A Multilevel Gender Equity Pathways Framework for Women's STEM Trajectories in Latin America

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Abstract*– Women's underrepresentation in STEM (Science, Technology, Engineering, and Mathematics) remains a persistent challenge in Latin America, where gender norms, institutional conditions, relational support, socioeconomic inequality, and motivational mechanisms shape educational trajectories. Existing studies address career choice, access, retention, mentoring, role models, stereotypes, and institutional policies, but this evidence remains dispersed across countries, disciplines, and educational stages. This paper proposes the Multilevel Gender Equity Pathways Framework to organize this evidence into a trajectory-centered conceptual model. A structured integrative literature review with thematic synthesis was conducted. The search process identified a broader pool of 50 potentially relevant documents, from which 25 core sources were retained for direct synthesis and citation based on their empirical, conceptual, methodological, and regional relevance. The framework conceptualizes women's STEM trajectories as a pathway embedded within interacting sociocultural, institutional, relational, and individual systems. These systems shape six pathway outcomes: early interest, career choice, access, persistence, graduation, and professional progression. The framework also incorporates a feedback loop in which women's professional progression generates visibility and role models that can influence future participation in STEM. The proposed model offers a conceptual basis for research, institutional diagnosis, and gender-equity strategies in STEM education in Latin America.

***Keywords*-- Women in STEM, STEM Education, Gender Equity, Latin America, Pathway Framework.**

I. Introduction

Women's underrepresentation in STEM (Science, Technology, Engineering, and Mathematics) remains a persistent educational, social, and institutional challenge. Although women's participation in higher education has increased in many contexts, their representation in engineering, computing, information and communication technologies, manufacturing, construction, and other technical fields continues to lag behind that of men [1]. In Latin America, this imbalance intersects with institutional conditions, socioeconomic inequality, gender norms, and uneven opportunities for access, persistence, and professional progression [2], [3]. Addressing this problem requires more than documenting gender gaps in enrollment. Women's participation in STEM is shaped by mechanisms operating at the individual, relational, institutional, and sociocultural levels. At the individual level, career choices are influenced by self-efficacy, outcome expectations, perceived value, goals, and perceived costs [4], [5]. Stereotype threat can affect performance, identity, and belonging in academic environments where technical competence is culturally associated with masculinity [6]. Relational mechanisms are also important: role models can make STEM participation visible, challenge gendered expectations, and support women's identification with technical careers [7]. Taken together, these mechanisms indicate that motivation and persistence are not isolated individual attributes, but socially embedded processes shaped by educational experiences, institutional environments, and broader sociocultural expectations.

Because these mechanisms accumulate across educational and professional stages, women's STEM trajectories cannot be fully understood through linear explanations. A central limitation of the STEM gender literature is the frequent use of the "leaky pipeline" metaphor. This metaphor is useful for showing that women leave STEM at different transition points, but it does not fully capture the diversity of women's routes into, through, and beyond STEM [8]. Women's trajectories may involve vocational-technical education, delayed entry, program changes, re-entry, interdisciplinary transitions, or movement between academic and professional domains. A pathway-based perspective is therefore more appropriate for analyzing women's participation in STEM as a cumulative and dynamic process.

This perspective is particularly relevant in Latin America, where STEM education is shaped by institutional diversity, socioeconomic inequality, public and private higher education systems, technological universities, vocational-technical routes, and uneven access to academic and professional opportunities. Regional evidence illustrates these multilevel dynamics across several contexts. In Mexico, women's retention in STEM has been associated with mentoring, academic monitoring, faculty awareness, digital platforms, and institutional support systems [2]. In Chile and Colombia, female STEM teachers and secondary-to-tertiary transitions have been linked to women's participation in postsecondary STEM programs [9], [10]. In Colombia, research on Green-STEM vocational pathways shows that gender barriers operate through interdependent institutional, relational, and structural mechanisms [11]. In Peru and Ecuador, STEM choice and degree attainment are shaped by sociocultural conditions, motivation, academic preparation, socioeconomic status, and institutional support [12], [13].

Regional initiatives and national studies further highlight the importance of institutional and sociocultural conditions.

