A Mixed-Methods Evaluation of STEM education integrated Skill Training, Employment, and the Social Transformation of Marginalized Women

Swati Mujumdar*, Hrushikesh Kedari

Symbiosis Skills and Professional University, Mumbai - Pune Expy, Kiwale, Pimpri-Chinchwad, Maharashtra, India- 412101

Email: phd@sspu.ac.in

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ABSTRACT:
The translation of high-quality technical education into meaningful employment, economic agency and enhanced social standing is particularly significant for women from disadvantaged backgrounds. This study evaluates a fully funded, residential, industry-partnered DMA/DME programme in Western India involving all 135 female graduates. Findings show substantial gains in household empowerment: the proportion reporting "No Say" in household decisions declined from 77.8% to 0%, with a strong overall effect ($\chi^2(3, N = 135) = 231.82$, $p < .001$; Cramér's $V = 0.93$). The Social Empowerment Index reached 89.0/100, with low variation across domains (CV = 4.1%), indicating broad-based gains. Employment outcomes were equally notable, with 100% placement and 96.3% one-year retention. Overall, the findings suggest that fully funded, industry-aligned STEM education can simultaneously strengthen employability, career trajectories and women's household agency, highlighting its potential as an inclusive pathway to social and economic empowerment.

Keywords: women's empowerment, STEM skill-based education, technical and vocational education and training (TVET), career decision self-efficacy, social empowerment

INTRODUCTION

Across low- and middle-income economies, persistent disparities in education, formal employment, asset control, mobility, and household voice continue to constrain women's substantive choices (Human Development Report Office, 2024; UN Women, 2023). India reflects this tension: female labour-force participation rose from 23.3% in 2017–18 to 41.7% in 2023–24, yet women with advanced degrees constitute only 2.9% of the employed female workforce, despite accounting for 43% of STEM enrolment (Ministry of Finance, Government of India, 2026). Increased participation has therefore not translated into proportional representation in technically demanding, better-remunerated occupations.

This gap is mirrored in STEM scholarship. A review of higher-education literature found gender referenced in 69% of studies on underrepresented groups, while other dimensions of disadvantage received less attention (Bruijnzeel et al., 2022). Research remains concentrated in schools and conventional universities, leaving fully funded, industry-linked vocational pathways for marginalized adult women underexplored. This omission is significant given the interconnected objectives of SDGs 4, SDG 5, SDG 8, and SDG 10, which link inclusive education with gender equality, decent employment, and reduced inequalities (United Nations, 2015). From a capability perspective, education matters not only as resource provision but as an expansion of substantive freedoms (Sen, 1999).

Bibliometric evidence similarly identifies SDG alignment as a growing theme in STEM education, though implementation evidence remains limited (Almarashdi et al., 2026).

In India, disadvantage is multidimensional, shaped by caste, economic status, and regional gender norms (Vignitha et al., 2024). Industrial automation and precision manufacturing remain strongly gender-segregated. Evidence from Assam shows that technological familiarity, financial literacy, and pre-marital agency predict empowerment, suggesting technical competence contributes beyond income effects (Nath & Das, 2024). STEM self-efficacy is also linked to career persistence (Yamani & Almazroa, 2024; Jiang et al., 2024), while European and Vietnamese studies highlight persistent gender differences in STEM attitudes (Grimalt-Álvaro et al., 2025; Nguyen Cong et al., 2025).

Technical and Vocational Education and Training (TVET) has emerged as a key policy mechanism, with UNESCO and the ILO emphasising its role in skills development and decent work (International Labour Organization, 2024; UNESCO, 2022). Yet conventional short-cycle TVET often reproduces segregation, directing women into feminised, low-wage sectors (Subrahmanyam, 2023; Iyengar & Witenstein, 2021). Evidence suggests meaningful participation requires programme designs that provide women with substantive voice and support (Iyengar & Witenstein, 2021), while Indonesian TVET research highlights resource and pedagogical constraints (Setiyawan et al., 2026).

