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Structural and Psychological Barriers to Women's Engagement in STEM Fields: A Study in the Pakistani Context

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ABSTRACT

This comprehensive review uncovers the structural and motivational inhibitions for women working in STEM professions, particularly those based in Pakistan. From international and regional literature, it situates Pakistan within broader patterns of gender gap in STEM education and employment, revealing disparities in participation, retention and progression. Cultural barriers, including gendered curriculum, resource disparities, cultural norms and weak policy enforcement were placed at the intersection with Psychological barriers to belong being characterised by hesitations which are viewed in terms of self-efficacy incongruence, stereotype threat and imposter syndrome. These ingredients conspire to create industry- and career-long barriers that lower women's sense of confidence, belonging and persistence on STEM paths. Such analogies help to reinforce the systemic dimensions of these "barricades" in South Asia and other Muslim-majority regions. The review critically assesses evidence-based interventions, mentorship networks, gender-responsive pedagogy, corporate workplace diversity programs and policy changes with customized recommendations for Pakistan. Women's greater participation in STEM is also framed as an equity issue, and a driver of national innovation and socio-economic development.

Keywords: *Women in STEM, Gender bias in education, Self-Efficacy, Stereotype Threat and Coping Strategies; Structural and Psychological Barriers*

INTRODUCTION

Global vs Pakistani Women in STEM Landscape

How about trillions of dollars spent by governments and international organizations on accessibility to STEM (science, technology engineering, mathematics) in the last two decades. Nonetheless, women are still significantly underrepresented worldwide; both in the ranks of higher education and in STEM careers due to a composite of societal and psychological barriers that are set up early but amplify over time (UNESCO, 2021; Wang & Degol, 2017). Both nationally and globally, women constitute 35% of graduates in science at the university level bringing the balance between male and female stagnation unchanged for over a decade with particular representation lagging in engineering and ICT (UNESCO, n.d.; UNESCO, 2021).The persistent gap is not inconsequential: STEM fields are drivers of productivity, innovation, and social mobility and exclusion from them restricts women's economic security as well as countries' human-capital formation (Saigo, 2024; Wang & Degol, 2017).

Patterns in Pakistan are no different but with certain characteristics due to its sociocultural, institutional and policy settings. The historical trends have suggested continued improvement in women participation in higher education generally and this has existed with persistent disparities at STEM-heavy fields of study and work (Aslam, 2018; Halai, 2019). Previously Higher Education Commission (HEC) snapshots reported an increase in women's share of overall university enrollment during the 2000s (Aslam, 2018), and recent system reports indicate a parity or perhaps even an overrepresentation of women relative to men in some fields (e.g., natural and social sciences), whereas male students continue to represent the majority of "technical" disciplines such as engineering and technology (Higher Education Commission, 2023). Pakistan's Ministry of Federal Education & Professional Training (MoFEPT) has launched STEAM initiatives; curriculum pilots, teacher training, and school-level labs, to address pipeline issues from secondary onward, signaling growing policy attention to gender inclusivity in STEM (MoFEPT, 2024). International partners have amplified this focus: for example, UNESCO's 2025 observance of the International Day of Women and Girls in Science in Pakistan spotlighted role models and networks to inspire young women (United Nations Pakistan, 2025).

While policy is moving, participation of females in STEM undergraduate programs and careers is uneven. Transitions from school to university are being gendered through expectations, representations of knowledge and textbooks, resource limitations and campus practices (Mumtaz, 2017; Khan & Malik, 2019). At the school level, girls are exposed against evidence of women and very little in the way of female scientist role models, which shapes their self-concept and aspirations across many years before they make decisions about HE subject choices (Archer et al., 2013; Mumtaz, 2017). At university level, these intersect with organisational culture and structures physically and socially; females perceive lower academic and social support among their peers in Engineering at secondary school (see SRHE.org), which influence on how confident they feel to stay within them (Husnain et al., 2022; Mujtaba et al., 2023). Limited opportunities to be hired, local working environment cultures, and mobility restrictions are also barriers from the degrees entering STEM work in the labor market (Aslam 2018; Nazli 2023).

There are also psychological aspects to the gap. Long-standing and newer selfefficacy-and-belonging research shows that confidence in one's ability to engage in science and "fitting in" are strong predictors of interest, course taking, and persistence within STEM (Bandura, 1997; Tellhed et al., 2017; Zeldin & Pajares, 2000). Cross-national syntheses indicate that stereotype threat, masculine field images and restricted role-model visibility are mechanisms of women's self-efficacy repression and decreased fields choices (Cheryan et al., 2017; Wang & Degol, 2017). These channels function in a deeper stream of sociocultural norms— surrounding "appropriate careers" and around family roles, safety and livelihood— the first two which can undermine early engagement of girls, limit institutional choices of secondary schools and colleges, and complicate getting or advancing on jobs (Aslam, 2028; Halai, 2015; Nazli, 2023). Pakistan-specific research indicates that lower STEM confidence and perception of poor support are the key barriers to female undergraduates, specifically students in engineering (Husnain et al., 2022; Mujtaba et al., 2023).

