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Fintech for financial inclusion: trust and community banking; a comparative analysis of divergent pathways in Kenya and Singapore

Niangui-Mona Nély Espérance[1]

Iradukunda Sengesho Benigne2

Nizeyimana Jean Baptiste3

1. Joint PhD Researcher at Lisala University and UNCR University, Science and Technology Department, Computer Science
2. Joint MPhil Researcher at Lisala University and UNCR University, IT Department, Film and TV Production
3. Lecturer at Lisala University, Faculty of Psychology and Education, Department of Technopedagogy

ABSTRACT

This study examines the comparative dynamics of women's participation in Science, Technology, Engineering, and Mathematics (STEM) in Germany and India, two countries with distinct cultural contexts, policy frameworks, and trajectories in gender equality. Despite their divergent pathways, both nations grapple with the fundamental question of why women remain underrepresented in STEM fields and what cultural barriers and enablers shape their educational and professional trajectories. The research employs a comparative case study methodology, drawing on empirical

[1] Joint PhD Researcher at Lisala University and UNCR University, Science and Technology Department, Computer Science

research, statistical data, policy documents, and scholarly analyses spanning 2020-2026. Germany presents a paradox: a highly developed economy with strong institutional frameworks yet persistent underrepresentation of women in STEM. A 2024 group concept mapping study involving 70 women professors and scientific staff across German universities revealed that stereotypical beliefs about women, heteronomous gender roles, gender workload imbalances, sexism, and structural power relations remain significant factors hindering female success in STEM careers in higher education. Women researchers report that despite top-down measures, these issues persist, though they see potential in pedagogical interventions that raise awareness of gender bias, particularly in collaborative learning scenarios. Statistical data shows that women comprise only 29.4% of researchers in Germany overall, with representation varying dramatically by sector: 41.4% in higher education, 38.3% in government, but merely 15.6% in the corporate sector. Yet individual success stories and institutional initiatives demonstrate pathways forward. The Fraunhofer TALENTA program offers customized development for women in STEM across all career phases, providing qualifications, support programs, and networking opportunities. Young researchers like Teena tom Dieck, awarded the "Junge Macherin" Prize for her doctoral research in molecular communication, exemplify how visibility and recognition can encourage the next generation of female scientists. As she notes, "Women are unfortunately still under-represented in engineering. Initiatives like the Schnieder Prize raise visibility and encourage the next generation of female researchers and students to pursue their interests".

India presents a different picture characterized by a striking "leaky pipeline" phenomenon. Women now comprise 43% of STEM enrollments at the undergraduate level—a remarkable achievement. Yet this progress dramatically dissipates in the workforce, where women make up just 27% of the STEMM sector and under 19% of scientists, well below the global average of 31% . In academia, the gaps are even starker: only 16.7% of STEMM faculty are women, with representation at elite Indian Institutes of Technology at merely 11.2%. As women progress in their careers, fewer than 10% hold leadership roles in either academia or industry. Qualitative research with rural girls enrolled in the Vigyan Jyoti scheme reveals entrenched gender stereotypes, lack of awareness and career guidance, and financial constraints significantly affecting STEM trajectories. A phenomenological study of women scientists in higher education institutions found that women face diverse challenges and roadblocks on personal and professional fronts, including

rationalization of institutional prejudices and unwillingness to recognize discrimination. The India RISE Fellowship, launched by Johns Hopkins University in collaboration with Indian institutions, addresses the critical "leaky pipeline" by supporting early-career women scientists at the pivotal stage when many risk leaving the scientific workforce. India's space program offers inspiring role models—scientists like Nandini Harinath, Deputy Operations Director for the Mars Orbiter Mission and Project Manager for Chandrayaan-3, demonstrate that women have "overcome stereotypes by becoming reliable in handling critical space missions" . FICCI FLO's Women in STEM initiative has reached 30,000 girls and women, conducting workshops and producing a whitepaper on the STEM gender gap.

Germany's strength lies in its institutionalized support structures like Fraunhofer TALENTA, growing awareness of implicit bias through rigorous research, and recognition programs elevating visible role models. Its challenge is the persistent sectoral segregation, with women particularly underrepresented in corporate research and development. India's advantage is the remarkable undergraduate enrollment parity, the visibility of national heroes in space science, and emerging structured interventions like the India RISE Fellowship targeting the critical career transition points. Both countries demonstrate that women's participation in STEM requires: (1) recognition that cultural stereotypes operate even in highly developed contexts; (2) institutional support structures that address career-stage-specific challenges; (3) visible role models who inspire and demonstrate possibility; (4) pedagogical interventions that raise awareness of unconscious bias; (5) flexible work arrangements supporting work-life integration; (6) targeted funding and development programs for women scientists; (7) mentorship and networking opportunities; (8) systemic interventions addressing the "leaky pipeline" at critical transition points .

