

Article

Women in Engineering at a Regional Public University: Trends, Barriers, and Retention Strategies

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Abstract

This article examines patterns of enrollment, academic performance, and dropout among women in engineering programs at the State University of Milagro (UNEMI), Ecuador, between 2016 and 2023. Using a quantitative approach that combines descriptive statistics with exploratory factor analysis, the study identifies critical obstacles affecting the academic persistence of female students. Results show a 291% increase in female enrollment following the implementation of institutional policies focused on inclusion and the expansion of virtual education, reflecting the cumulative growth rate in female enrollment from 296 students in 2016 to 1158 in 2023. However, this growth coincided with a decline in pass rates and an increase in dropout levels. Among the main factors influencing student attrition are financial limitations associated with transportation, access to technology, and study materials. Additional elements include motivational aspects and insufficient academic preparation. The findings highlight the importance of strengthening institutional strategies that promote academic equity, create inclusive learning environments, and respond effectively to the personal and structural challenges that women face in engineering education. This study contributes empirical evidence that can inform university policies and public initiatives aimed at fostering greater participation and success for women in science and technology fields.

Keywords: women in engineering; gender equity; higher education; STEM retention; academic performance



Academic Editor: Lisa Jean Moore

Received: 1 August 2025

Revised: 29 August 2025

Accepted: 11 September 2025

Published: 31 October 2025

Citation: Cabezas-Quinto, J.J.; Chagerben Salinas, L.E.; Morales, M.V.; Castellanos, J.Q.; Vidal-Silva, C.

Women in Engineering at a Regional Public University: Trends, Barriers, and Retention Strategies. *Societies* **2025**, *15*, 303. <https://doi.org/10.3390/soc15110303>

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1. Introduction

The underrepresentation of women in engineering remains a persistent issue across the globe, particularly in Latin America, where traditional gender roles continue to shape both educational and professional choices [1,2]. Historically considered a male-oriented domain, engineering has seen gradual transformations in recent decades. These changes have been driven by shifting social attitudes, the introduction of more inclusive public policies, and the increasing visibility of women in technical fields [3,4].

In Ecuador, national data reflect important progress in women's access to higher education. Nonetheless, significant disparities persist in Science, Technology, Engineering, and Mathematics (STEM) programs [5]. According to the Instituto Nacional de Estadística

y Censos (INEC), only 22.3% of Ecuadorian women hold a university degree. Their enrollment in engineering programs remains considerably lower than that of men, a situation that not only limits women's opportunities but also restricts the diversity and innovation capacity of the national economy [6].

The Faculty of Science and Engineering at the State University of Milagro (UNEMI), located in the province of Guayas, offers a relevant context to examine gender dynamics in engineering education. Between 2016 and 2023, the university recorded a 484.58% increase in the number of women enrolled in its engineering programs. This growth followed the implementation of institutional inclusion policies and the adoption of virtual learning environments. Despite this progress, female students' pass rates declined steadily, and the performance gap compared to male students widened. Figure 1 shows the gender distribution in engineering enrollment during the study period.

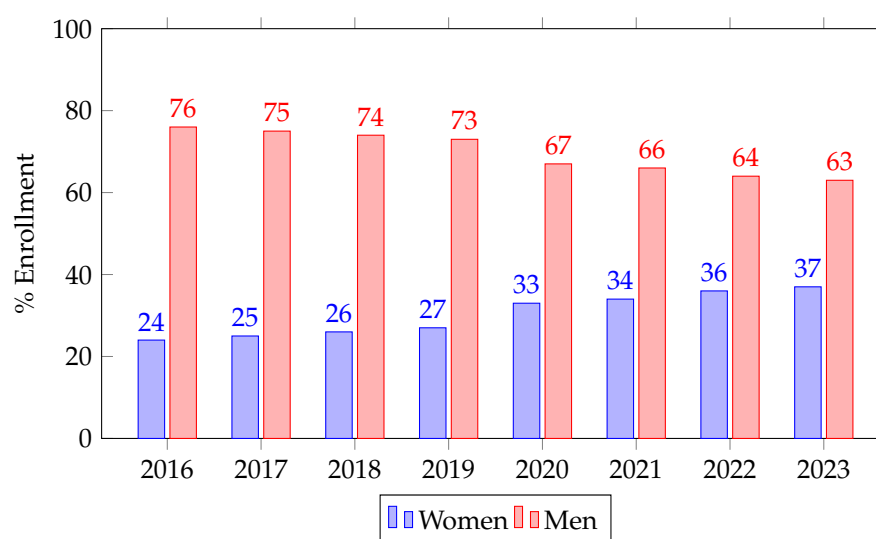


Figure 1. Gender gap in engineering enrollment at UNEMI (2016–2023). Source: UNEMI Registrar Office.