Existing evidence largely emphasises immediate labour-market outcomes—placement, wages, enterprise formation—while neglecting household bargaining power, mobility, domestic responsibilities, and social recognition (Anand et al., 2025; Singh & Patel, 2024; Kabeer, 1999; Sharma & Kumar, 2024). Kabeer's resources–agency–achievements framework conceptualises empowerment as expanded capacity to make strategic life choices (Kabeer, 1999, 2005). Rowlands (1997) distinguishes power to, power within, power with, and power over, while Freire (1970) emphasises education's potential to challenge unequal arrangements.

Economic perspectives reinforce this rationale. Human capital theory links education with productivity and mobility (Becker, 1993), feminist economics highlight relational returns. Complementary evidence shows digital-literacy interventions improve women's confidence in ICT use (Gogoi et al., 2025), while Ghanaian and global studies highlight the importance of role models, counselling, and parental engagement in STEM participation (Awoniyi & Jokotagba, 2025; Gülhan, 2023).

Collectively, these strands suggest that institutionally provided technical skills, career support, and enabling environments may be more consequential for women's STEM trajectories than inherited social advantage. This study addresses these gaps by examining a fully funded, university-nested, industry-aligned technical education model and its relationship with employment outcomes and multidimensional socio-familial empowerment among marginalized women, thereby integrating labour-market and household-level outcomes into a common evaluative framework.

METHODOLOGY

Research design

A mixed-methods concurrent triangulation design was adopted (Creswell & Plano Clark, 2018). Quantitative and narrative data were gathered in the same post-programme window, analysed independently, and brought together only at interpretation — a sequence chosen to prevent either strand from framing the other prematurely. The design is standard in programme evaluation where effect estimation and contextual understanding are both required (Creswell, 2015). The population comprised women from economically disadvantaged and socially marginalised communities who completed the multi-year DMA/DME programme. No sampling frame was applied: all 135 graduates were enumerated, which removes sampling error while bounding generalisability in ways addressed under Limitations.

The framework integrates human capital theory, Sen's capability approach and Kabeer's triad into a single sequence: funded access enables technical and digital skill formation, which builds human capital and expands capability and agency; expanded agency alters intra-household bargaining position, which in turn generates social recognition and mobility, culminating in multi-dimensional empowerment aligned with SDGs 4, 5, 8 and 10.

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of Symbiosis Skills and Professional University (protocol SSPU/IEC/2026/2503A, approved 12 December 2025). Objectives and procedures were explained to

participants, and written informed consent was obtained before data collection. Participation was voluntary and withdrawal was permitted at any stage without consequence.

Result and Discussion

Cohort profile

The cohort comprised 135 female graduates of the DMA/DME programme, all of whom completed the programme and originated from marginalised and economically disadvantaged backgrounds. As the programme cohort was fully enumerated, the study included all eligible graduates rather than a sample, with 100% completion. This provides complete coverage of the intervention cohort while restricting generalisability to comparable institutional and population contexts.

Household decision-making authority

Authority within the household is the most direct available indicator of a woman's bargaining position. Table1 and Figure 1 compare the distribution before and after programme participation. The movement is categorical rather than incremental: the baseline modal category disappears entirely.

Table 1 Household decision-making authority, pre- versus post-programme (N = 135)

Decision-making authority	Pre-programme, n (%)	Post-programme, n (%)
No say	105 (77.8)	0 (0.0)
Some say	30 (22.2)	14 (10.4)
A lot of say	0 (0.0)	65 (48.1)
Major decisions	0 (0.0)	56 (41.5)
Total	135 (100.0)	135 (100.0)

Before the intervention, more than three-quarters of respondents reported no participation in household decisions and none reported substantial authority. Afterwards, the 'no say' category was empty and 89.6% reported either considerable influence or primary decision-making responsibility.