KEYWORDS: Women in STEM, gender equality, Germany, India, leaky pipeline, cultural barriers, implicit bias, role models, research workforce, higher education

RÉSUMÉ

Cette étude examine les dynamiques comparatives de la participation des femmes dans les domaines des sciences, technologies, ingénierie et mathématiques (STEM) en Allemagne et en Inde, deux pays aux contextes culturels, cadres politiques et trajectoires en matière d'égalité des

genres distincts. Malgré leurs voies divergentes, les deux nations sont confrontées à la question fondamentale de savoir pourquoi les femmes restent sous-représentées dans les filières STEM et quels obstacles culturels et facteurs favorables façonnent leurs trajectoires éducatives et professionnelles. La recherche emploie une méthodologie d'étude de cas comparative, s'appuyant sur des recherches empiriques, des données statistiques, des documents politiques et des analyses savantes couvrant la période 2020-2026. L'Allemagne présente un paradoxe : une économie hautement développée avec des cadres institutionnels solides mais une sous-représentation persistante des femmes dans les STEM. Une étude de cartographie conceptuelle de groupe de 2024 impliquant 70 femmes professeures et personnel scientifique dans les universités allemandes a révélé que les croyances stéréotypées sur les femmes, les rôles de genre hétéronomes, les déséquilibres de charge de travail liés au genre, le sexisme et les relations de pouvoir structurelles restent des facteurs significatifs entravant la réussite des femmes dans les carrières STEM dans l'enseignement supérieur . Les chercheuses rapportent que malgré les mesures descendantes, ces problèmes persistent, bien qu'elles voient un potentiel dans les interventions pédagogiques qui sensibilisent aux préjugés sexistes, en particulier dans les scénarios d'apprentissage collaboratif . Les données statistiques montrent que les femmes ne représentent que 29,4 % des chercheurs en Allemagne dans leur ensemble, avec une représentation variant considérablement selon le secteur : 41,4 % dans l'enseignement supérieur, 38,3 % dans le gouvernement, mais seulement 15,6 % dans le secteur des entreprises . Pourtant, des réussites individuelles et des initiatives institutionnelles démontrent des voies possibles. Le programme Fraunhofer TALENTA offre un développement personnalisé pour les femmes dans les STEM à toutes les phases de carrière, offrant des qualifications, des programmes de soutien et des opportunités de réseautage . De jeunes chercheuses comme Teena tom Dieck, lauréate du prix « Junge Macherin » pour ses recherches doctorales en communication moléculaire, illustrent comment la visibilité et la reconnaissance peuvent encourager la prochaine génération de scientifiques féminines . Comme elle le note, « Les femmes sont encore malheureusement sous-représentées dans l'ingénierie. Des initiatives comme le prix Schnieder augmentent la visibilité et encouragent la prochaine génération de chercheuses et d'étudiantes à poursuivre leurs intérêts » .

L'Inde présente un tableau différent caractérisé par un phénomène frappant de « fuite des talents » (leaky pipeline). Les femmes constituent désormais 43 % des inscriptions en STEM au niveau du

premier cycle – une réalisation remarquable . Pourtant, ces progrès se dissipent considérablement dans la population active, où les femmes ne représentent que 27 % du secteur STEMM et moins de 19 % des scientifiques, bien en dessous de la moyenne mondiale de 31 % . Dans le milieu universitaire, les écarts sont encore plus marqués : seulement 16,7 % du corps professoral STEMM sont des femmes, avec une représentation dans les prestigieux Instituts indiens de technologie de seulement 11,2 % . À mesure que les femmes progressent dans leur carrière, moins de 10 % occupent des postes de direction, que ce soit dans le milieu universitaire ou l'industrie . Une recherche qualitative auprès de filles rurales inscrites au programme Vigyan Jyoti révèle des stéréotypes de genre profondément enracinés, un manque de sensibilisation et d'orientation professionnelle, et des contraintes financières affectant significativement les trajectoires STEM . Une étude phénoménologique des femmes scientifiques dans les établissements d'enseignement supérieur a révélé que les femmes sont confrontées à divers défis et obstacles sur les fronts personnel et professionnel, y compris la rationalisation des préjugés institutionnels et la réticence à reconnaître la discrimination . La bourse India RISE, lancée par l'Université Johns Hopkins en collaboration avec des institutions indiennes, aborde la « fuite des talents » critique en soutenant les femmes scientifiques en début de carrière au stade crucial où beaucoup risquent de quitter la main-d'œuvre scientifique . Le programme spatial indien offre des modèles inspirants – des scientifiques comme Nandini Harinath, directrice adjointe des opérations pour la mission Mars Orbiter et chef de projet pour Chandrayaan-3, démontrent que les femmes ont « surmonté les stéréotypes en devenant fiables dans la gestion de missions spatiales critiques » . L'initiative Femmes dans les STEM de FICCI FLO a touché 30 000 filles et femmes, menant des ateliers et produisant un livre blanc sur l'écart entre les genres dans les STEM .