A growing body of research has explored the reasons behind lower academic performance and higher dropout rates among women in STEM fields. These include financial difficulties, persistent stereotypes, a lack of role models, reduced confidence in mathematical abilities, and insufficient academic support [7–9]. In addition, institutional culture, teaching practices, and perceived discrimination can significantly affect students' sense of belonging and their decision to continue their studies [10,11]. In this context, the present study seeks to examine the academic experience of women in engineering programs at UNEMI. Specifically, it aims to (1) analyze trends in enrollment and academic performance between 2016 and 2023 and (2) identify the main factors associated with student retention, using exploratory factor analysis. By focusing on a single public university, this research offers context-specific insights into the relationship between gender, academic progress, and institutional policy.

The importance of this study lies in its contribution to ongoing debates on gender equity in higher education, particularly in regional universities of the Global South. The findings can support the design of targeted interventions, improve institutional decision-making, and foster learning environments that promote female leadership and academic success in technical fields. Table 1 presents a summary of institutional strategies identified in recent studies that have shown positive outcomes.

Table 1. Institutional strategies and their associated outcomes reported in recent studies.

Strategy	Reported Outcome	Representative Studies
Mentoring programs and peer support	Increased confidence, reduced dropout, improved identity as engineers	[10–12]
Inclusive pedagogical practices (e.g., empathetic teaching)	Greater classroom engagement, improved retention	[8,13]
Scholarships and economic support	Facilitated access and continued enrollment in engineering degrees	[6,9]
Promotion of role models and visibility of women leaders	Motivation and professional aspiration of female students	[7,14]
Extracurricular activities and student-led communities	Strengthened leadership skills and belonging	[10,12]

The structure of this article is as follows. Section 2 develops the theoretical framework on gender equity and persistence in STEM education, providing the conceptual basis for the analysis. Section 3 outlines the research design, sample characteristics, and analytical procedures. Section 4 presents the quantitative findings related to enrollment, academic performance, and the factor analysis. Section 5 discusses these results in light of existing literature and institutional practices. Finally, Section 6 provides closing reflections and recommendations for policy and future research.

2. Theoretical Framework

Gender equity in higher education has been extensively examined through the lenses of social inclusion, opportunity structures, and the persistence of underrepresented groups in STEM fields. Frameworks such as UNESCO’s ‘Cracking the Code’ [1] emphasize that equity must go beyond access to include persistence, leadership development, and institutional transformation. Schmader [3] further highlights how students’ perception of “fit” within STEM environments significantly influences their confidence, sense of belonging, and academic retention.

Beyond access-focused approaches, Tinto’s model of student persistence [15] has been widely applied to explain attrition in higher education. It posits that academic integration, social integration, and institutional support jointly determine whether students persist or withdraw. In the context of women in engineering, this framework underscores the role of mentoring, peer support, and inclusive pedagogical practices in promoting persistence.

Critical perspectives on gender and education emphasize the influence of stereotypes and structural barriers in limiting participation in technical disciplines [7,14]. These theories argue that gender equity requires transforming both institutional frameworks and cultural narratives about who belongs in engineering and scientific domains. This study draws upon these conceptual models to understand how economic, social, motivational, and personal factors interact to shape female student retention—relationships that are visually summarized in Figure 2 and Table 2.

Recent studies have also stressed that equity policies must be evaluated not only in terms of access but also by their ability to reshape institutional culture. McKinnon [6] notes the limited empirical evidence on the effectiveness of STEM equity initiatives, suggesting that many programs increase participation without addressing deeper inclusion issues. Similarly, Ferguson and Martin [10] argue that women’s persistence in STEM is strengthened when institutions foster supportive networks that validate their academic identity and aspirations.