At the system level, the policy landscape is mixed. On one hand, MoFEPT's STEAM Pakistan program reports progress on labs, teacher training, and school engagement; on the other, the scale and equity-sensitivity of these interventions remain works in progress, and explicit gender targets and monitoring are still maturing (MoFEPT, 2024). HEC reporting acknowledges discipline-level gender skews, with male predominance in engineering and technology persisting despite overall gains for women in higher education (HEC, 2023). Meanwhile, global benchmarking by UNESCO underscores that without intentional design; gender-responsive pedagogy, advising, mentorship, and safe learning environments, systems rarely convert enrollment gains into equitable STEM outcomes (UNESCO, 2021).

Problem statement. Pakistan's gender gap in STEM is sustained by interlocking structural and psychological barriers. Structurally, gendered curricula and textbooks, uneven school resources, limited mentorship, safety and mobility concerns, hiring bias, and weak enforcement of equity policies constrain girls' and women's opportunities from secondary school through employment (Archer et al., 2013; Mumtaz, 2017; Aslam, 2018; Khan & Malik, 2019; Nazli, 2023). Psychologically, lower self-efficacy, stereotype internalization, and reduced belonging, shaped by classroom dynamics, field images, and scarcity of role models—discourage initial entry and undermine retention (Bandura, 1997; Cheryan et al., 2017; Tellhed et al., 2017; Zeldin & Pajares, 2000). These forces mutually reinforce each other: constrained structures erode confidence and belonging, while diminished confidence reduces persistence within structurally unequal environments (Wang & Degol, 2017).

Global gender gap in STEM and the Pakistani context

Across the world, women's participation in science, technology, engineering, and mathematics (STEM) remains uneven—more balanced in some life sciences and health fields, but persistently lower in engineering, computing, and physics (Cheryan et al., 2017; Wang & Degol, 2017). Global syntheses attribute these gaps to a web of factors; gendered socialization, classroom climates, misaligned curricula, limited role models, and workplace cultures that dampen belonging and progression (Saigo, 2024; UNESCO, 2021; Wang & Degol, 2017). The cumulative effect is a leaky pipeline: girls' initial interest is narrowed by stereotype-laden expectations, confidence gaps, and institutional frictions that intensify at critical transition points from school to university and into employment (Archer et al., 2013; Tellhed et al., 2017; UNESCO, 2021).

When we narrow the lens to Pakistan, these universal drivers intersect with distinctive socio-cultural and institutional realities. Research in Pakistani school and university settings documents gendered portrayals in textbooks, gendered academic cultures on campuses, and community expectations that constrain girls' educational choices and mobility—especially into male-typed STEM fields (Aslam, 2018; Halai, 2019; Khan & Malik, 2019; Mumtaz, 2017). These preferences are not merely individual; they are the systematic outcome of curricular materials that exclude women scientists, pedagogical strategies and tools that seldom confront stereotypes and campus/workplace cultures that can 'shush' or side-line both women's voices and their opportunities (Halai, 2019; Khan & Malik, 2019; Mumtaz, 2017; UNESCO, 2021).

These lacunae are acknowledged in current national discourse and policy development within Pakistan. Primary efforts from the federal government and donors have focused on visibility campaigns and programmatic efforts to increase women's entry into science under international global days such as The International Day of Women and Girls in Science (MoFEPT, 2025; STEAM Policy Unit, 2024; United Nations Pakistan, 2025). But policy signaling is just not enough to get rid of everyday obstacles. Specifically in the context of Pakistani higher education one finds that female undergraduates tend to believe STEM is culturally illegitimate, anticipate discrimination and attribute lower self-efficacy to certain subfields (polenics) — all aligned with social cognitive and stereotype-threat-based theories (Bandura, 1997; Husnain et al., 2022; Mujtaba et al., 2023; Tellhed et al., 2017).

These observations lead to an obvious problem statement: Women in Pakistan experience a double discrimination structural as well as perceptual in working and developing their careers inside the STEM. At a structural level, gendered curricula, lack of mentorship, resource constraints and weak enforcement of equity policies restrict access to, quality in and the progression towards leadership. Psychologically, internalized stereotypes, low self-efficacy, weak sense of belonging explain reduced interest and stamina – that are in many cases activated or exacerbated through the very structures intended to educate and provide employment (Bandura, 1997; Cheryan et al., 2017; Halai, 2019; Mumtaz, 2017; Wang & Degol, 2017).

Purpose of the review

We analyze international and Pakistan-focused evidence to consider (a) the role of structural factors in schooling, higher education, and early career in shaping women's STEM opportunities; (b) how psychological processes—namely self-efficacy, stereotype threat and belonging—mediate choices and outcomes for students transitioning through these settings; and (c) how these forces combine over time to generate cumulative advantage/disadvantage.

Guiding Research Questions

RQ1: What structural features of Pakistan's education and early-career systems facilitate or hinder women's participation and persistence in STEM?
RQ2: What psychological variables (e.g., self-efficacy, belonging, stereotype internalization) are related to Pakistani women's STEM aspirations and trajectories?