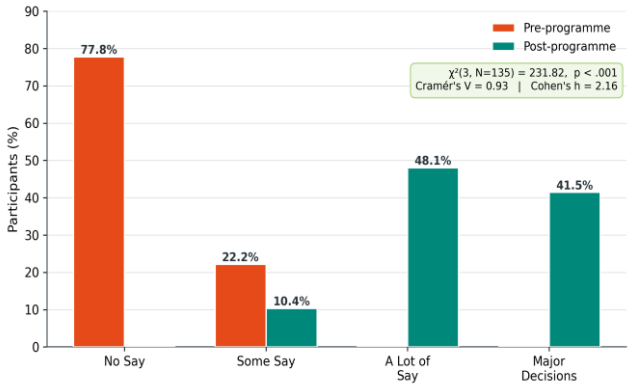

Figure 1 Household decision-making authority before and after the programme (N = 135)

Autonomy across independent life domains

Authority in the abstract means little unless it attaches to specific decisions. Table 2 disaggregates the domains in which respondents reported exercising independent or primary authority, with Wilson intervals attached to each estimate. Educational autonomy was reported by 92.6% (95% CI: 86.9–95.9), employment and career autonomy by 88.9% (82.5–93.2), and leading roles in marriage and personal decisions by 74.1% (66.1–80.7).

Table 2 Autonomy across independent life domains, with Wilson 95% confidence intervals

Independent decision-making domain	n	%	95% CI
Future educational pursuits	125	92.6	86.9–95.9
Employment & career choices	120	88.9	82.5–93.2
Marriage decisions & personal autonomy	100	74.1	66.1–80.7
Major household purchases	20	14.8	9.8–21.8
Educational trajectories of siblings	18	13.3	8.6–20.1

Autonomy concentrated in domains concerning the respondent's own life course and receded sharply in domains involving collective household resources — major purchases (14.8%) and siblings' education (13.3%). The confidence intervals reinforce the reading: the personal-domain estimates are tightly bounded, while the household-level estimates are both

lower and less precisely estimated. Personal agency, on this evidence, expanded well ahead of authority over shared assets — an unevenness worth naming rather than averaging away, and an obvious target for programme extension.

Composite Social Empowerment Index

Table 3 present the eight-domain composite, which resolves to 89.0/100. The headline figure is less interesting than its distribution. Across the eight domains the standard deviation was 3.63 and the coefficient of variation just 4.1%, indicating that gains were spread rather than concentrated — the programme did not simply move employment outcomes and leave the social domains behind.

Table 3 Domain scores for the composite Social Empowerment Index

Empowerment domain	Post-intervention score (%)
Family decision-making authority	89.6
Educational autonomy	92.6
Employment & career autonomy	88.9
Respect from elders & family members	88.9
Recognition of opinions within household	92.6
Assignment of meaningful family responsibilities	86.7
Independent spatial mobility	81.5
Gender agency & resistance to discrimination	91.1
Overall composite SEI	89.0

Independent spatial mobility (81.5) sits lowest and educational autonomy and opinion recognition jointly highest (92.6). Mobility is plausibly the domain most tightly bound to community norms rather than individual capability, which would account for its comparative lag.

Relative Importance Index hierarchy

Table 4 rank the domains by relative importance.

Table 4 Relative Importance Index and rank

Empowerment outcome	RII	Rank
Educational autonomy	0.926	1
Opinion recognition	0.926	1
Gender agency & advocacy	0.911	3
Family decision-making authority	0.896	4
Employment autonomy	0.889	5
Respect from elders	0.889	5
Meaningful family responsibilities	0.867	7
Independent spatial mobility	0.815	8

One methodological caution belongs here rather than in a footnote. The RII values are a linear rescaling of the Table 4 domain scores (RII = SEI/100) and therefore correlate with them perfectly by construction. This is reported as an internal coding-consistency check and carries no independent evidential weight; it should not be presented as convergent validation of two separate instruments.

Normalised gain and transformation ratio

Applied to the decision-making data, Hake's normalised gain returned g = 0.75, which falls in the high-transformation band by conventional educational benchmarks, and the Transformation Ratio returned TR = 2.71 — an average 2.7-fold increase in household decision-making authority relative to baseline.