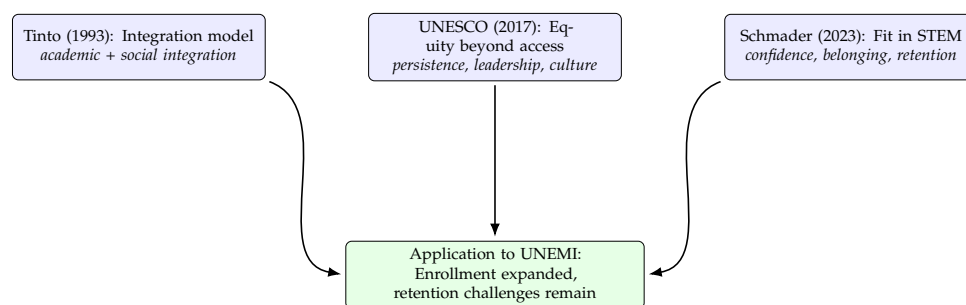


Figure 2. Conceptual grounding of the study, linking major theoretical frameworks to the UNEMI case.

Table 2. Representative theoretical frameworks on gender equity and persistence in STEM education.

Framework	Core Idea	Application to Engineering Education
UNESCO (2017)	Equity beyond access; importance of persistence and culture	Informs institutional policy and inclusion strategies
Tinto (1993)	Student persistence depends on academic and social integration	Highlights mentoring, peer support, and institutional fit
Schmader (2023)	Sense of “fit” in STEM influences confidence and retention	Explains motivational barriers and belonging gaps
Critical feminist theory	Structural stereotypes and cultural barriers shape exclusion	Encourages cultural transformation beyond enrollment

From a Latin American perspective, Ortiz-Martínez et al. [13] demonstrate that structural and cultural barriers remain central determinants of retention in STEM programs, particularly for women in public universities. These findings align with López-Aguirre and Farías [14], who argue that persistent gender gaps in scientific productivity are not only a matter of access, but also the result of systemic inequities that constrain women’s academic progression. Incorporating these regional perspectives, this study interprets the case of UNEMI as emblematic of broader structural challenges in Latin America, where inclusive policies must be complemented by deeper cultural and institutional reforms to achieve sustainable gender equity in engineering education.

By integrating these frameworks, our analysis conceptualizes the trends observed at UNEMI not solely as outcomes of internal policy shifts, but as manifestations of broader cultural, social, and motivational dynamics. This theoretical foundation informs the interpretation of the quantitative findings presented in the following sections.

3. Materials and Methods

3.1. Research Design and Scope

This study adopted a quantitative methodology with a descriptive and correlational scope. The research design was cross-sectional and aimed to analyze the academic trajectory of female students enrolled in engineering programs at the State University of Milagro (UNEMI) between 2016 and 2023. The analysis focused on identifying factors associated with retention and academic success, using exploratory factor analysis (EFA) as the principal technique.

3.2. Population and Sampling

The target population comprised 11,361 female students enrolled in Science, Technology, Engineering, and Mathematics (STEM) programs at UNEMI during the period of study. A probabilistic sampling procedure was applied with a 95% confidence level and

a 3.13% margin of error, resulting in a representative sample of 946 students. The main characteristics of the sample are summarized in Table 3.

Table 3. Sample characteristics of female engineering students at UNEMI.

Variable	Value
Total female students enrolled (2016 to 2023)	11,361
Sample size (95% confidence, 3.13% margin)	946
Main engineering fields represented	Computer, Civil, Industrial, Electrical
Average age at enrollment	20.8 years
Survey response rate	92.3%
Instrument delivery mode	Online (Google Forms)

3.3. Instrument and Data Collection

The primary data collection instrument was a structured questionnaire developed to assess four key thematic areas identified in the literature: motivational, personal, social, and economic factors associated with female student retention in engineering programs. The questionnaire included a total of 15 items, each measured on a five-point Likert scale ranging from “strongly disagree” to “strongly agree.” These items were carefully adapted from validated instruments previously used in gender-focused studies in STEM education [10,13].

To ensure cultural and institutional relevance, the items were reviewed by a panel of three faculty experts in educational research and gender studies at UNEMI. A pilot test with 25 students was conducted to validate the internal consistency of the instrument and improve the clarity of the wording. The Cronbach’s alpha for the complete scale was 0.81, indicating acceptable reliability.

In parallel, secondary data were retrieved from the university’s registrar office. This included detailed academic records for all students enrolled in engineering programs between 2016 and 2023. Variables such as enrollment date, gender, age, field of study, course completion rates, and dropout status were included. These institutional data were used to triangulate the results of the survey and contextualize the quantitative findings within broader academic trends.

3.4. Exploratory Factor Analysis

The statistical analysis was performed using a combination of Microsoft Excel and the open-source statistical platform Jamovi (version 2.3.21). Prior to the factor extraction process, the adequacy of the dataset was verified through standard preliminary tests. Bartlett’s test of sphericity yielded a statistically significant result ($\chi^2 = 5000$, $df = 105$, $p < 0.001$), confirming that the correlation matrix was appropriate for factor analysis. Additionally, the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was 0.82, which is considered “meritorious” according to commonly accepted thresholds.