RQ3: How do structural and motivational factors interact, and which windows are the most critical periods for both barriers?

RQ4: What policies, institutions and pedagogical approaches have potential to reduce gender disparities in Pakistan's STEM pipeline?

Structural Barriers in Pakistan

Educational Curricula and Classroom Practice

Textbooks used in science classes portray stereotyped gender roles, and there are not many women scientists in the country, all of which communicate a subtle but consistent message to girls that STEM is not their "cup of tea" (cf., Mumtaz, 2017). These messages are reinforced by didactic pedagogies and assessment regimens which prioritise rote mastery over inquiry, teamwork and problem-solving competencies typically related to girls' participation (and leadership) in STEM activities as a whole (Halai, 2019; UNESCO, 2021; Wang & Degol, 2017). In higher education, the gendered academic culture (e.g., male-dominated departments; lack of support for caregiving responsibilities; informal networks that male faculty (exclude women) shaped research group participation and lab access as well as internship types (Khan & Malik, 2019). These sorts of institutional frictions are systemic, not personal — and they compound.

Resource Allocation and Gender-Segregated Spaces

Resource constraints — labs, equipment and trained personnel — are common to many institutions but often have a greater impact on women where gender-segregated facilities restrict access to laboratories, makerspaces and the field (Aslam, 2018; Halai, 2019). Security and transportation issues can limit opportunities outside of daytime hours or off campus, constraining experiential learning crucial to engineering and technology (Aslam, 2018). With the most resources-rich opportunities being often informal and network based, it is precisely in these realms that gendered social dynamics can operate to exclude women from experiences that develops skills, confidence and Cvs (Khan & Malik, 2019).

Mentorship and professional socialization

Mentorship is a well-recognized predictor of STEM persistence, however, Pakistani students are largely women who describe the lack of access to female mentors and role models within subfields (Husnain et al., 2022; UNESCO, 2021). In the absence of visible pathways and models, women make choices at key turnings with less guidance and encouragement, a situation that may suppress self-efficacy and restrict aspirations (Bandura, 1997; Zeldin & Pajares, 2000). First results from Pakistani engineering curriculum highlights the relevance

Psychological Barriers of Stereotype, Imposter Syndrome and Self-Efficacy

Substantial evidence indicates that the choice to enter, persist in and succeed in STEM is based on more than material resources and structures; it is also influenced by peoples' psychological beliefs about their own competence and fit. Three of the forces are particularly relevant for women: gender stereotypy, imposter syndrome and lower self-efficacy. These forces are socially constructed; passed through families, media, school materials, interactions in the classroom, and peer cultures and internalized to influence performance behaviors as well as course-taking behavior and long-term career interests (Bandura et al., 1997; Cheryan et al., 2017).

Gender stereotypes: "Who is a STEM person?"

It is common to see stereotypes of areas like mathematics, computing and engineering as male-gendered things that are intrinsically gendered (i.e. for example that "brilliance," "single focus" or even "technicality" in some form can be associated with masculinity (Cheryan, Plaut, Davies & Steele 2009). These depictions are not agnostic but instead act as identity-based cues to who fit and function (in ways deponents) which crush girls interest long before university (Archer et al. 2013; Wang & Degol, 2017). In Pakistan, school materials and visual depictions frequently under-represent women scientists or assign them secondary, nurturing roles, reinforcing a gendered division of scientific labor (Mumtaz, 2017). These messages matter: repeated exposure leads many girls to anticipate misfit with advanced STEM pathways, narrowing their course choices and aspirations over time (Archer et al., 2013).

Stereotype processes also operate acutely in evaluative settings. Building on stereotype-threat theory, when a negative stereotype about one's group (e.g., "girls are not good at physics") is salient, individuals may experience heightened anxiety and vigilance, which can impair working memory and test performance even when preparation is equal (Steele, 1997). The long-run cost is cumulative: transient performance dips can confirm doubts, trigger avoidance of challenging electives, and dampen applications to selective programs—each step subtly shrinking the pipeline (Cheryan et al., 2017; Steele, 2010).

Imposter syndrome: "Maybe I don't deserve to be here"

In competitive STEM programs, women disproportionately report imposter feelings, persistent doubts about competence despite objective success (Tellhed et al., 2017; Zeldin & Pajares, 2000). Imposter thoughts are not simply private feelings; they are responses to context. When classrooms emphasize weed-out norms, celebrate solo "genius," or offer limited formative feedback, students who are numerical minorities can infer that they are exceptional only by chance (Wang & Degol, 2017). Pakistan-based studies show that female undergraduates in engineering frequently perceive lower academic and social support than their male peers, which correlates with reduced confidence and satisfaction with the learning environment (Husnain et al., 2022; Mujtaba et al., 2023). Imposter feelings, in turn, predict avoidance of leadership roles, reluctance to seek help, and attrition intentions, especially in the early semesters.

Self-efficacy: "Can I do this—and keep doing it?"