The W-STEM project shows how coordinated institutional strategies can support women's access to STEM in Latin American higher education [14]. Evidence from Chile on affirmative action policies for women's access to engineering programs highlights the importance of linking access to academic progression and inclusion within institutional cultures [15]. At the sociocultural level, gender stereotypes, socioeconomic status, ethnicity, territory, family expectations, cultural beliefs, and labor market structures shape how girls and women perceive STEM opportunities. Studies on math-gender stereotypes in Chile show that associations between mathematics and masculinity persist among youth and adults and are related to educational level, socioeconomic status, and perceptions toward science [16]. Taken together, this evidence shows that women's participation in STEM is shaped by interacting systems rather than by a single barrier, intervention, or decision point. However, research on women in STEM in Latin America remains fragmented across countries, disciplines, educational stages, and analytical levels. Some studies focus on career choice, while others examine access, retention, mentoring, role models, stereotypes, institutional policy, vocational-technical education, or professional progression. This fragmentation limits the development of integrated explanations and makes it difficult for institutions to design pathway-oriented gender-equity strategies.

This paper responds to this gap by proposing the Multilevel Gender Equity Pathways Framework for women's STEM trajectories in Latin America. The framework organizes existing evidence into a trajectory-centered multilevel model that connects four interacting systems: sociocultural context, institutional ecosystem, relational support networks, and individual motivational mechanisms. These systems shape six interconnected STEM pathway outcomes: early interest, career choice, access, persistence, graduation, and professional progression. The framework also incorporates a feedback loop in which women's professional progression generates visibility and role models that can influence future participation in STEM.

The objective of this paper is to develop a literature-informed conceptual framework that supports future research, institutional diagnosis, and gender-equity interventions in STEM education in Latin America. The contribution of the paper lies in shifting the analysis from isolated barriers toward a pathway-based, multilevel understanding of women's STEM trajectories. The guiding research question is:

How can existing evidence on women's participation in STEM in Latin America be organized into a multilevel framework that conceptualizes access, persistence, and professional progression across STEM pathways?

II. Methodological Approach

A. Research Design

This study uses a structured integrative literature review with thematic synthesis to develop a literature-informed conceptual framework. Integrative reviews are appropriate for synthesizing heterogeneous evidence and generating conceptual understanding across diverse research designs [17]. The review process involved five stages: problem identification, literature search, relevance-based screening, data extraction and thematic coding, and framework synthesis. This process enabled the analysis to move from dispersed evidence to a structured conceptual model of women's STEM trajectories in Latin America.

B. Literature Search Strategy

A targeted literature search was conducted using academic databases, publisher platforms, and scholarly search engines commonly used in education, engineering education, and social science research. Sources included Scopus, Web of Science, ScienceDirect, SpringerLink, Taylor & Francis Online, MDPI, Frontiers, IEEE Xplore, CLEI Electronic Journal, and Google Scholar. Searches prioritized studies published between 2019 and 2026. Foundational theoretical works published before this period were included as needed to support the framework's conceptual basis.

Search terms were used in English and Spanish, including "women in engineering," "women in STEM," "gender gap in STEM," "gender equity in engineering education," "STEM retention women," "STEM career choice women," "female role models STEM," "mentoring women in STEM," "gender stereotypes mathematics," "affirmative action women engineering," "vocational technical education STEM women," "Latin America STEM gender," "mujeres en ingeniería," "brecha de género STEM," "mujeres en ciencia y tecnología," "retención de mujeres en STEM," "estereotipos de género matemáticas," and "mentoría mujeres STEM."

The search prioritized peer-reviewed articles and conference papers addressing women's access, persistence, participation, or progression in STEM, with emphasis on Latin American contexts.

C. Corpus and Selection Criteria

The search process identified a broader pool of 50 potentially relevant documents. After relevance-based screening, 24 core sources were retained for direct synthesis and citation based on their empirical, conceptual, methodological, and regional relevance.

Relevance was assessed based on direct alignment with the framework levels, pathway outcomes, the Latin American context, and empirical or conceptual contribution. Sources were retained when they addressed at least one of the following areas:

1. Women's participation, access, persistence, or progression in STEM, STEMM, ICT, vocational-technical STEM, engineering, or related technical fields.
2. Latin American contexts or theoretical foundations applicable to the analysis.
3. Individual mechanisms such as self-efficacy, motivation, expectations, identity, belonging, or perceived fit.
4. Relational mechanisms such as family influence, peer effects, teachers, mentors, or role models.