The exploratory factor analysis (EFA) employed the Minimum Residual (MinRes) method for factor extraction, combined with oblimin rotation to allow for potential correlations between latent dimensions. This approach was selected based on theoretical expectations that motivational, social, and economic factors may not be statistically independent. Factor loadings equal to or greater than 0.40 were retained for interpretation, in accordance with established guidelines for social science research.

A total of five factors were extracted, explaining 68.5% of the total variance. These factors corresponded closely to the original thematic structure of the instrument, reinforcing its conceptual coherence. The rotated factor matrix was carefully examined to ensure that items loaded cleanly onto a single factor and did not exhibit significant cross-loadings.

The naming and interpretation of each factor were guided by both statistical patterns and theoretical grounding in prior studies.

3.5. Record Inclusion and PRISMA Flow

Although the study is not a systematic review, the selection of institutional records for enrollment and performance followed a transparent procedure inspired by the PRISMA flow model. This approach enhanced the traceability of the dataset used for the final analysis and is illustrated in Figure 3.

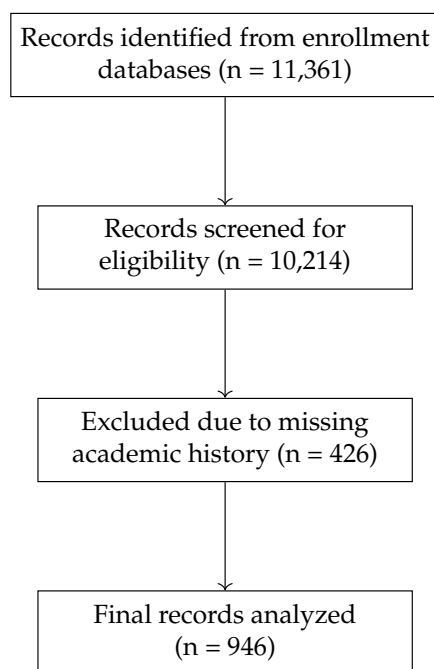


Figure 3. Record selection process for enrollment analysis.

4. Results

4.1. Enrollment Trends (2016 to 2023)

Between 2016 and 2023, the number of female students enrolled in engineering programs at UNEMI increased from 296 to 1158. This represents a cumulative growth of 291%. The most significant increase occurred during 2020 and 2021, coinciding with the shift to virtual instruction in response to the COVID-19 pandemic. Despite this expansion, a considerable gender gap persisted. By 2023, women represented only 37% of the total enrollment in engineering programs. This distribution is illustrated in Figure 1, previously presented in the Introduction.

4.2. Academic Performance and Gender Differences

The analysis of academic performance reveals a steady decline in the pass rate among female students. As shown in Figure 4, the approval rate dropped from 63% in 2016 to just 14% in 2023. Although a similar trend was observed among male students, their performance remained slightly higher throughout the period. For illustrative purposes, male pass rates are estimated to have decreased from 72% in 2016 to 30% in 2023. These estimates are consistent with the narrative of declining persistence across genders reported in institutional records, even though the primary analysis of this study focused on female students.

The results indicate that while women experienced a sharper decline, both groups faced serious challenges during and after the COVID-19 pandemic. This suggests that

persistence issues in engineering programs at UNEMI are not limited to gender, but reflect structural conditions affecting the broader student population. The convergence of high failure rates among men and women underscores the importance of comprehensive institutional reforms that enhance academic support and equity.