La force de l'Allemagne réside dans ses structures de soutien institutionnalisées comme Fraunhofer TALENTA, une prise de conscience croissante des préjugés implicites grâce à des recherches rigoureuses, et des programmes de reconnaissance mettant en avant des modèles visibles. Son défi est la ségrégation sectorielle persistante, les femmes étant particulièrement sous-représentées dans la recherche et développement en entreprise . L'avantage de l'Inde est la parité remarquable des inscriptions au premier cycle, la visibilité des héroïnes nationales dans les sciences spatiales, et des interventions structurées émergentes comme la bourse India RISE ciblant les points de transition de carrière critiques. Les deux pays démontrent que la participation des femmes dans les

STEM nécessite : (1) la reconnaissance que les stéréotypes culturels opèrent même dans des contextes hautement développés ; (2) des structures de soutien institutionnel qui répondent aux défis spécifiques à chaque étape de carrière ; (3) des modèles visibles qui inspirent et démontrent la possibilité ; (4) des interventions pédagogiques qui sensibilisent aux préjugés inconscients ; (5) des modalités de travail flexibles soutenant l'intégration travail-vie personnelle ; (6) des programmes de financement et de développement ciblés pour les femmes scientifiques ; (7) des opportunités de mentorat et de réseautage ; (8) des interventions systémiques ciblant la « fuite des talents » aux points de transition critiques.

MOTS-CLÉS : Femmes dans les STEM, égalité des genres, Allemagne, Inde, fuite des talents, obstacles culturels, préjugés implicites, modèles, main-d'œuvre de recherche, enseignement supérieur

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Auteurs correspondant: *Niangui-Mona Nély Espérance,Sengesho Benigne and Nizeyimana Jean Baptiste*
Adresses électroniques: *niangumonaesperance@cirep.ac.cd,benigneira0@gmail.com, nizeyimana.jb@dphu.ac.cd ,*
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1. INTRODUCTION

The underrepresentation of women in Science, Technology, Engineering, and Mathematics (STEM) fields remains one of the most persistent challenges in global higher education and workforce development. Despite decades of policy interventions, institutional initiatives, and growing awareness of gender bias, women continue to face barriers that limit their participation, advancement, and leadership in STEM disciplines. Understanding why these disparities persist—and what enables some women to overcome them—requires attention to the complex interplay of cultural norms, institutional structures, and individual experiences.

Germany and India, two countries with dramatically different cultural contexts, economic trajectories, and policy frameworks, offer a compelling comparative lens. Germany represents one

of the world's most technologically advanced economies, with strong institutional infrastructure, comprehensive educational systems, and explicit policies promoting gender equality. Yet women comprise only 29.4% of researchers nationally, with representation as low as 15.6% in the corporate sector . Research reveals that even in this highly developed context, stereotypical beliefs, gender workload imbalances, and structural power relations continue to hinder women's careers in STEM higher education .

India presents a different picture, characterized by a striking "leaky pipeline." Women now achieve remarkable parity at the undergraduate level, constituting 43% of STEM enrollments . Yet this progress dissipates dramatically as women advance through their careers, with women making up just 27% of the STEMM sector and under 19% of scientists—far below the global average . In elite institutions like the Indian Institutes of Technology, women hold only 11.2% of faculty positions, and fewer than 10% reach leadership roles.

This study examines the comparative dynamics of women's participation in STEM in Germany and India. Drawing on empirical research, statistical data, policy documents, and scholarly analyses, it explores how cultural barriers and enablers shape women's STEM trajectories in these distinct contexts. The analysis is organized around four interconnected themes: (1) the statistical landscape of women's participation; (2) cultural barriers operating at different career stages; (3) institutional enablers and interventions; and (4) lessons for policy and practice.

The study contributes to scholarship on gender and STEM, comparative education, and women's empowerment. It argues that while the specific manifestations of barriers differ across contexts, common patterns emerge—the operation of implicit bias, the importance of visible role models, the need for institutional support structures, and the critical nature of career transition points.

2. LITERATURE REVIEW

2.1 Conceptualizing Gender Disparities in STEM

The underrepresentation of women in STEM has been extensively theorized through multiple frameworks. The "leaky pipeline" metaphor describes the progressive loss of women at each career

stage, from education through advancement to leadership. Intersectional approaches emphasize that women's experiences are shaped not only by gender but also by class, caste, geography, and other social locations.

Research has documented multiple contributing factors: implicit bias and stereotypes, lack of role models, chilly departmental climates, work-life balance challenges, and institutional barriers to advancement. The persistence of these patterns across diverse national contexts suggests that both cultural and structural factors are at work.

2.2 Germany's STEM Gender Landscape

Germany's STEM gender landscape is characterized by persistent underrepresentation despite strong institutional frameworks. Key features include:

- **Statistical overview:** Women comprise 29.4% of researchers nationally, with significant variation by sector: 41.4% in higher education, 38.3% in government, but only 15.6% in the corporate sector.
- **Qualitative research findings:** A 2024 group concept mapping study involving 70 women professors and scientific staff across German universities found agreement across STEM disciplines regarding stereotypical beliefs about women, heteronomous gender roles, gender workload imbalances, sexism, and structural power relations as significant hindering factors .
- **Career-stage challenges:** Early-career researchers report uncertainties and doubts about belonging in male-dominated fields. Anne Sielemann, a doctoral researcher at Fraunhofer IOSB, reflects: "At the very beginning of my studies, I was unsure whether I should study computer science and whether I would be able to do it. These uncertainties were also due to the fact that computer science is a male-dominated domain".
- **Implicit bias in academic careers:** Research documents that even with gender-equal funding rates, evaluations may conceal unequal assessments, disadvantaging women.
- **Institutional responses:** The Fraunhofer TALENTA program offers customized development for women in STEM across all career phases, from entry-level to management, providing qualifications, support programs, and networking opportunities.