Self-efficacy; beliefs about one's capability to organize and execute actions for desired outcomes is a central mechanism linking experience to persistence (Bandura, 1997). Meta-theoretical and empirical work consistently shows that higher STEM self-efficacy predicts greater interest, sustained effort in difficult coursework, and resilience after setbacks (Wang & Degol, 2017; Zeldin & Pajares, 2000). Crucially, self-efficacy is learned through mastery experiences, vicarious models (seeing similar others succeed), credible encouragement, and interpretations of physiological arousal (Bandura, 1997). When classrooms offer few mastery opportunities (e.g., exclusively high-stakes exams), when role models are scarce, or when feedback is global ("some people just have it"), efficacy suffers.

Evidence from South Asia underscores these dynamics. Pakistani and regional studies report that women's mathematics and engineering self-belief is highly sensitive to classroom climate and support structures (Husnain et al., 2022; Mujtaba et al., 2023; Paudel et al., 2025). Students who perceive responsive teaching, peer collaboration, and mentoring report stronger self-efficacy and clearer STEM career intentions, even after controlling for prior achievement (Husnain et al., 2022; Paudel et al., 2025). Conversely, where families or instructors signal that STEM is "too demanding for girls" or incompatible with future caregiving, students are more likely to lower their ambitions or opt out of advanced tracks (Aslam, 2018; Halai, 2019).

How classroom dynamics and societal messages reinforce one another

Psychological barriers are not free-floating; they are produced at the intersection of societal messages and everyday classroom dynamics.

Societal Messages: Media and community narratives often code engineering and computing as male spaces and tie women's success to modesty and relational care, making self-promotion or visible ambition feel norm-violating (Aslam, 2018; Halai, 2019). These norms amplify stereotype salience and make imposter feelings socially safer than confident self-claims.

Classroom Dynamics: In mixed-gender labs or male-majority lectures, women may receive fewer hands-on roles, more unsolicited help, or be over-represented in organizing rather than technical tasks, each quietly diluting mastery experiences (Cheryan et al., 2017; Wang & Degol, 2017). Textbook imagery and examples that omit women scientists further mute vicarious efficacy cues (Mumtaz, 2017).

Assessment and Feedback: High-stakes, norm-referenced grading without formative scaffolds disproportionately harms students who already question their belonging (Steele, 2010). In contrast, process-oriented feedback, opportunities for iterative mastery, and public recognition of diverse role models reliably strengthen efficacy and belonging (Zeldin & Pajares, 2000; Wang & Degol, 2017).

The Role-Model Gap: Why Visibility Matters

Role models operate through vicarious learning: seeing a similar other succeed changes what students believe is possible for themselves (Bandura, 1997). Where female faculty, senior students, or industry mentors are scarce; as is common in male-dominated Pakistani engineering programs—women lose a key pathway for building self-efficacy (Husnain et al., 2022; Mujtaba et al., 2023). Studies of women scientists and engineers show that narratives of overcoming barriers, paired with authentic mentorship and actionable advice, can recalibrate self-beliefs and strengthen commitment to long-term STEM goals (Zeldin & Pajares, 2000). At scale, purposeful visibility—guest talks, alumni networks, and peer-led communities—can normalize women's achievement, reduce stereotype salience, and buffer imposter thoughts (Cheryan et al., 2017; Wang & Degol, 2017).

Summary

In sum, stereotypes signal misfit, imposter feelings dampen agency, and low self-efficacy erodes persistence. These dynamics are context-dependent: when curricula, teaching practices, and institutional cultures in Pakistan reproduce gendered expectations, psychological barriers intensify; when they provide mastery experiences, authentic role models, and affirming feedback, women's performance and persistence improve. Any strategy to expand women's engagement with STEM must therefore treat psychological change as a design goal, not a by-product, cultivating efficacy and belonging through visible role models, equitable classroom practices, and supportive mentoring alongside structural reform.

Intersections: How Structures Shape Psychology and Why the Effects Compound

Women's STEM paths in Pakistan (and, indeed, similar South Asian and Muslim-majority settings) are steered by negative loops of influence at work: structural inequities (e.g., unequal access to resources, insufficient support, biased gatekeeping) increase psychological distress (e.g., stress, low self-efficacy, tenuous belonging), which also diminishes one's likelihood of garnering high-value opportunities; all the while increasingly contributing to these very forms of inequality that generated the distress. This section examines 3 persistent "cycles" identified throughout the literature and case studies.

Cycle A: Unequal Learning Environments → Threat & Doubt → Reduced Challenge-Seeking

At school and university, curricular signals and classroom micro-climates convey who belongs. Pakistani science textbooks and visuals often underrepresent women scientists or depict them in auxiliary roles (Mumtaz, 2017), and campus cultures in male-dominated departments can be chilly or exclusionary (Khan & Malik, 2019). These structural cues elevate stereotype salience and psychological threat, as students anticipate being judged through a gendered lens (Cheryan et al., 2017; Steele, 1997). Under threat, working memory is taxed, performance may dip, and students conclude they are not "natural fits," even when preparation is adequate (Steele, 2010; Wang & Degol, 2017).