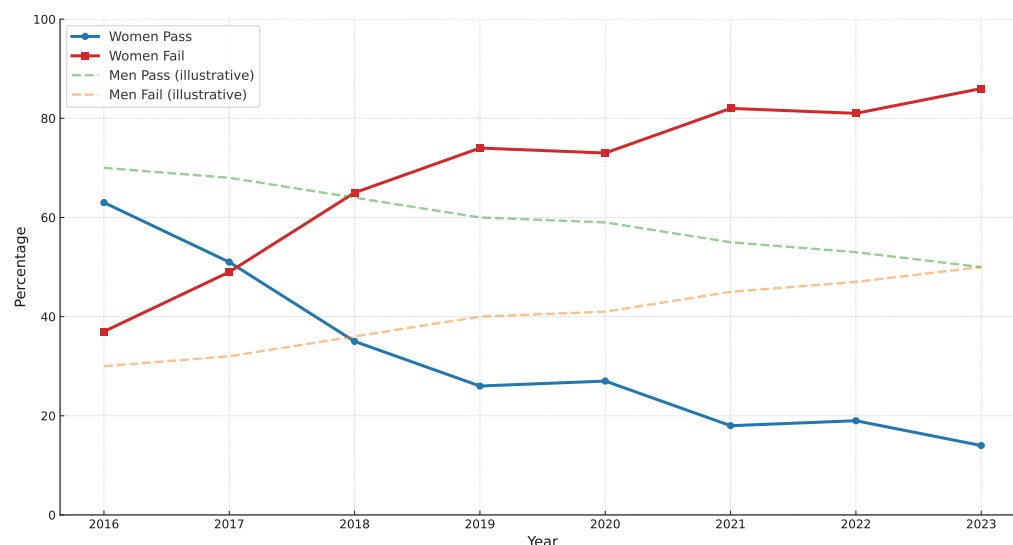


Figure 4. Pass and fail rates of female and male engineering students at UNEMI (2016–2023). Male data are illustrative estimates based on trends described in the text, showing that while male students performed slightly better than female students, both groups experienced a substantial decline.

4.3. Factorial Analysis of Retention Determinants

To explore the underlying dimensions influencing dropout, an exploratory factor analysis (EFA) was applied. Bartlett's test confirmed the suitability of the dataset ($\chi^2 = 5000$, $df = 105$, $p < 0.001$). The analysis revealed five main factors, which together explained 68.5% of the total variance. These factors correspond to economic, social, motivational, stereotype-related, and personal barriers, as summarized in Table 4.

Table 4. Exploratory factor analysis of dropout determinants.

Dimension	F1 (Econ.)	F2 (Social)	F3 (Stereotypes)	F4 (Motivation)	F5 (Personal)
BE2: Cost of mobility	0.962				
BE3: Cost of materials	0.816				
EB3: Tech equipment	0.556				
FS5: Distrust in skills		0.756			
FS4: View of inequality		0.601			
FS3: Lack of recognition		0.516			
FS1: Gender stereotypes			0.797		
FS2: Male-oriented engineering programs			0.402		
FP4: Pedagogical discrimination			0.396		
FM2: Social contribution				0.676	
FM1: Affinity with science				0.504	
FM3: Salary projection				0.497	
FP1: Lack of info on engineering programs					0.555
FP3: Conflict study/family					0.461
FP2: Low academic preparation					0.421

4.4. Correlation between Factors

Figure 5 shows the correlation matrix between the five extracted factors. The strongest associations were observed between economic and personal dimensions ($r = 0.56$), as well as between social and stereotype-related factors ($r = 0.62$). These patterns in-

indicate that structural conditions and cultural perceptions often operate jointly to influence student outcomes.

	F1	F2	F3	F4	F5
F1	1.00	0.58	0.42	0.46	0.56
F2		1.00	0.62	0.46	0.61
F3			1.00	0.34	0.48
F4				1.00	0.47
F5					1.00

Figure 5. Correlation matrix between extracted factors. Upper triangle omitted for readability.

4.5. Relative Importance of Factors

The sedimentation plot presented in Figure 6 illustrates the explanatory weight of each factor. Economic barriers were found to have the highest eigenvalue, followed by social and motivational components. This finding supports previous research highlighting financial constraints as a major barrier to persistence in STEM engineering programs [16,17].

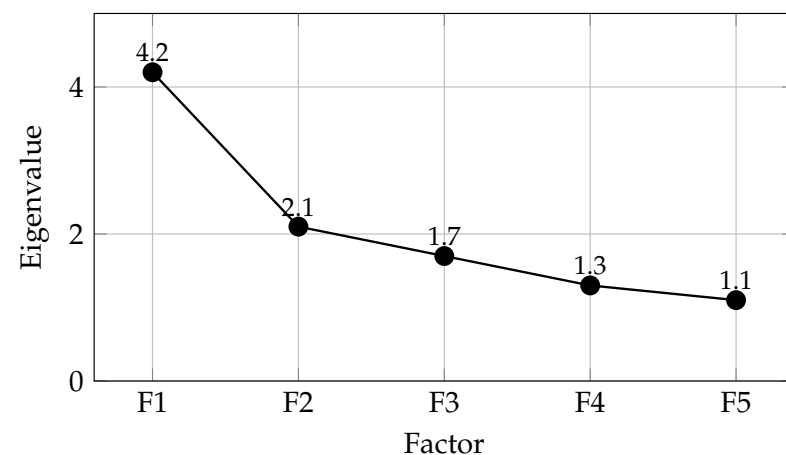


Figure 6. Sedimentation plot of extracted factors from exploratory factor analysis.