5. Institutional mechanisms such as affirmative action, mentoring programs, inclusive pedagogy, monitoring, financial aid, or institutional climate.
6. Sociocultural mechanisms such as stereotypes, socioeconomic status, ethnicity, gender norms, or cultural expectations.
7. Interventions, policies, or educational strategies aimed at improving gender equity in STEM.

Studies using related labels such as STEMM, STEAM, ICT, TVET, and Green-STEM were included when they addressed mechanisms relevant to women's STEM trajectories.

D. Data Extraction and Thematic Coding

A data extraction matrix was used to record study type, country or context, population, STEM field, pathway outcome, level of influence, mechanisms, and associated outcomes. The corpus was coded thematically to identify recurring barriers, facilitators, interventions, and pathway outcomes. The specific coding dimensions are compiled in Table I.

E. Framework Synthesis

The framework was developed through three analytical steps. First, recurring mechanisms were identified across the corpus. Second, these mechanisms were grouped into four levels of influence: sociocultural context, institutional ecosystem, relational support networks, and individual motivational mechanisms. Third, these levels were mapped onto six STEM pathway outcomes: early interest, career choice, access, persistence, graduation, and professional progression. This process produced a trajectory-centered multilevel framework that organizes evidence across stages and systems.

TABLE I
CODING DIMENSIONS USED TO SYNTHESIZE THE CORPUS

Coding dimension	Description
Study type	Empirical quantitative, qualitative, mixed-methods, intervention, policy-oriented, review, or conceptual study.
Country or context	Geographic, regional, national, or institutional setting.
Population	Girls, secondary students, undergraduate students, vocational-technical students, faculty, mentors, or women professionals.
STEM field	Engineering, STEM, STEMM, ICT, STEAM, TVET, or Green-STEM.
Pathway outcome	Early interest, career choice, access, persistence, graduation, professional progression, or leadership.
Level of influence	Sociocultural, institutional, relational, or individual.
Type of mechanism	Barrier, facilitator, intervention, policy, cultural factor, motivational factor, or outcome.
Associated outcome	STEM interest, career choice, retention, academic performance, belonging, identity, inclusion, graduation, or leadership.

III. THEMATIC SYNTHESIS OF LITERATURE

A. Sociocultural Context

The sociocultural context includes gender norms, stereotypes, socioeconomic status, ethnicity, territory, labor market expectations, and cultural beliefs about science and technology.

These conditions shape how girls and women perceive STEM careers before entering higher education and continue to influence their experiences during and after university.

The systematic review by Verdugo-Castro et al. identified stereotypes, stereotype threat, family influence, educational environments, peer groups, culture, self-concept, self-efficacy, self-confidence, and self-perception as factors associated with women's decisions to enter STEM [1]. In Chile, math-gender stereotypes persist among youth and adults and are associated with educational level, socioeconomic status, and perceptions toward science [16]. In Ecuador, women and individuals from lower-income households were less likely to hold STEM degrees [3]. In Peru, ethnicity, prior STEM interest, and opportunity-related motivation were associated with women's STEMM career choice [12].

These studies show that gender gaps in STEM are embedded in broader social and structural conditions. Sociocultural factors shape opportunity structures, perceived legitimacy, career expectations, and the visibility of women in technical fields.

B. Institutional ecosystem

The institutional ecosystem includes policies, inclusive pedagogy, academic monitoring, institutional climate, financial aid, mentoring systems, and access and retention strategies. Institutions influence women's STEM pathways through admission processes, teaching practices, advising, evaluation, support systems, and professional transition opportunities.

Research from Mexico shows that women's retention in STEM can be supported through mentoring, timely monitoring, digital platforms, faculty awareness, and interaction with successful women in STEM [2]. The W-STEM project illustrates how regional initiatives can promote institutional strategies for women's access to STEM in Latin American higher education [14]. In Chile, affirmative action policies for women's access to engineering programs underscore the importance of linking access to academic progression and inclusion [15]. In Ecuador, women's engineering trajectories highlight the need to link enrollment growth to retention, academic support, and institutional strategies [13]. In Colombia, Green-STEM vocational pathways show that institutional strategies can address gender barriers through participatory and gender-transformative approaches [11].

Outreach and school-based initiatives in Uruguay and Chile further demonstrate how early exposure, ICT engagement, and gendered STEAM models can strengthen girls' participation before university entry [18], [19]. Gender-equity interventions also require attention to how equity discourses are translated into school practices, particularly when interventions address mathematical ability, visibility, and gendered expectations [20].