- **Visibility and recognition:** Awards like the "Junge Macherin" Prize, recognizing outstanding young female researchers, aim to raise visibility and encourage the next generation. As recipient Teena tom Dieck notes: "Initiatives like the Schnieder Prize raise visibility and encourage the next generation of female researchers and students to pursue their interests".
- **Workplace flexibility:** Researchers at Fraunhofer IOSB emphasize the importance of flexible work arrangements and supportive colleagues. Anna Taphorn notes: "What I particularly like about this job is the flexibility I have in all areas. I can organize my working hours very flexibly" .

2.3 India's STEM Gender Landscape

India's STEM gender landscape is characterized by remarkable progress at undergraduate entry followed by dramatic attrition through the pipeline. Key features include:

- **Enrollment parity:** Women now constitute 43% of STEM enrollments at the undergraduate level, a significant achievement.
- **Workforce drop-off:** This progress dissipates in the workforce, where women make up just 27% of the STEMM sector and under 19% of scientists—well below the global average of 31%.
- **Academic representation:** In higher education, only 16.7% of STEMM faculty are women, with representation at elite Indian Institutes of Technology at merely 11.2% and universities at 27%.
- **Leadership gap:** As women progress in their careers, fewer than 10% hold leadership roles in both academia and STEMM industry.
- **Rural girls' barriers:** Qualitative research with rural girls enrolled in the Vigyan Jyoti scheme reveals entrenched gender stereotypes, lack of awareness and career guidance, and financial constraints significantly affecting STEM trajectories.
- **Institutional prejudices:** A phenomenological study of women scientists in higher education institutions found that women face diverse challenges on personal and professional fronts, including rationalization of institutional prejudices and unwillingness to recognize discrimination.
- **Role models in space science:** India's space program offers inspiring figures like Nandini Harinath, Deputy Operations Director for the Mars Orbiter Mission and Project Manager for

Chandrayaan-3. As she notes, women have "overcome stereotypes by becoming reliable in handling critical space missions in recent years".

- **Grassroots initiatives:** FICCI FLO's Women in STEM initiative has reached 30,000 girls and women, conducting workshops and producing a whitepaper on the STEM gender gap.
- **Structured interventions:** The India RISE Fellowship, launched by Johns Hopkins University in collaboration with Indian institutions, addresses the critical "leaky pipeline" by supporting 40 early-career women scientists annually at the pivotal stage when many risk leaving the scientific workforce.

2.4 Comparative Insights

Comparative analysis reveals both common patterns and context-specific dynamics:

- **Leaky pipeline commonality:** Both countries experience attrition of women through the career pipeline, though the pattern differs—Germany's attrition is more gradual, while India's is dramatic after strong undergraduate enrollment.
- **Sectoral segregation:** In Germany, women are particularly underrepresented in corporate R&D; in India, the gap is most pronounced in elite academic institutions.
- **Cultural barriers operate everywhere:** Even in highly developed Germany, stereotypical beliefs and gender workload imbalances persist ; in India, these are compounded by financial constraints and rural-urban divides .
- **Institutional interventions matter:** Both countries have developed targeted programs—Germany's Fraunhofer TALENTA, India's RISE Fellowship—that address career-stage-specific challenges.
- **Role models are universally important:** From Teena tom Dieck in Germany to Nandini Harinath in India, visible women scientists inspire and demonstrate possibility.
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3. RESEARCH QUESTIONS

This study addresses the following research questions:

1. How do patterns of women's participation in STEM differ between Germany and India across educational and career stages?
2. What cultural barriers operate at different career stages in each country, and how do these barriers manifest?
3. What institutional enablers and interventions have been developed in each context, and how effective are they?
4. What lessons can be drawn from comparative analysis for strengthening women's participation in STEM globally?

4. METHODOLOGY

This study employs a comparative case study methodology to examine women's participation in STEM in Germany and India. The research design integrates document analysis of primary sources with synthesis of secondary literature to develop a comprehensive understanding of gender dynamics in STEM in both countries.

Primary sources analyzed include: peer-reviewed research on gender bias in German STEM higher education; statistical data on women researchers globally ; policy documentation from German research institutions ; Indian government and institutional data on women in STEM ; qualitative research on barriers faced by Indian women scientists ; and program documentation for targeted interventions .

The comparative framework examines four dimensions of women's STEM participation: (1) statistical patterns across career stages; (2) cultural barriers and their manifestations; (3) institutional enablers and interventions; and (4) role models and visibility.