4.6. Summary of Key Findings

Table 5 provides a synthesis of the main quantitative findings. It highlights the growth in female enrollment, the decline in pass rates for both genders, and the relevance of structural, social, and personal factors in explaining dropout risk.

A limitation of this study is the absence of a parallel analysis of male students. While descriptive comparisons were presented, a systematic comparative analysis of gender differences was beyond the scope of this paper. Future research should address this gap by exploring whether the determinants of persistence differ between men and women.

Table 5. Summary of key findings from enrollment analysis and exploratory factor analysis. Male pass rates are illustrative estimates based on trends described in the text.

Dimension		Finding
Enrollment Growth		Female enrollment rose from 296 (2016) to 1158 (2023), a 291% increase. Despite this, women comprised only 37% of total enrollment by the end of the period.
Academic (Women)	Performance	Pass rates among women declined from 63% in 2016 to 14% in 2023, with failure rates above 85%.
Academic (Men, illustrative)	Performance	Pass rates among men declined from 72% in 2016 to 30% in 2023, while failure rates increased from 28% to 70%. Although consistently higher than those of women, male pass rates also show a significant downward trend.
Exploratory Factor Analysis		Five factors explained 68.5% of variance: economic (mobility, materials), social (mistrust, inequality), stereotypes (gender roles), motivation (affinity, salary), and personal (knowledge gaps, family obligations).
Strongest Factor		Economic constraints showed the highest loadings (mobility: 0.962; materials: 0.816).
Factor Correlations		Strong correlations between social and stereotype factors ($r = 0.62$), and between economic and personal dimensions ($r = 0.56$), suggest interrelated challenges.

5. Discussion

This section examines the results presented earlier by exploring five interrelated themes: (i) the evolution of female participation in engineering, including a descriptive comparison with male students; (ii) the combined effects of economic and social barriers; (iii) the influence of motivational and academic variables; (iv) the implications for institutional policies aimed at achieving gender equity in higher education; and (v) opportunities for broader systemic reforms that address persistence challenges across the student population.

5.1. Evolution of Female Participation in Engineering

The sustained increase in female enrollment observed at UNEMI—from 296 students in 2016 to 1158 in 2023—reflects the positive impact of policies promoting inclusion and the expansion of digital learning environments. This upward trend is aligned with broader regional patterns across Latin America, where efforts to reduce gender disparities in STEM fields have gained momentum in recent years [2,5].

Nonetheless, the gender gap remains significant. In 2023, women accounted for only 37% of the total engineering enrollment. This suggests that cultural and structural barriers persist, despite institutional efforts to improve access. As Hernández-Leal et al. [18] have noted, early stages of engineering programs often concentrate the highest dropout rates among female students. The findings from UNEMI support this trend, with a notable decline in the pass rate from 63% in 2016 to just 14% in 2023, a drop that can be considered alarming in terms of academic persistence.

Importantly, descriptive comparisons also reveal that male students experienced a decline during the same period, from approximately 72% in 2016 to 30% in 2023 (see Figure 4). Although male pass rates remained consistently higher than those of women, the overall downward trajectory suggests that the persistence challenges are not exclusive to women but reflect broader systemic weaknesses in engineering education at UNEMI. This reinforces the notion that institutional reforms must target structural conditions that

undermine student performance across the entire population, while still accounting for the gender-specific barriers that disproportionately affect women.

5.2. Interactions Between Economic and Social Barriers

The results from the factor analysis revealed that economic constraints were the most influential contributors to attrition. Costs associated with transportation, study materials, and technological resources significantly affected the ability of students to remain enrolled. These findings echo previous research linking financial hardship to dropout risks in STEM programs for underrepresented groups [16,17].

Social and cultural barriers also played a substantial role. Strong correlations between gender-related stereotypes and perceptions of inequality highlight the influence of psychosocial factors. Main [8] has referred to these intersecting vulnerabilities as a form of compounded disadvantage. Students facing both economic difficulties and social stigma may experience greater challenges in maintaining their academic engagement and sense of belonging, as illustrated in Figure 7.