Institutional strategies are therefore most relevant when they address multiple points of the pathway: attraction, access,

academic integration, retention, graduation, and professional transition.

C. Relational Support Networks

Relational support networks include family, peers, teachers, mentors, female role models, professional networks, and academic and emotional support. These networks influence how women interpret their capacities, opportunities, and belonging in STEM.

Role models are especially relevant in male-dominated fields because they make participation in STEM visible and challenge gendered expectations [7]. In Chile, exposure to female STEM teachers in vocational-technical education influenced women's postsecondary STEM trajectories [9]. In Colombia, a higher proportion of female STEM teachers in secondary education was associated with women's enrollment in tertiary STEM programs [10]. Evidence from college peer effects also shows that peer composition can shape STEM outcomes [21].

Relational support contributes to persistence and progression. Mentoring, teacher encouragement, peer validation, and professional networks can strengthen confidence, academic integration, and career aspiration [2], [22]. These mechanisms connect social support with individual motivation and institutional commitment.

D. Individual Motivational Mechanisms

Individual motivational mechanisms include self-efficacy, STEM identity, belonging, motivation, expectations, self-concept, perceived fit, and confidence. These mechanisms influence whether women imagine themselves as capable of entering and succeeding in STEM.

Social Cognitive Career Theory emphasizes self-efficacy, outcome expectations, and goals as central components of career interest, choice, and performance [4]. Expectancy-Value Theory explains motivation through expectations for success, task value, and perceived costs [5]. Stereotype threat research shows how negative stereotypes can affect performance, identity, and sense of belonging [6].

In Latin American contexts, motivational mechanisms are shaped by institutional and sociocultural conditions. Studies from Chile show that women's STEM choices are influenced by perceived fit, academic expectations, motivational beliefs, prior performance, and social context [23]-[25]. These findings support the interpretation of individual motivation as socially embedded.

IV. Proposed Framework

A. Framework Overview

The proposed Multilevel Gender Equity Pathways Framework conceptualizes women's participation in STEM as a dynamic pathway embedded within interacting sociocultural, institutional, relational, and individual systems. The framework places the STEM pathway at the center and situates it within multilevel systems that shape access, persistence, graduation, and professional progression.

The framework is organized around five components: sociocultural context, institutional ecosystem, relational support networks, individual motivational mechanisms, and STEM pathway outcomes. The pathway outcomes are: (1) early interest, (2) career choice, (3) access, (4) persistence, (5) graduation, and (6) professional progression.

This structure reflects two analytical principles. First, gender gaps in STEM are cumulative across the trajectory. Second, pathway outcomes are shaped by interactions among systems rather than by isolated individual decisions.

B. Framework Dimensions

Table II describes the interconnected dimensions, underlying mechanisms, and outcomes of the Multilevel Pathways Framework for Gender Equity, establishing the analytical boundaries for further discussion.

TABLE II
DIMENSIONS, MECHANISMS, AND OUTCOMES OF THE MULTILEVEL GENDER EQUITY PATHWAYS FRAMEWORK

Framework dimension	Key mechanisms	Representative evidence	Associated outcomes
Sociocultural context	Gender norms, stereotypes, socioeconomic status, ethnicity, territory, labor market expectations, and cultural beliefs.	Stereotypes, socioeconomic inequality, gender norms, ethnicity, income conditions [1], [3], [12], [16].	Opportunity structures, perceived legitimacy, early interest, and career expectations.
Institutional ecosystem	Policies, inclusive pedagogy, academic monitoring, institutional climate, financial aid, mentoring systems, access, and retention strategies.	Retention strategies, W-STEM, affirmative action, institutional support, Green-STEM/TVET interventions [2], [11], [13]-[15].	Access, retention, academic integration, graduation, and professional transition.
Relational support networks	Family, peers, teachers, mentors, female role models, professional networks, and academic and emotional support.	Role models, female STEM teachers, peer effects, mentoring, teacher support [2], [7], [9], [10], [21], [22].	Encouragement, validation, belonging, confidence, persistence.
Individual motivational mechanisms	Self-efficacy, STEM identity, belonging, motivation, expectations, self-concept, perceived fit, confidence.	SCCT, EVT, stereotype threat, motivational beliefs, major choice [4]-[6], [23]-[25].	STEM interest, career choice, persistence intention, achievement, agency.
STEM pathway outcomes	Early interest, career choice, access, persistence, graduation, and professional progression.	Pipeline/pathway literature, major choice, vocational transitions, institutional interventions [8], [9], [11], [14], [23].	Movement across the STEM pathway.

