11 in favour of males. In MPhil engineering, negative D coefficients ranging from -0.3 to -1 indicate that female students often outnumber males at this level, although participation in MPhil programs is generally lower compared to UG and PG levels. At the PhD level, male dominance is again evident, with D coefficients between 1.16 and 1.6, suggesting that women face barriers to advancing into doctoral research and academic careers in engineering. The total D coefficient for engineering fluctuates between 1.387 and 1.506, reflecting a persistent gender imbalance, with males dominating across all levels of engineering education.

In contrast, the gender dynamics in science education are more balanced. At the undergraduate (UG) level, D coefficients fluctuate between 0.07 and -0.08, indicating a relatively balanced gender distribution, with recent years showing a slight female majority. This aligns with broader national trends, where women are increasingly pursuing science fields at the undergraduate level. At the postgraduate (PG) level, D coefficients are consistently negative, ranging from -0.17 to -0.94, indicating that female students consistently outnumber males in postgraduate science programs. A similar trend is observed at the MPhil level, where negative D coefficients between -0.3 and -0.7 show greater female participation in research-oriented fields. However, at the PhD level, D coefficients are positive, ranging from 0.05 to 0.36, indicating a slight male dominance in doctoral-level science programs. Despite the relatively balanced enrollment at the UG and PG levels, the male advantage at the PhD level points to structural barriers limiting women's access to advanced research careers. Overall, total D coefficients for science fluctuate between -0.117 and 0.088, indicating a more balanced gender distribution across all levels of science education, though disparities emerge at specific academic levels such as the PhD.

8. Conclusion

The analysis of gender disparities in STEM education over the past decade shows distinct patterns across engineering and science disciplines. In engineering, male students have consistently outnumbered female students at nearly all academic levels, with the widest gaps observed at the undergraduate and PhD levels. These findings suggest that structural barriers and cultural stereotypes continue to discourage women from pursuing careers in technical fields. Although there have been occasional improvements at the postgraduate level, more focused efforts are needed to encourage women's participation and support their advancement in engineering through scholarships, mentorship programs, and inclusive policies.

In science education, the picture is more encouraging, with female students often outnumbering males at the postgraduate and MPhil levels. However, at the PhD level, male dominance re-emerges, indicating that women face challenges in transitioning to advanced research roles. This suggests that, while women are increasingly pursuing science education, they may still encounter institutional hurdles or a lack of support when it comes to building long-term research careers.

These trends highlight the need for tailored approaches to achieving gender parity in STEM. In engineering, the focus should be on attracting more female students at the undergraduate level and ensuring they are encouraged to continue to postgraduate and research programs. In science, the emphasis should be on removing barriers to research careers and providing the necessary support for women to thrive in academia and advanced studies. Achieving gender equity in STEM education is not just about fairness—it's about ensuring that talented individuals, regardless of gender, have equal opportunities to contribute to innovation and growth. A more diverse and inclusive STEM workforce will lead to better ideas, broader perspectives, and stronger solutions, driving both economic progress and social development in India.

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