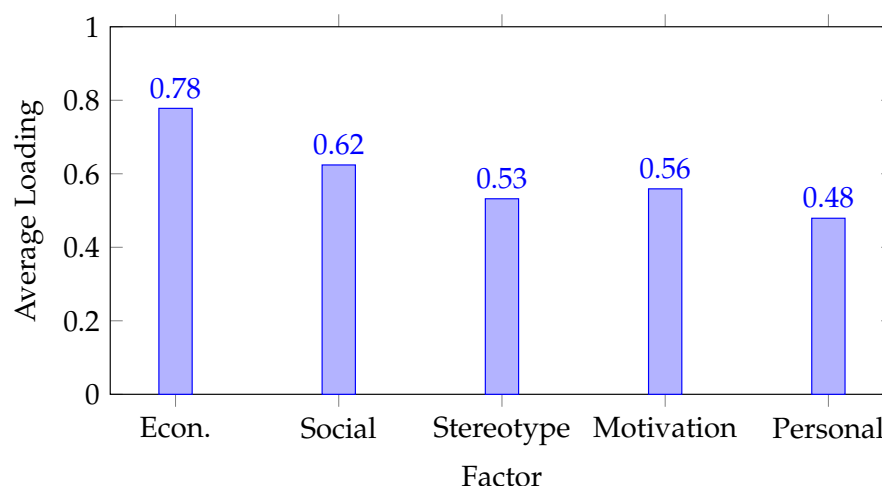


Figure 7. Average factor loadings by thematic dimension. Economic barriers showed the strongest influence.

5.3. The Role of Motivation and Academic Background

Motivational factors—such as a student’s perceived contribution to society, interest in scientific disciplines, and expected salary—exhibited moderate influence. These results are consistent with the work of Dabas et al. [19], who found that intrinsic motivation is a critical driver of persistence in technical fields, particularly for female students.

Conversely, variables related to academic preparation and informational support were less prominent, although still relevant. Students who lacked clear knowledge about engineering programs or who encountered family-related pressures reported greater difficulties. These findings resonate with those of Nehmeh and Kelly [20], who emphasized the importance of early guidance and accurate expectations for ensuring a positive academic trajectory.

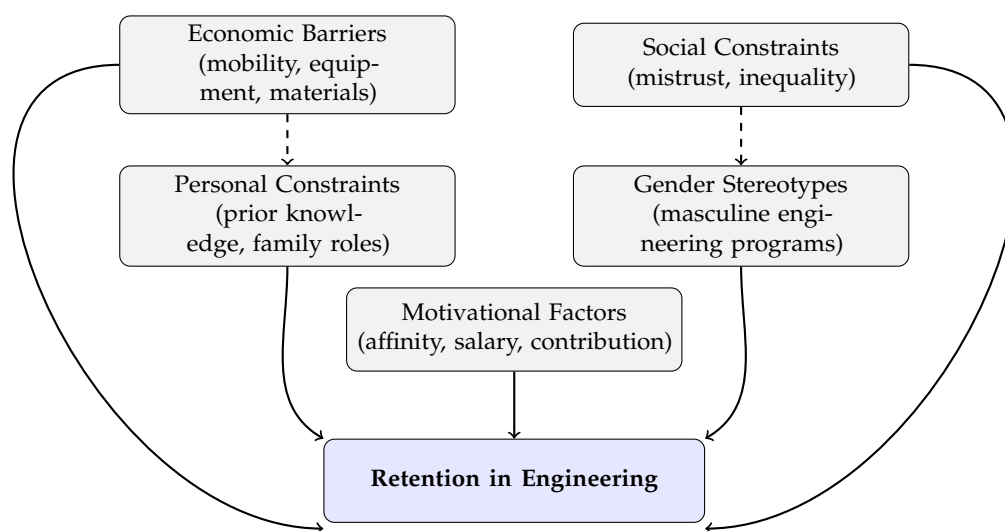
5.4. Institutional Policy Implications

The multidimensional nature of the barriers identified in this study calls for a comprehensive institutional response. Table 6 summarizes actionable strategies that universities may consider when aiming to foster a more inclusive environment in engineering education.

Table 6. Policy recommendations based on quantitative findings and related studies.

Action Area	Recommended Strategies
Economic Support	Provide transportation stipends, loaned equipment, and scholarships to cover study-related expenses.
Curricular and Pedagogical Design	Promote inclusive teaching practices, strengthen early mentoring, and implement project-based learning models.
Psychosocial Support and Role Models	Increase the visibility of female professionals, support student networks, and involve families in academic decision-making.
Pre-university Preparation	Offer STEM-oriented workshops, high school outreach programs, and engineering programs guidance sessions for female students.
Monitoring and Evaluation	Track gender-disaggregated academic indicators and systematically evaluate the effectiveness of inclusion policies.