C. Framework Logic

Fig. 1 presents the Multilevel Gender Equity Pathways Framework for women's STEM trajectories in Latin America. The framework represents women's STEM trajectories as a pathway embedded within interacting sociocultural, institutional, relational, and individual systems. These multilevel influences shape six pathway outcomes - early interest, career choice, access, persistence, graduation, and professional progression - while a feedback loop highlights how women's professional progression can generate visibility and role models that inspire future generations and strengthen the pathway.

The pathway component is represented at the center of the framework as a sequence of six interconnected outcomes. The surrounding multilevel systems do not operate independently of the pathway; rather, they shape women's movement through each stage and influence whether transitions are enabled, delayed, interrupted, or sustained. Sociocultural conditions influence how science, technology, engineering, mathematics, and technical careers are perceived. Institutional ecosystems determine the availability and quality of access, support, monitoring, pedagogy, and progression opportunities. Relational support networks provide validation, mentoring, guidance, and role models. Individual motivational mechanisms mediate the ways women interpret their capabilities, sense of belonging, expectations, and future possibilities. The framework incorporates a feedback loop. Women's professional progression generates visibility, role models, and social influence that can strengthen early interest in STEM among future generations. Professional progression is therefore a pathway outcome and a mechanism for transforming future participation.

D. Interpretation of the Framework

The framework shifts attention from isolated barriers to cumulative pathway mechanisms. A single outreach activity may increase early interest, but persistence requires academic integration, mentoring, inclusive pedagogy, financial support, and a supportive institutional climate. Access policies can increase enrollment, but progression depends on retention systems, a sense of belonging, academic achievement, professional networks, and opportunities for labor market transition. The framework positions institutions as key sites for coordinating pathway-oriented gender-equity strategies in STEM education. Effective strategies connect early outreach, career guidance, access policies, academic support, mentoring, inclusive teaching, financial aid, institutional climate, professional transition, and leadership development.

V. Discussion

The proposed framework shares foundational assumptions with established global models while extending them to address the specificities of Latin American STEM contexts. Social Cognitive Career Theory [4] provides a well-validated account of how self-efficacy, outcome expectations, and goals shape career interest, choice, and persistence. Expectancy-Value Theory [5] explains motivation through perceived task value, success expectations, and costs. Both theories inform the individual motivational mechanisms dimension of the framework and are extensively used in international STEM gender research. The framework builds on these foundations by situating individual mechanisms within the relational, institutional, and sociocultural systems that shape them, an integration consistent with the multilevel turn in STEM education research globally.

The framework also addresses limitations identified in the international literature. The leaky pipeline metaphor [8] has been widely used to track women's attrition across successive STEM transitions, but it offers a linear, loss-centered representation that does not capture re-entry, vocational routes, interdisciplinary movement, or the diversity of women's STEM trajectories. The pathway-based perspective adopted here offers a broader analytical lens that accommodates these dynamics, consistent with critiques of pipeline logic in global scholarship.

What distinguishes the framework from globally developed models is its grounding in Latin American evidence and its attention to region-specific conditions: institutional diversity across public, private, and vocational-technical systems; socioeconomic inequality and its intersection with gender, ethnicity, and territory [3], [12]; the influence of math-gender stereotypes in contexts where associations between mathematics and masculinity persist across educational levels and socioeconomic groups [16]; and the role of regional initiatives such as W-STEM in coordinating institutional gender-equity strategies [14]. These conditions shape how global mechanisms, self-efficacy, role models, stereotype threat, and mentoring operate in practice, and they justify a framework developed from and for the Latin American context rather than adapted from models designed elsewhere.

A. Interpreting the Framework: From Dispersed Evidence to Pathway Logic

This paper proposed the Multilevel Gender Equity Pathways Framework to organize dispersed evidence on women's STEM trajectories in Latin America. The main contribution of the framework is not the identification of isolated barriers or facilitators, but the organization of these mechanisms into a pathway-based and multilevel structure.

The synthesis indicates that women's participation in STEM is shaped by interacting sociocultural, institutional, relational, and individual systems that influence movement across interconnected educational and professional transitions.