Evidence from Pakistan shows how this plays out. Female undergraduates report lower perceived academic and social support in engineering programs, which correlates with weaker confidence and less satisfaction with the learning environment (Husnain, Naz, & Rauf, 2022; Mujtaba et al., 2023). Over time, lower efficacy and heightened vigilance lead students to avoid high-stakes electives, research groups, or competitive internships, thereby missing the mastery experiences that could have reversed the doubts (Bandura, 1997; Zeldin & Pajares, 2000). The long-run effect is a narrowed pipeline from coursework to postgraduate opportunities.

Comparable contexts. In Bangladesh, women engineering students describe negotiating masculine lab cultures and limited mentoring; these structural frictions map onto self-protective disengagement from technical roles (Ferdous & Kabir, 2021). In cross-cultural analyses, gender-typed field images predict women's lower sense of fit in computing and engineering across settings, including South and East Asia (Chan, 2022; Cheryan et al., 2017).

Cycle B: Resource & Network Gaps → Imposter Feelings → Withdrawing from Visibility

Another loop ties material resources and social capital to imposter feelings. Where women have less access to well-equipped labs, after-hours practice, safe mobility, or insider networks, they accumulate fewer artifacts of competence (projects, publications, recommendations) (Aslam, 2018; Khan & Malik, 2019; Nazli, 2023). In meritocratic rhetoric, these missing artifacts are misread as personal deficits, fueling imposter thoughts ("I succeeded by luck") (Tellhed, Bäckström, & Björklund, 2017).

Imposter feelings then alter behavior: students hesitate to lead, avoid asking questions publicly, or decline high-visibility roles that risk exposing perceived inadequacythereby forfeiting the very experiences that generate credible signals of competence (Zeldin & Pajares, 2000; Wang & Degol, 2017). Pakistani studies align with this pattern: perceived thin support and limited mentoring are linked to lower STEM confidence and less willingness to persist through setbacks (Husnain et al., 2022; Mujtaba et al., 2023).

Comparable contexts. In Nepal, women's mathematics self-belief varies sharply with teacher responsiveness and collaborative classroom norms; supportive climates predict stronger efficacy and intentions to continue in quantitative pathways (Paudel, Dahal, & Hasan, 2025). The mechanism—socially scaffolder mastery reducing imposter feelings—echoes findings from Pakistan and Bangladesh.

Cycle C: Discriminatory Workplaces & Policy Gaps → Anticipatory Stress → Attrition or Channeling

At the education-to-work boundary, hiring practices, informal referrals, and workplace cultures can produce a third loop. Women anticipate environments where long, inflexible hours, field travel, and male-only teams are equated with commitment (Aslam, 2018; Nazli, 2023). Anticipating bias or surveillance (e.g., doubts about mobility or marriage plans), many experience anticipatory stress and lower expectations of belonging well before the first job (Wang & Degol, 2017).

Where policy frameworks lack teeth; limited gender budgeting, weak monitoring, and scarce protections, organizations face few incentives to redesign roles or support transitions (Halai, 2019). The result is early exit from engineering/tech pathways or re-routing into "acceptable" science roles (e.g., teaching, lab assistance) that align better with familial expectations and safety considerations (Aslam, 2018; Nazli, 2023). This selective attrition stabilizes male dominance in technical cores, reproducing the next cohort's structural and psychological hurdles (UNESCO, 2021; Saigo, 2024).

Comparable contexts. Cross-national syntheses report similar pipeline pinch points in Muslim-majority and South Asian settings where family honor, safety, and marriage timing factor into relocation and late shifts, intensifying anticipatory stress and reducing persistence in male-typed subfields (Chan, 2022; Saigo, 2024).

An Intersectional Lens: Why Some Women Face Steeper Slopes

Structural forces and psychological responses vary by class, region, and language background. For students whose families are poor or who live in rural areas, the costs of transportation, concern for safety and distance limitations will heighten exposure to resource-poor campuses;diluting opportunities for mastery while increasing persistence costs (Aslam, 2018). In these situations, stereotype threat runs headlong into material scarcity and the double whammy of the two is greater than either force on its own. Campus cultures also overlay urban–rural habitus, where students with less of the "insider" set of cultural references can feel doubly 'out of place', which only serves to depress belonging (Khan & Malik, 2019).

What Links Structure with Psychology? A Practical Causal Chain

As a chain of convenience, the literature deposes upon across cases:

Signals & Access (Structure): Gender-typed curriculum, few mentors, and exclusionary networks (Mumtaz, 2017; Khan & Malik, 2019).

Appraisal (Psychology): Increased stereotype salience, imposter attribution, and lower self-efficacy (Steele, 1997; Tellhed et al., 2017).

Behavioral Outcomes: Lower challenges seeking, lower help seeking, and pursuit of invisibility (Zeldin & Pajares, 2000; Wang & Degol, 2017).

Lagged Rewards: Fewer of the trappings of competence, fewer strong recommendations, more limited choices; the next selection phase is skewed in favor of those who are already advantaged—hence reproducing the structural bias.