The analysis covers the period from approximately 2020 to 2026, capturing recent research findings and policy developments.

5. RESULTS

5.1 Patterns of Participation Across Career Stages

Germany: Germany's STEM participation pattern shows moderate undergraduate enrollment followed by gradual attrition. Key features include:

- **Overall research workforce:** Women comprise 29.4% of researchers nationally, below many European counterparts.
- **Sectoral variation:** Representation varies dramatically by sector:
  - Higher education: 41.4%
  - Government research: 38.3%
  - Corporate sector: 15.6%
- **Academic pipeline:** Women's representation declines through the academic ranks, though systematic data for 2026 is limited.
- **Institutional concentration:** Women researchers are more concentrated in higher education and government research than in corporate R&D, suggesting sector-specific barriers.

India: India's participation pattern shows remarkable undergraduate parity followed by dramatic attrition. Key features include:

- **Undergraduate enrollment:** Women constitute 43% of STEM enrollments—near parity and significantly higher than many developed countries.
- **Workforce participation:** This drops to 27% of the STEMM sector overall.
- **Scientific workforce:** Women make up under 19% of scientists in India, well below the global average of 31%.
- **Academic faculty:** Only 16.7% of STEMM faculty are women, with stark variation:
  - Indian Institutes of Technology: 11.2%
  - Universities: 27%
- **Leadership representation:** Fewer than 10% of women hold leadership roles in either academia or STEMM industry.
- **Timing of attrition:** The most dramatic drop occurs between undergraduate completion and workforce entry, with continued attrition through career progression.

Table 1: Comparative Participation Patterns

Stage	**Germany**	**India**
Undergraduate enrollment	Not specified in sources	43%
Research workforce overall	29.4%	27% (STEMM sector)
Scientists specifically	29.4% (researchers)	<19%
Academic faculty	Not specified	16.7% STEMM faculty
Elite institutions	Not specified	IITs: 11.2%
Corporate R&D	15.6%	Not specified
Leadership roles	Not specified	<10%

5.2 Cultural Barriers and Manifestations

Germany: Research reveals persistent cultural barriers despite institutional progress. Key findings include:

- **Stereotypical beliefs:** The 2024 group concept mapping study found agreement across STEM disciplines regarding stereotypical beliefs about women as significant hindering factors.
- **Heteronomous gender roles:** Traditional expectations about women's roles continue to shape perceptions and opportunities.
- **Gender workload imbalances:** Women report shouldering disproportionate service and teaching loads, leaving less time for research.
- **Sexism and structural power relations:** These remain significant factors, with women faculty and staff reporting experiences of discrimination.
- **Imposter syndrome:** Early-career researchers report doubts about belonging. Anne Sielemann reflects: "At the very beginning of my studies, I was unsure whether I should study computer science and whether I would be able to do it".
- **Self-presentation differences:** Sielemann observes: "Men are socialized differently and it is easier for them to claim that they have done something well. Women, on the other hand, often find this more difficult" .

- **Lack of prior programming experience:** Sielemann notes: "I was the only one in my group of friends who had never programmed before. Many had taken computer science at school and already knew how to program" .

India: Cultural barriers in India are compounded by economic and social factors. Key findings include:

- **Entrenched gender stereotypes:** Qualitative research with rural girls in the Vigyan Jyoti scheme reveals persistent stereotypes affecting STEM trajectories.
- **Lack of awareness and career guidance:** Many girls lack information about STEM career pathways.
- **Financial constraints:** Economic barriers significantly affect rural girls' ability to pursue STEM education.
- **Institutional prejudices:** A phenomenological study found that women scientists face rationalization of institutional prejudices and unwillingness to recognize discrimination.
- **Personal-professional challenges:** Women report diverse challenges on both personal and professional fronts.
- **Lack of women leaders:** Nandini Harinath identifies "lack of women leaders" as a significant challenge in the space industry.
- **Balancing family and career:** Implicit in the "leaky pipeline" is the challenge of balancing family responsibilities with demanding scientific careers during critical childbearing years.

Table 2: Comparative Cultural Barriers

Dimension	**Germany**	**India**
Stereotypes	Stereotypical beliefs about women persist	Entrenched gender stereotypes
Gender roles	Heteronomous gender roles shape expectations	Traditional expectations strong

Workload	Gender workload imbalances	Not specified
Discrimination	Sexism and structural power relations	Institutional prejudices; rationalization
Early-career doubts	Imposter syndrome common	Lack of awareness/career guidance
Self-presentation	Gender differences in self-promotion	Not specified
Economic barriers	Less prominent	Significant financial constraints
Leadership gap	Not specified	Lack of women leaders identified

5.3 Institutional Enablers and Interventions

Germany: Germany has developed targeted institutional interventions. Key features include:

- **Fraunhofer TALENTA:** A customized development program for women in STEM across all career phases, from entry-level to manager. Offers qualifications, support programs, and networking opportunities.
- **Flexible work arrangements:** Institutions like Fraunhofer IOSB emphasize flexibility in working hours and home office arrangements, supporting work-life integration.
- **Supportive colleagues:** Researchers emphasize the importance of collegial support. Anna Taphorn notes: "The colleagues are great, and there are many role models in management positions and in the departments where women play a visible role".
- **Visibility and recognition:** Awards like the "Junge Macherin" Prize highlight outstanding young researchers and encourage the next generation.
- **Pedagogical interventions:** The 2024 study suggests potential in working on awareness of gender bias with pedagogical interventions, particularly in online group learning scenarios.
- **Research on bias:** Ongoing research documents implicit bias and informs intervention design. The 2024 study itself provides evidence for designing targeted interventions.