This interpretation shifts the focus from whether women enter STEM to how their trajectories are enabled, delayed, interrupted, or sustained across time. Early interest, career choice, access, persistence, graduation, and professional progression are therefore not independent outcomes. They are connected stages of a cumulative pathway shaped by the conditions surrounding women's educational and professional experiences.

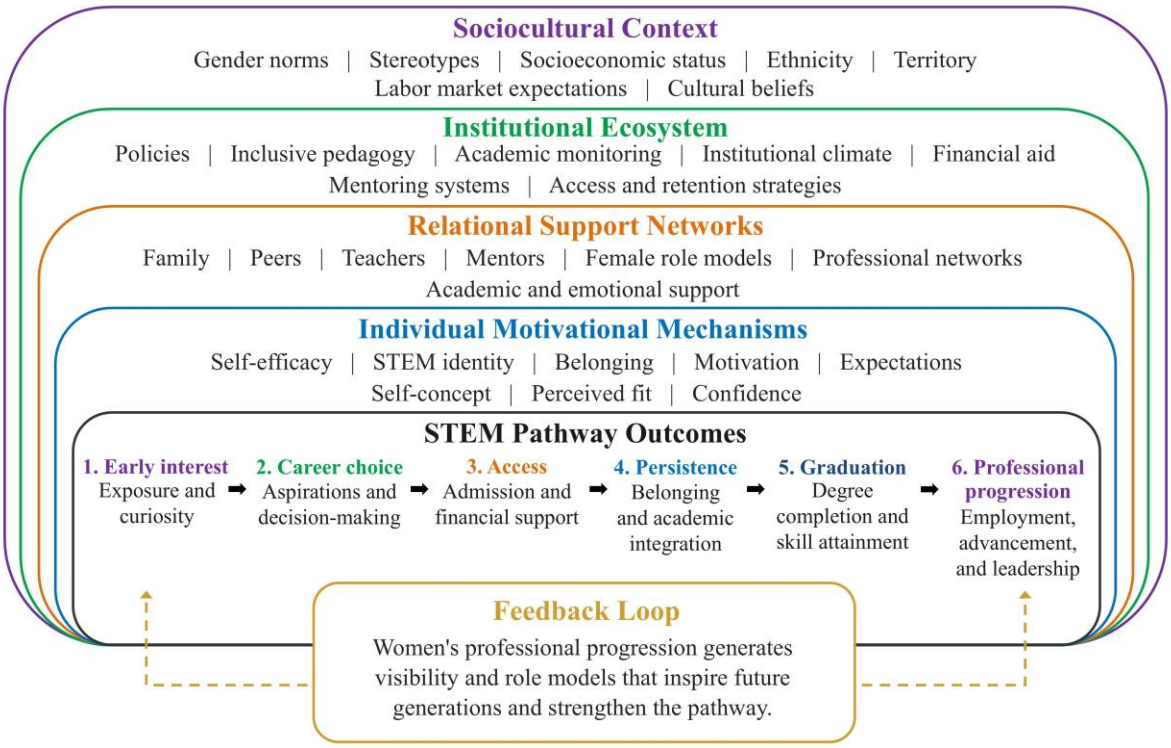


Fig. 1. Multilevel Gender Equity Pathways Framework for Women's STEM Trajectories in Latin America.

B. Positioning the Framework within Global Literature

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C. Illustrative Applications of the Framework

The framework's analytical logic can be illustrated through three cases drawn from the reviewed corpus. First, the W-STEM project [14] exemplifies how the institutional ecosystem can operate across multiple pathway stages simultaneously. Rather than targeting a single transition point, W-STEM coordinated institutional strategies addressing access, academic integration, mentoring, and role model visibility across Latin American higher education institutions. This case illustrates how pathway-oriented institutional action differs from isolated program implementation. Second, evidence from Chile on female STEM teachers in vocational-technical education [9] demonstrates how relational support networks operate at the career choice and access stages. Exposure to female STEM teachers during secondary education increased women's

likelihood of pursuing postsecondary STEM programs, showing that relational mechanisms embedded in institutional settings can redirect trajectories before university entry. Third, the Green-STEM TVET case from Colombia [11] illustrates how sociocultural context and the institutional ecosystem interact at the early interest and career-choice stages. Gender barriers in vocational STEM pathways were shown to operate through interdependent structural and institutional mechanisms, and participatory gender-transformative strategies were needed to address them.