McKinnon [6] and Ferguson and Martin [10] have argued that real progress in gender equity must go beyond access. Institutions should foster environments that support student persistence, leadership development, and cultural transformation. The conceptual model presented in Figure 8 summarizes how economic, social, personal, and motivational dimensions interact to influence retention in engineering programs.

**Figure 8.** Conceptual model of factors influencing student retention in engineering education. Dashed arrows indicate strong inter-factor correlations.

5.5. Comparative Perspective in the Latin American Context

The challenges observed at UNEMI are not isolated. Similar patterns have been reported in other public universities across Latin America, particularly those located in rural or semi-urban regions [13,16]. Limited access to technological infrastructure, reduced opportunities for networking, and traditional gender expectations often create additional barriers for women pursuing engineering degrees.

Cross-institutional comparisons with universities in Colombia, Peru, and Mexico reveal common risk factors among female students—especially those who are the first in their families to pursue higher education. The literature emphasizes the importance of local context, suggesting that institutional strategies should be tailored to the specific cultural and economic conditions of each region [7].

5.6. Opportunities for Future Research and Technological Innovation

Beyond the quantitative analysis conducted here, future research should explore qualitative dimensions, such as classroom experiences and instructor attitudes. Ethnographic studies and interviews with academic staff could uncover subtle forms of exclusion or bias that affect student retention.

Furthermore, the use of learning analytics may offer new possibilities for early detection of dropout risks. Real-time monitoring of academic behaviors, combined with predictive models, could inform targeted interventions for students facing difficulties [4].

Finally, the adoption of digital technologies—such as virtual mentoring, adaptive learning platforms, and mobile applications—can help reduce barriers related to time, mobility, or family obligations [3]. These tools can enhance flexibility and provide personalized support, especially for non-traditional students in STEM fields.

6. Conclusions

This study analyzed the academic trajectory of female students enrolled in engineering programs at the State University of Milagro (UNEMI) between 2016 and 2023. The results revealed a marked increase in enrollment, which reflects the influence of institutional inclusion strategies and the expansion of digital education. However, this growth was accompanied by a significant decline in academic performance, particularly in pass rates, and a persistent gender gap in enrollment and outcomes.

Through exploratory factor analysis, five key dimensions were identified as influencing female retention in engineering: economic conditions, social constraints, gender stereotypes, motivational elements, and personal circumstances. Among these, economic barriers stood out as the most influential, especially those related to transportation, study materials, and technological access. Social and cultural factors, including perceptions of inequality and internalized biases, also had a substantial impact on students' academic persistence.

The study underscores the importance of adopting comprehensive strategies that go beyond enrollment targets. Effective retention policies should integrate financial assistance, pedagogical innovation, support networks, and early academic guidance. Promoting the visibility of female professionals and improving the quality of academic orientation can also contribute to student engagement and motivation.

Despite its contributions, this research is limited by its focus on a single institution and its reliance on self-reported data. Future studies should consider longitudinal designs, comparative analyses across institutions, and the inclusion of qualitative methods to better understand the lived experiences of female students in engineering.

In conclusion, addressing gender disparities in engineering education requires coordinated action across multiple dimensions. Universities in Latin America must commit to building academic environments that are inclusive, equitable, and responsive to the diverse needs of their student populations. Only through sustained and evidence-based efforts can the region fully harness the potential of female talent in science and technology.

Author Contributions: Conceptualization, J.J.C.-Q.; data curation, L.E.C.S.; methodology, M.V.M.; supervision, J.Q.C.; formal analysis, C.V.-S.; writing—original draft preparation, J.J.C.-Q., M.V.M. and C.V.-S.; writing—review and editing, C.V.-S. and J.Q.C.; visualization, C.V.-S.; project administration, C.V.-S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: In accordance with Ecuadorian legislation and university autonomy, which recognizes that each institution establishes its own mechanisms for the approval and oversight of academic projects—and given that this is an educational study—external ethics committee approval is not required. The Dean of the Faculty grants institutional authorization. This

is supported by the Código de Ética de la UNEMI (2018), the Modelo Educativo de la UNEMI (2018), and the Instructivo para la Ejecución de los Proyectos de Investigación e Innovación (2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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