India: India has developed multiple intervention strategies. Key features include:

- **India RISE Fellowship:** Launched by Johns Hopkins University in collaboration with Indian institutions, this 12-month program supports 40 early-career women scientists annually with advanced research training, dedicated mentorship, and leadership development. Addresses the critical "leaky pipeline" at the stage when many women risk leaving science.
- **Vigyan Jyoti scheme:** Government program supporting rural girls in STEM, providing the population for research documented in the IAFOR study .
- **FICCI FLO Women in STEM initiative:** Has reached 30,000 girls and women through workshops and produced a whitepaper on the STEM gender gap .
- **Role model visibility:** ISRO scientists like Nandini Harinath serve as national role models, demonstrating that women can lead critical space missions .
- **Space startup ecosystem:** Harinath notes increasing opportunities in the space startup sector: "The number of space startups is increasing day by day. There are good opportunities available in satellite development" .
- **Societal applications:** Satellite technology applications in agriculture, disaster management, and environmental monitoring create diverse career pathways .

Table 3: Comparative Institutional Enablers

Dimension	**Germany**	**India**
Targeted development programs	Fraunhofer TALENTA	India RISE Fellowship
Scale	Institutional-level	National (40 fellows/year)
Career-stage focus	All phases (entry-level to manager)	Early-career scientists
Components	Qualifications, support, networking	Research training, mentorship, leadership development
Grassroots initiatives	Not specified	FICCI FLO (30,000 reached)
Government schemes	Not specified	Vigyan Jyoti (rural girls)
Role model visibility	Teena tom Dieck (FAU)	Nandini Harinath (ISRO)

Flexibility	Flexible hours, home office	Not specified
Bias awareness research	2024 GCM study	Research on institutional prejudices

5.4 Role Models and Visibility

Germany: Role models in Germany operate primarily at institutional and disciplinary levels:

- **Teena tom Dieck:** FAU doctoral researcher in molecular communication systems, recipient of "Junge Macherin" Prize. Her message: "Women are unfortunately still under-represented in engineering. Initiatives like the Schnieder Prize raise visibility and encourage the next generation".
- **Visible women in leadership:** Fraunhofer researchers note "many role models in management positions".
- **Peer support:** TALENTA program facilitates "exchange with other TALENTA participants," creating peer networks.

India: Role models in India achieve national prominence:

- **Nandini Harinath:** ISRO scientist, Deputy Operations Director for Mars Orbiter Mission, Project Manager for Chandrayaan-3. Key message: women have "overcome stereotypes by becoming reliable in handling critical space missions in recent years".
- **ISRO women scientists:** India's space program has produced multiple visible women leaders who inspire national pride.
- **FICCI FLO sessions:** Direct engagement with role models like Harinath reaches hundreds of attendees, as demonstrated by the 188 participants in the featured session .
- **Media coverage:** Prominent coverage in national media amplifies visibility.

Table 4: Comparative Role Models and Visibility

Dimension	**Germany**	**India**

Prominent example	Teena tom Dieck (FAU)	Nandini Harinath (ISRO)
Field	Molecular communication	Space science (Mars Orbiter, Chandrayaan-3)
Recognition mechanism	"Junge Macherin" Prize	National media; FICCI FLO sessions
Scale of influence	Institutional/discipline	National
Key message	"Initiatives raise visibility"	"Women have overcome stereotypes"

5.5 Summary of Comparative Findings

Table 5: Comprehensive Comparative Analysis

Dimension	**Germany**	**India**
Undergraduate enrollment	Not specified	43%
Research workforce	29.4% (researchers)	27% (STEMM sector)
Scientists	29.4% (researchers)	<19%
Academic faculty	Not specified	16.7% STEMM faculty
Elite institutions	Not specified	IITs: 11.2%
Corporate R&D	15.6%	Not specified
Leadership	Not specified	<10%
Key barriers	Stereotypical beliefs; gender roles; workload imbalances; sexism; structural power	Entrenched stereotypes; lack of guidance; financial constraints; institutional prejudices
Early-career challenges	Imposter syndrome; self-presentation differences	Awareness; career guidance
Institutional interventions	Fraunhofer TALENTA	India RISE Fellowship

Grassroots initiatives	Not specified	FICCI FLO (30,000 reached)
Role models	Teena tom Dieck	Nandini Harinath
Strengths	Institutionalized support; bias research; flexibility; visible management	Undergraduate parity; national role models; emerging structured interventions
Challenges	Sectoral segregation (corporate R&D)	Dramatic pipeline leakage; leadership gap

6. DISCUSSION OF RESULTS

6.1 Explaining Divergent Pathways: The Leaky Pipeline at Different Stages

The differences between Germany's and India's patterns of women's STEM participation reveal distinct dynamics in the "leaky pipeline."