D. Relationship with Existing Literature: Beyond Linear and Individual Explanations

The proposed framework extends previous literature in two ways. First, it moves beyond linear interpretations of women's participation in STEM. The "leaky pipeline" metaphor has been useful for identifying points at which women leave STEM. Still, it provides a limited representation of the diversity of women's routes into, through, and beyond STEM [8]. A pathway-based perspective offers a broader analytical lens because it accounts for vocational-technical routes, delayed entry, program changes, re-entry, interdisciplinary movement, and transitions between education and employment.

Second, the framework moves beyond explanations that locate women's underrepresentation primarily in individual preferences, motivation, or ability. Individual mechanisms such as self-efficacy, outcome expectations, perceived value, identity, belonging, and perceived fit remain central [4], [5]. However, these mechanisms are shaped by relational support, institutional environments, and sociocultural expectations. Stereotype threat, role models, teacher influence, peer effects, mentoring, institutional climate, and socioeconomic conditions all contribute to how women interpret their place and possibilities in STEM [6], [7], [9], [10], [12], [16].

E. Integrating Sociocultural, Institutional, Relational, and Individual Mechanisms

A key value of the framework is that it connects mechanisms that are often studied separately. Sociocultural conditions shape the perceived legitimacy of STEM careers for girls and women. Institutional ecosystems influence access, academic integration, support, retention, and professional transition. Relational networks provide encouragement, validation, mentoring, and role models. Individual motivational mechanisms mediate how women interpret their capabilities, belonging, expectations, and future opportunities.

This integration is important because no single level is sufficient to explain women's STEM trajectories. For example, mentoring may support persistence, but its impact depends on institutional commitment, academic monitoring, inclusive pedagogy, and the broader climate in which it occurs. Similarly, access policies may increase enrollment, but progression requires sustained support across academic, relational, financial, and professional dimensions. The framework, therefore, conceptualizes gender equity as a coordinated pathway issue rather than as a set of isolated interventions.

F. Significance for Latin American STEM contexts

The framework is particularly relevant for Latin America because institutional diversity, socioeconomic inequality, territorial disparities, public and private higher education systems, technological universities, vocational-technical pathways, and persistent gender norms shape women's STEM trajectories in the region. Regional evidence shows that women's STEM participation is influenced by retention strategies in Mexico, female STEM teachers and educational transitions in Chile and Colombia, Green-STEM vocational pathways in Colombia, sociocultural determinants of STEMM choice in Peru, and socioeconomic and demographic factors in Ecuador [2], [3], [9]-[13].

By organizing this evidence into a common structure, the framework supports comparison across countries, institutions, and STEM fields. It also helps identify where gender-equity efforts are concentrated and where gaps remain. Some contexts may emphasize access, while others may require stronger attention to persistence, academic integration, professional transition, or visibility of women role models. In this sense, the framework provides a structure for understanding both shared regional patterns and context-specific mechanisms.

G. From Isolated Interventions to Pathway-Oriented Gender-Equity Ecosystems

The framework also has practical significance for the design of gender-equity strategies. Many interventions focus on specific actions, such as outreach activities, mentoring programs, scholarships, awareness campaigns, or role-model initiatives. Although these actions are valuable, they may have limited impact when they are not connected across the full STEM pathway.

A pathway-oriented approach requires institutions to connect early exposure, career guidance, access policies, academic support, inclusive pedagogy, mentoring, financial aid, retention monitoring, professional networks, and leadership opportunities. Under this logic, gender-equity work becomes an ecosystem rather than a collection of disconnected programs. The framework can therefore support institutional diagnosis by helping universities, STEM schools, and technical institutions examine whether their strategies address the full trajectory from early interest to professional progression.

VI. Implications for Research, Practice, and Policy

A. Research Implications

The framework can guide comparative, longitudinal, and mixed-methods studies on women's STEM pathways. Future research can examine which mechanisms are most influential at different pathway outcomes. Family, school experiences, stereotypes, and role models may shape early interest. Persistence may depend more directly on institutional climate,

pedagogy, peer relationships, financial support, mentoring, and a sense of belonging.

The framework can also support cross-country comparisons across Mexico, Chile, Colombia, Ecuador, Peru, Uruguay, Brazil, and other Latin American contexts. It can be adapted to engineering, computing, mathematics, natural sciences, ICT, TVET, STEAM, and Green-STEM fields.