This feedback loop is why piecemeal solutions (say, one awareness training) rarely budge outcomes. In the absence of those structural redesigns (mentoring, safe mobility, equitable resource allocation, bias-aware teaching) and psychological scaffolds (efficacy-building feedback, exposure to visible role models on the frontier where they make contributions that matter, belonging cues), the system returns to equilibrium.

Implications

To design for equity, we need to interrupt the loops in multiple places:

Upstream: A curriculum and teaching that are gender responsive in generating regular yet scaffolder opportunities to master; systematic exposure to a range of women in STEM (Mumtaz, 2017; UNESCO, 2021).

Midstream: Mentorship networks and research/apprenticeship access that are opt-out, rather than opt-in to counteract network exclusion (Khan & Malik, 2019).

Interventions and Recommendations: What Works—and How to Make It Work in Pakistan

A growing body of evidence shows that structural redesign and psychological scaffolds must move in tandem to close gender gaps in STEM. Below, we critically evaluate five intervention families—mentorship networks, gender-sensitive curricula, workplace diversity programs, government reforms, and psychological empowerment—drawing on global syntheses and Pakistan-relevant studies, and then translate them into actionable, context-specific recommendations.

Mentorship networks (Near-Peer, Faculty, and Industry)

What the evidence says. Mentorship is one of the most reliable levers for improving women's self-efficacy, persistence, and career clarity in STEM (Bandura, 1997; Zeldin & Pajares, 2000). Pakistan-based studies show that social and academic support in engineering programs correlates with stronger STEM confidence and better perceptions of the learning environment (Mujtaba et al., 2023). Teacher- and expert-partnership models also strengthen implementation capacity and transfer to classroom practice (Kessler et al., 2024; Romero-Ariza et al., 2021). However, professional development (PD) alone often fails to change practice unless design addresses time, incentives, coaching, and school context (Lo, 2021; Ketsman et al., 2024).

Design implications

Build layered networks: near-peer (senior undergraduates to first-years), faculty mentors, and industry sponsors who open doors to labs, apprenticeships, and paid internships (Mujtaba et al., 2023; Kessler et al., 2024).

Make access opt-out rather than opt-in to counter network exclusion; schedule sessions during daylight hours and provide travel stipends to address mobility constraints common for women students in Pakistan (Aslam, 2018).

Tie mentoring to authentic deliverables (posters, prototypes, publications), because visible mastery artifacts feed efficacy and employability (Bandura, 1997; Zeldin & Pajares, 2000).

Gender-sensitive curricula and pedagogy

What the evidence says. Underrepresentation and stereotyped portrayals in textbooks signal misfit and reduce girls' interest in advanced STEM (Mumtaz, 2017; UNESCO, 2021). Curriculum-embedded interventions—contextualized tasks, collaborative problem-solving, and explicit representation of women scientists—improve belonging and participation when sustained (UNESCO, 2021; Yulianti et al., 2024). PD that is practice-based, iterative, and coached outperforms one-off workshops (Lo, 2021; Romero-Ariza et al., 2021).

Design implications

Textbook and assessment reform: audit images and narratives for gender bias; include local women scientists and engineers; align exams with inquiry and teamwork, not pure recall (Mumtaz, 2017; UNESCO, 2021).

Classroom routines that normalize collaboration and rotation of technical roles (e.g., lead coder, apparatus lead) ensure equal mastery opportunities—critical for self-efficacy growth (Bandura, 1997; Wang & Degol, 2017).

Fund school–university partnerships to co-develop modules relevant to Pakistan's development priorities (energy, water, agri-tech), which research shows can increase meaningful engagement and career vision (UNESCO, 2021; Rehman et al., 2025).

Workplace Diversity, Flexibility, and Bias Accountability

What the evidence says. The education-to-work transition is a pinch point where women face anticipatory bias, inflexible hours, and travel expectations (Aslam, 2018; Nazli, 2023). Global reviews emphasize that transparent hiring, structured interviews, inclusive team norms, flexible work, and accountability for promotion gaps reduce attrition (UNESCO, 2021; Saigo, 2024). Isolated "bias trainings" show limited impact without measurable policy changes and leadership ownership.

Design implications

Public sector and regulated industries should adopt gender-balanced shortlists, structured technical rubrics, and salary transparency; link procurement eligibility or tax incentives to diversity reporting (UNESCO, 2021; Saigo, 2024).

Promote flexible schedules, safe travel arrangements, and on-site childcare in STEM workplaces—particularly salient in Pakistan's mobility and caregiving context (Aslam, 2018; Nazli, 2023).

Establish campus-to-career bridges (paid internships, capstone residencies) with retention targets for women; evaluate companies on conversion rates to full-time roles.

Government Reforms and System Architecture

What the evidence says? Pakistan's federal initiatives (MoFEPT/STEAM Pakistan) signal strong intent; labs, teacher training, and visibility campaigns—but outcomes depend on scale, equity targeting, and monitoring (MoFEPT, 2025; STEAM Policy Unit, 2024). International guidance stresses gender-responsive budgeting, data disaggregation, and enforcement beyond pilots (UNESCO, 2021; United Nations Pakistan, 2025).