Germany's pattern suggests a more gradual but persistent attrition. Women achieve moderate representation in higher education research (41.4%) but drop dramatically in the corporate sector (15.6%) . This sectoral segregation may reflect different workplace cultures, flexibility provisions, and advancement opportunities between academic and corporate research environments. The persistence of stereotypical beliefs, gender workload imbalances, and structural power relations even among successful women academics suggests that cultural barriers operate throughout the career.

India's pattern reveals a dramatic drop after strong undergraduate enrollment. The transition from 43% undergraduate enrollment to 27% STEMM sector participation and under 19% scientists represents massive leakage . The elite institutional gap—11.2% at IITs versus 27% at universities—suggests that competitive pressures may exacerbate gender disparities. The leadership gap—fewer than 10% in leadership roles—indicates that leakage continues through all career stages .

6.2 Cultural Barriers: Universal Patterns, Local Manifestations

Both countries demonstrate that cultural barriers operate even in very different contexts. The German study's finding that stereotypical beliefs, heteronomous gender roles, and sexism remain significant factors despite decades of gender equality policy echoes the Indian finding of entrenched stereotypes and institutional prejudices .

However, manifestations differ. In Germany, barriers include subtle biases in evaluation, workload imbalances, and self-presentation differences . Anne Sielemann's observation about gendered socialization in self-promotion reflects a pattern documented across Western contexts. In India, barriers include financial constraints affecting rural girls, lack of career guidance, and rationalization of institutional prejudices .

The common thread is that cultural change lags behind policy change. Even when formal barriers are removed, informal norms, expectations, and biases persist.

6.3 The Power of Institutional Interventions

Both countries demonstrate that targeted institutional interventions can make a difference. Germany's Fraunhofer TALENTA program provides structured support across career stages, with participants emphasizing the value of networking and peer exchange . The program's existence signals institutional commitment and provides resources that individual women can leverage.

India's India RISE Fellowship, launched by Johns Hopkins University with Indian partners, addresses a critical career transition point—early-career scientists at risk of leaving research . The fellowship's combination of research training, mentorship, and leadership development targets the multiple factors contributing to pipeline leakage.

FICCI FLO's grassroots initiative reaching 30,000 girls and women demonstrates the potential of civil society engagement . The combination of structured fellowships for advanced researchers and broad outreach to students creates a pipeline approach.

6.4 Role Models as Catalysts

Both countries illustrate the importance of visible role models. Teena tom Dieck's recognition through the "Junge Macherin" Prize provides visibility within German engineering . Nandini Harinath's prominence as an ISRO scientist leading Mars and Moon missions provides national-level inspiration .

Research confirms that role models counter stereotype threat and expand women's sense of possibility. When women see others like themselves succeeding, they are more likely to persist through challenges. The FICCI FLO session with Harinath, reaching 188 attendees, demonstrates this principle in action .

6.5 Implications for Policy and Practice

The findings have significant implications for strengthening women's participation in STEM.

First, pipeline interventions must be stage-specific. India's dramatic undergraduate-to-workforce drop requires different interventions than Germany's sectoral segregation. Programs should target critical transition points with appropriate supports.

Second, cultural change requires sustained effort. The German study's finding that stereotypical beliefs persist despite policy progress underscores that legislation alone is insufficient. Cultural change requires awareness-raising, bias training, and ongoing dialogue.

Third, institutional support structures matter. Fraunhofer TALENTA and India RISE Fellowship demonstrate that structured programs with dedicated resources can support women's advancement.

Fourth, visibility and recognition encourage persistence. Awards like the "Junge Macherin" Prize and public recognition of scientists like Harinath provide role models and signal that women belong in STEM.

Fifth, flexibility enables work-life integration. German researchers' emphasis on flexible hours and home office arrangements suggests that workplace flexibility supports retention, particularly during childbearing years.

Sixth, mentorship and networking build community. Peer exchange through programs like TALENTA and formal mentorship in RISE Fellowship create communities that buffer against isolation.

Seventh, intersectional approaches are essential. India's rural girls face compounded barriers of gender, geography, and economic status. Interventions must address multiple dimensions of disadvantage.

Eighth, data and research inform practice. The German GCM study and Indian phenomenological research provide evidence for designing targeted interventions.

7. CONCLUSION

This comparative analysis of women's participation in STEM in Germany and India reveals two distinct pathways shaped by cultural context, institutional development, and policy frameworks. Germany, with its strong institutional infrastructure and explicit gender equality policies, has achieved moderate representation of women in higher education research (41.4%) but faces persistent sectoral segregation, with women vastly underrepresented in corporate R&D (15.6%) . Research reveals that even among successful women academics, stereotypical beliefs, gender workload imbalances, and structural power relations remain significant barriers . Yet institutional interventions like Fraunhofer TALENTA and recognition through awards like the "Junge Macherin" Prize provide structured support and visibility, with young researchers like Teena tom Dieck serving as role models .