B. Institutional Practice Implications

The framework can function as a diagnostic and planning tool for universities, STEM schools, and technical institutions seeking to develop pathway-oriented gender-equity strategies. Table III translates the framework's dimensions and pathway outcomes into concrete institutional actions.

TABLE III
PATHWAY-ORIENTED INSTITUTIONAL RECOMMENDATIONS DERIVED FROM THE FRAMEWORK

Pathway stage	Mechanisms to address	Concrete institutional action
Early interest	Math-gender stereotypes, sociocultural norms, limited STEM visibility	Outreach programs that connect girls with female STEM professionals; career guidance that challenges gender stereotypes and presents vocational-technical and interdisciplinary STEM routes [9], [11], [16].
Career choice	Role models, family influence, perceived fit and costs	Visibility campaigns featuring women in diverse STEM fields; counseling that addresses perceived costs and outcome expectations and challenges gendered career beliefs [4], [5], [7].
Access	Admission policies, financial barriers, academic preparation gaps	Link affirmative action policies to academic and psychosocial support systems; ensure access initiatives connect to retention structures rather than operating as isolated enrollment measures [15].
Persistence	Institutional climate, mentoring, inclusive pedagogy, peer effects, retention monitoring	Gender-disaggregated retention monitoring; structured mentoring programs with female role models; faculty development in inclusive pedagogy; institutional awareness of peer composition effects on STEM outcomes [2], [21], [22].
Graduation	Academic integration, financial support, sense of belonging	Financial aid linked to academic performance tracking; belonging-oriented institutional climate strategies; early identification of students at risk of dropout and timely academic support [13].
Professional progression	Professional networks, leadership visibility, role model generation and feedback loop	Leadership development programs; professional networking initiatives; systematic visibility of women's STEM careers to generate feedback loop effects that strengthen early STEM interest among future generations [7], [14].

Across all stages, the framework suggests that gender-equity work is most effective as an ecosystem rather than a collection of disconnected programs. Institutions can use the framework to map their existing initiatives onto the pathway, identify gaps or concentrations at particular stages, and design coordinated strategies that address the full trajectory from early interest to professional leadership.

C. Policy Implications

For policy, the framework suggests that gender equity should be addressed across the full pathway. Policies focused only on admission or enrollment provide a partial response. Comprehensive strategies should address early interest, career guidance, access, academic integration, retention, graduation, professional transition, and leadership.

Regional initiatives such as W-STEM show the relevance of institutional strategies for women's access to STEM [14]. Evidence from Mexico, Chile, Colombia, Ecuador, Peru, and Uruguay indicates that policies are more coherent when they connect access, support, pedagogy, mentoring, role models, and retention [2], [9]-[13], [15], [18], [19].

VII. LIMITATIONS AND FUTURE WORK

The proposed framework is conceptual and requires empirical validation. The relevance-based selection of 25 core sources prioritized framework development over exhaustive coverage of the literature on women in STEM. Evidence is unevenly distributed across countries, disciplines, and educational stages.

The framework does not assign causal weight to each mechanism. It organizes mechanisms conceptually and identifies how they interact across pathway outcomes. Future studies should validate and refine the framework through expert review, Delphi studies, interviews with women in STEM, institutional case studies, longitudinal data, and stakeholder-based evaluation.

A future line of work is to operationalize the framework into an institutional diagnostic instrument. Such an instrument could include indicators for each level and pathway outcome, allowing universities and STEM schools to assess whether their gender-equity strategies address access, persistence, graduation, and professional progression.

VIII. CONCLUSION

This paper proposed the Multilevel Gender Equity Pathways Framework for understanding women's participation in STEM in Latin America. The framework organizes existing evidence into four interacting systems: sociocultural context, institutional ecosystem, relational support networks, and individual motivational mechanisms. These systems shape six STEM pathway outcomes: early interest, career choice, access, persistence, graduation, and professional progression.

By shifting the discussion from isolated barriers to cumulative pathway mechanisms, the framework provides a

conceptual structure for analyzing and strengthening women's STEM trajectories across Latin American educational and institutional contexts. The feedback loop further emphasizes that women's professional progression can generate visibility and role models that influence future generations and strengthen the pathway.

Future research should empirically validate the framework and adapt it to different Latin American countries, institutional contexts, STEM fields, and educational pathways.

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