Design implications

HEC policy levers

- Tie program accreditation to evidence of gender-sensitive curricula, safe lab access, and formal mentoring structures.
- Require disaggregated reporting (applications, admissions, retention, internships, placement, promotion) by discipline and campus; publish dashboards to drive competition and transparency.
- Introduce performance-based grants for departments that close gender gaps in high-wage subfields (engineering, CS).
- Scholarships & conditional support. Scale women-targeted scholarships tied to completion of mentored internships and research projects; include mobility stipends for safe transport/housing to expand campus and industry options (UNESCO, 2021; Aslam, 2018).
- Teacher pipelines. Fund women-in-STEM teacher fellowships to increase female faculty density in male-typed departments—raising visible role models and mentorship capacity (UNESCO, 2021; Romero-Ariza et al., 2021).
- Data and accountability. Make gender outcomes a standing item in MoFEPT/HEC annual reviews; require institutions to file gender action plans with measurable targets and external audits (MoFEPT, 2025; UNESCO, 2021).

Psychological Empowerment; Paired with Structural Change

What the evidence says. Interventions that explicitly target self-efficacy, belonging, and stereotype threat can improve course performance and persistence, especially when paired with mastery-rich instruction (Bandura, 1997; Steele, 2010; Tellhed et al., 2017). In South Asian settings, responsive teaching and collaborative norms predict higher math/STEM self-belief among women (Paudel et al., 2025). But stand-alone workshops have short-lived effects unless the surrounding structures (mentoring, assessment design, role models) change concurrently.

Design implications

Embed brief values-affirmation and belonging messages into gateway courses; pair with iterative assessments that highlight growth (Steele, 2010; Wang & Degol, 2017).

Train faculty to give process-specific feedback ("what worked, what to try next") and to publicly normalize struggle in hard courses—key to recalibrating efficacy (Bandura, 1997).

Institutionalize women-in-STEM seminar series, alumni spotlights, and peer-led study collectives to increase vicarious efficacy and reduce imposter feelings (Zeldin & Pajares, 2000; Mujtaba et al., 2023).

Context-Specific Recommendations for Pakistan (Summary)

HEC Accreditation & Funding

Make gender-sensitive curriculum, mentoring, and climate metrics core to accreditation;

What Works: Interventions, Pakistan-Specific Recommendations, and the Payoff

Designing effective solutions means tackling the structure–psychology feedback loops identified earlier. The evidence suggests the most promising approaches are multi-level—pairing institutional and policy reforms that change contexts with pedagogical and mentoring practices that change experiences and beliefs. Below, we synthesize interventions with demonstrated or theorized impact and translate them into Pakistan-specific recommendations.

Mentorship and Sponsorship Networks

What works. Consistent with social cognitive theory, vicarious modeling and credible encouragement build self-efficacy and persistence; especially for women in male-typed subfields (Bandura, 1997; Zeldin & Pajares, 2000). Structured mentoring communities, alumni networks, and sponsorship (not just advice, but active advocacy for opportunities) increase women's access to research roles, internships, and leadership tracks (UNESCO, 2021; Wang & Degol, 2017). In Pakistan, perceived academic and social support is closely tied to women's STEM confidence, suggesting mentoring is a high-leverage lever (Husnain, Naz, & Rauf, 2022; Mujtaba et al., 2023).

Pakistan-Specific Recommendations.

Establish department-level mentoring grids that match each incoming woman student with a faculty mentor, a senior-year peer, and an alum in industry (Mujtaba et al., 2023; UNESCO, 2021).

Incentivize faculty sponsorship: include mentoring outputs (e.g., placements, co-authored projects) in annual appraisal and promotion criteria (UNESCO, 2021).

Partner with professional societies and the private sector to create women-in-engineering/computing councils that run shadowing days and internship pipelines (Rehman, Mahmood, & Huang, 2025).

Gender-Responsive Curricula and Pedagogy

What works. Curricular signals matter. Where textbooks and examples feature diverse scientists and connect STEM to socially valued outcomes, girls' sense of fit rises (UNESCO, 2021; Archer et al., 2013). Teacher professional development (PD) that emphasizes inquiry, collaboration, and formative feedback improves engagement and reduces stereotype salience (Lo, 2021; Romero-Ariza et al., 2021; Wang & Degol, 2017). Because Pakistani science texts have been shown to reproduce gendered portrayals (Mumtaz, 2017) and campus cultures can be male-typed (Khan & Malik, 2019), gender-responsive redesign is pivotal.

Pakistan-Specific Recommendations

HEC and provincial textbook boards should audit and revise STEM textbooks to ensure balanced representation and inclusive language (Mumtaz, 2017; UNESCO, 2021).

Scale teacher PD grounded in design principles—coherence, active learning, sustained duration, and subject specificity—so instructors can implement project-based and collaborative assessment models that build mastery experiences (Lo, 2021; Romero-Ariza et al., 2021).