Employment placement and occupational progression

Every graduate entered employment immediately following completion (n = 135; Wilson 95% CI: 97.3–100.0), all within a standardised take-home band of ₹16,000–₹18,000 per month. Table 5 contrasts the entry-level distribution with roles held at follow-up. At entry, 39.3% began as trainees and 20.7% as interns, with 16.3% in designated technical roles, 9.6% in assembly, 8.1% in line operations and 5.9% in assistant positions. At follow-up the distribution had shifted upward across the board: 22.2% were working as specialist operators, 19.3% in junior engineering roles, 18.5% in junior design, 10.4% as line leaders and 7.4% in management, with only 0.7% remaining in basic administrative work.

Table 5 Occupational distribution at entry (a) and at follow-up (b)

Entry-Level Placement	Percentage %	Current Role	Percentage %
Trainee	39.3	Operator	22.2
Intern	20.7	Junior Engineer	19.30
Technical Roles	16.3	Junior Design	18.50
Assembly	9.6	Line Leader	10.40
Line Operations	8.10	Management	7.40
Assistant	5.90%	Data Entry	0.70%

Salary progression All working graduates reported positive salary movement following placement. Figure 2 shows the reported brackets: 23.0% at a 40% increase, 22.2% at 30%, 21.5% at 10% and 17.8% at 20%. These four categories account for 84.5% of the working cohort. The residual 15.5% was not assigned to any bracket in the instrument as made available for this analysis; it is displayed explicitly as an unrecorded category rather than redistributed or silently omitted, and is carried forward to Limitations as a data-completeness item requiring reconciliation against the raw response file before submission. Table 6 shows No graduate registered in the low-progression tier. The 3.7% reaching the high tier did so by combining programme outcomes with employer mobility — notably, the same five graduates who changed employers.

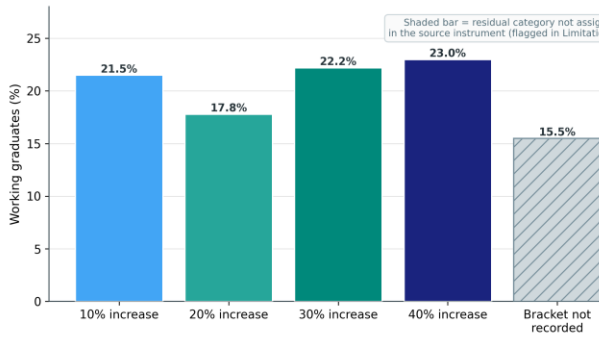

Figure 2 Reported salary progression since initial placement, including unrecorded residual

Career Progression Index

Table 6 Graduate classification by Career Progression Index tier

CPI score band	Progression level	Observed cohort distribution
0–2	Low professional progression	0 (0.0%)
3–4	Moderate professional progression	130 (96.3%)
5	High professional progression	5 (3.7%)

CONCLUSION

This study highlights how a fully funded, industry-aligned STEM training programme in Western India was strongly associated with improved employment trajectories and household empowerment among marginalized women. Quantitative results showed exceptionally high associations between programme participation and empowerment outcomes ($\chi^2 = 231.82$, $p < .001$; Cramér's $V = 0.93$), with a composite empowerment score of 89.0/100 and consistent gains across domains. Qualitative narratives reinforced these findings, illustrating how technical education and workplace integration extended beyond employability to reshape household decision-making, financial autonomy, and gender roles.

Taken together, the evidence positions gender-responsive skills universities as promising institutional mechanisms for advancing the objectives of SDGs 4, SDG 5, SDG 8, and SDG 10. While the study's contextual specificity limits causal attribution and generalisability, the results provide substantive support for further investment in inclusive, industry-integrated STEM skilling. Future research should employ longitudinal or multi-site designs to assess the durability of these empowerment gains and explore replication across diverse marginalized communities.

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