India presents a different picture characterized by a striking "leaky pipeline." Women achieve remarkable parity at undergraduate entry (43%) but then face dramatic attrition, dropping to 27% in the STEMM sector and under 19% of scientists . In elite institutions, representation plummets to 11.2% at IITs, and fewer than 10% reach leadership roles . Qualitative research reveals

entrenched stereotypes, lack of career guidance, financial constraints, and institutional prejudices as persistent barriers . Yet India's space program produces national heroes like Nandini Harinath, demonstrating that women "have overcome stereotypes by becoming reliable in handling critical space missions" . Emerging interventions like the India RISE Fellowship and grassroots initiatives reaching 30,000 girls offer hope for addressing the pipeline leakage .

Several cross-cutting conclusions emerge from this analysis.

First, the leaky pipeline operates in both countries, but at different stages. Germany's attrition is more gradual and sector-specific; India's is dramatic after undergraduate entry. Interventions must be stage-specific.

Second, cultural barriers persist despite policy progress. Even in highly developed Germany, stereotypical beliefs and gender role expectations continue to shape women's experiences . Cultural change requires sustained effort beyond legislative reform.

Third, institutional support structures matter. Targeted programs like Fraunhofer TALENTA and India RISE Fellowship provide resources, mentorship, and community that support women's advancement.

Fourth, visible role models inspire and demonstrate possibility. From Teena tom Dieck in Germany to Nandini Harinath in India, women scientists who achieve recognition provide evidence that success is possible.

Fifth, flexibility enables work-life integration. German researchers' emphasis on flexible hours and supportive colleagues highlights the importance of workplace practices that accommodate family responsibilities.

Sixth, intersectional approaches are essential**.** India's rural girls face compounded barriers requiring interventions that address gender, geography, and economic status simultaneously.

Seventh, research informs practice. Rigorous studies documenting barriers and evaluating interventions provide evidence for policy design.

For Germany, the path forward involves addressing sectoral segregation, particularly the dramatic underrepresentation in corporate R&D. Institutional support programs like TALENTA should be expanded, and flexibility provisions should be strengthened. The potential of pedagogical interventions identified in recent research should be explored systematically.

For India, the priority is plugging the pipeline leakage at critical transition points. The India RISE Fellowship's focus on early-career scientists addresses one critical juncture; similar interventions are needed at undergraduate-to-workforce transition and at mid-career advancement. Strengthening career guidance and addressing financial constraints for rural girls are essential complements.

For the broader global community, this comparison underscores that women's participation in STEM is not simply a function of development level or policy frameworks. Both Germany and India—different in almost every respect—demonstrate that cultural barriers persist across contexts, that institutional support structures matter, and that visible role models inspire. The shared challenge is translating occasional success stories into systemic transformation—building pipelines that retain women through all career stages and into leadership.

8. LIMITATIONS OF THE STUDY

This study has several limitations that should be acknowledged. First, the comparative analysis relies primarily on secondary sources and published research rather than primary data collection. Direct fieldwork in both countries, including interviews with women scientists, program administrators, and policymakers, would strengthen comparative insights.

Second, data availability and comparability differ between the two countries. German statistical data provides sector-specific breakdowns; Indian data provides detailed pipeline information. Direct comparisons should be interpreted cautiously.

Third, the German qualitative research cited draws on a specific methodology (group concept mapping) with 70 participants, providing rich insights but limited generalizability . The Indian qualitative research similarly focuses on specific populations .

Fourth, the study focuses on STEM broadly, with limited attention to disciplinary variation within STEM fields, which is significant.

Fifth, the voice of women who left STEM—those most affected by the "leaky pipeline"—is mediated through research rather than captured directly.

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10. AUTHOR CONTRIBUTIONS

The author conceived the study, designed the comparative framework, conducted the literature review and document analysis, synthesized findings across countries, and drafted the complete manuscript. The author takes full responsibility for the accuracy of information presented and interpretations offered.

11. COMPETING INTERESTS

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential competing interest.

12. AUTHORS' CONTRIBUTIONS

As sole author, I performed all roles including conceptualization, methodology development, investigation, formal analysis, writing, review, editing, and project administration.

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14. DATA AVAILABILITY

All sources analyzed in this study are publicly available documents, including academic articles, research reports, statistical databases, policy documents, and media reports. Primary sources are cited in the references and accessible through the referenced publications and organizations.

15. DISCLAIMER

The views expressed in this article are solely those of the author and do not necessarily reflect the views of any institution or organization with which the author may be affiliated. The analysis is provided for scholarly purposes and should not be construed as policy guidance or investment advice. Women's participation in STEM and related policies are subject to change, and readers should consult current official sources for specific information about Germany, India, and gender equality in STEM.

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