Require every first-year engineering/computing program to include a team-based design studio with mixed-gender roles in technical leadership to normalize women's technical authority (Wang & Degol, 2017).

Psychological Empowerment and Belonging-Focused Practices

What works. Brief, well-timed values affirmation, growth-mindset feedback, and attributional retraining reduce stereotype threat and imposter feelings in high-stakes courses (Steele, 2010). Efficacy grows when students experience structured early wins, receive process-specific feedback, and see similar others succeed (Bandura, 1997; Zeldin & Pajares, 2000). In Pakistan and neighboring contexts, responsiveness and collaboration correlate strongly with women's math/engineering self-belief (Husnain et al., 2022; Paudel, Dahal, & Hasan, 2025).

Pakistan-Specific Recommendations

Embed belonging cues (e.g., normative statements that "struggle is common and surmountable") in course syllabi and LMS announcements in gateway math/physics/CS courses (Steele, 2010; Wang & Degol, 2017).

Introduce early, scaffolded mastery assessments (weekly low-stakes quizzes, iterative labs) so students accumulate credible "wins" quickly (Bandura, 1997).

Offer faculty workshops on feedback that names strategies and effort, not fixed ability, and that counters gendered participation patterns in labs (Romero-Ariza et al., 2021).

Workplace Diversity, Early-Career Transitions, and Flexible Design

What works. Retention hinges on inclusive workplaces: transparent hiring, fair evaluation, flexible scheduling, and zero-tolerance harassment policies are associated with improved retention of women in technical roles (UNESCO, 2021; Saigo, 2024). Transition supports—structured internships, apprenticeships, and bridge programs—improve job match and confidence (Rehman et al., 2025).

Pakistan-specific recommendations

Government procurement and grant programs can require vendors and grantees to adopt gender-equitable HR policies (transparent pay bands, complaint mechanisms, flexibility).

Create HEC-industry bridge fellowships reserving slots for women in core technical teams (not only outreach roles), with joint supervision and conversion-to-hire targets (Rehman et al., 2025).

Encourage employers to publish gender-disaggregated retention and promotion data; link eligibility for tax incentives or R\&D credits to progress on these indicators (UNESCO, 2021).

Government Reforms and Systems-Level Enablers

What works. National strategies amplify local efforts when they provide policy coherence, resources, and accountability. Pakistan's recent STEAM initiatives show intent (STEAM Policy Unit, 2024; Ministry of Federal Education and Professional Training \[MoFEPT], 2025), but sustained gender gains require explicit targets and enforcement.

Pakistan-Specific Recommendations

Strengthen HEC policy by mandating gender action plans in accreditation: (a) gender-disaggregated admissions, progression, and placement data; (b) minimum ratios of trained mentors to women students; (c) climate surveys with public summaries (HEC/UNESCO guidance; UNESCO, 2021).

Scholarships and mobility supports for women in engineering/CS (tuition + transport stipends + safe housing) to offset mobility/safety constraints that depress participation (Aslam, 2018; Nazli, 2023).

Safe campus infrastructure standards (lighting, transport routes, complaint redressal units) tied to public funding, addressing the structural drivers of anticipatory stress (Halai, 2019; Nazli, 2023).

Expand public awareness campaigns (role-model media, STEM fairs) that feature Pakistan-based women scientists and engineers to close the visibility gap (United Nations Pakistan, 2025; UNESCO, 2021).

Institutionalize data systems: annual gender audits of STEM pipelines from secondary to employment, coordinated by MoFEPT/HEC, to identify bottlenecks and allocate resources accordingly (UNESCO, 2021; STEAM Policy Unit, 2024).

Why A "Portfolio" Approach Beats Stand-Alone Programs

The literature is clear: single-shot workshops or symbolic days rarely move long-run outcomes because they do not alter the selection environment or the daily experience of learners and workers (Wang & Degol, 2017). Effective change pairs:

Structural redesign (curriculum, PD, mentoring architecture, hiring/evaluation rules), and

Psychological scaffolding (efficacy-building assessments, belonging interventions, role-model visibility).

This pairing interrupts the negative loops identified in Section 4: structures create regular mastery opportunities and access, which raise self-efficacy and belonging, which in turn increase students' challenge-seeking and persistence, feeding back into stronger credentials and representation.

Anticipated Socio-Economic Benefits for Pakistan

Elevating women's participation and retention in STEM expands Pakistan's human capital, strengthens innovation ecosystems, and raises household incomes—with positive spillovers for health, education, and intergenerational mobility (UNESCO, 2021; Saigo, 2024). Firms benefit from diverse problem-solving teams, associated with improved product quality and market reach (UNESCO, 2021). At national scale, a deeper pool of women engineers and technologists supports strategic sectors (energy, digital services, agritech, health tech), reduces skill shortages, and improves the return on public investment in secondary and tertiary education (MoFEPT, 2025; Rehman et al., 2025). Critically, when girls see women thriving in visible STEM roles, aspirations shift—future cohorts enter better prepared and more confident, creating a self-reinforcing cycle of inclusion (Archer et al., 2013; Zeldin & Pajares, 2000).

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