

Female mentoring for student retention in engineering education: a systematic review

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Abstract— *Female student retention in engineering education remains a persistent structural challenge despite expanded participation initiatives in STEM. This study conducts a systematic literature review to synthesize existing evidence on female mentoring as a strategy for student retention in engineering programs. Guided by a structured search process across Scopus and Web of Science and applying PRISMA criteria, 48 peer-reviewed studies were analyzed. A bibliometric and thematic examination was conducted using Bibliometrix to identify structural patterns within the field. The findings indicate that mentoring is primarily conceptualized as a structured support intervention integrated into undergraduate contexts, particularly during first-year experiences. Retention outcomes are frequently associated with mediating mechanisms such as belonging, academic motivation, and institutional support. However, variability in program design, contextual implementation, and outcome measurement reveals conceptual fragmentation. The thematic structure suggests that while curricular and transitional themes are well-developed, mentoring-specific constructs remain partially specialized rather than fully central within the field. These results support the need for an integrative conceptual framework to strengthen theoretical coherence and guide future empirical research on gender equity and persistence in engineering education.*

Keywords— *Female mentoring; student retention; engineering education; women in engineering; STEM education.*

I. INTRODUCTION

The retention of women in engineering programs continues to represent a structural challenge in higher education. Although various initiatives have sought to encourage female participation in STEM disciplines, academic continuity continues to show vulnerabilities that affect female students differently [1], [2]. This problem is not limited to initial access, but manifests itself throughout the university career, where academic, social, and contextual factors influence the decision to persist or drop out of the program.

Several studies indicate that female retention in engineering is influenced by variables related to the construction of disciplinary identity and the perception of belonging within the academic environment [3], [4]. In particular, educational experience, interactions with teachers and peers, and opportunities for participation in academic communities emerge as elements that impact the consolidation of a professional identity in engineering [5], [6]. When these factors are not adequately developed, processes of demotivation or disengagement can arise that affect student retention.

Likewise, institutional factors that influence women's academic trajectories have been identified. Research

conducted in different contexts shows that organizational conditions, the existence of equity policies, and the academic support structure have an impact on the university experience of women in engineering [7], [8]. In some cases, contextual barriers that limit retention have been documented, especially in environments where female representation is low [2].

In light of these dynamics, female mentoring has been studied as an institutional strategy aimed at supporting female students during their education. Formal programs designed to strengthen persistence in the early stages of undergraduate studies have been reported [1], as well as initiatives that combine mentoring, community building, and professional networking to foster academic engagement [9], [10]. Other studies have analyzed the impact of peer mentoring and its influence on long-term academic trajectories [4].

However, although the literature shows multiple approaches to the study of female mentoring, the approaches present methodological and conceptual diversity. Some studies emphasize motivational dimensions [11], others focus on identity and educational experience [3], while more recent research incorporates predictive analyses on graduation and dropout rates [12]. This heterogeneity hinders an integrated understanding of how and under what conditions female mentoring contributes to student retention.

Consequently, there is a need to systematize the available evidence in order to clarify the current state of knowledge, identify common patterns, and define conceptual gaps in the field. The purpose of this research is to analyze the scientific literature on female mentoring and student retention in engineering education in a structured manner. In line with this, the study is guided by the following research questions.

RQ (Evidence base)

What evidence does the literature report on female mentoring as a strategy for student retention in engineering education?

RQ1 (Intervention components)

What characteristics and components are common to female mentoring programs associated with student retention?

RQ2 (Mechanisms of action)

What explanatory mechanisms or processes are identified in studies regarding how female mentoring contributes to student retention?

RQ3 (Implementation conditions)

What contextual or institutional factors influence the effectiveness of female mentoring in engineering?

RQ4 (Gaps and opportunities)

What gaps or limitations does the literature identify that justify the construction of an integrative conceptual model?

The contribution of this review is to offer a rigorous and organized synthesis that supports academic and institutional decision-making regarding the design and strengthening of support initiatives for women in engineering, providing useful inputs for improving equity and inclusion in higher education [5], [8]. In terms of the development agenda, this research will be directly linked to SDG 4 (Quality Education) by addressing strategies that promote retention and continuity in university education, and to SDG 5 (Gender Equality) by focusing on reducing gaps and promoting equitable academic trajectories in engineering [2], [4].

II. MATERIALS AND METHODS

A. Study design

This research was conducted using a non-experimental design, through a systematic review of the literature aimed at analyzing the scientific evidence on female mentoring as a strategy for student retention in engineering education. The methodological process was structured in accordance with the guidelines of the PRISMA 2020 protocol, in order to ensure transparency, traceability, and replicability in the identification, selection, and analysis of studies.

B. Search strategy and conceptual model

The PICOC model was used to structure the search strategy, as shown in Table I. It was decided to exclude the Comparison and Context components for methodological reasons specific to the field of engineering education.

TABLE I
PICOC Model Used for Search Strategy

Element	Definition	Operational description	Related keywords
P	Engineering students	Women enrolled in engineering programs in higher education	"female students", "women engineers", "engineering students", "women in engineering", "undergraduate engineering", "engineering students", "women in engineering"
I	Women's mentoring programs	Formal or informal mentoring programs aimed at women in engineering	"mentoring programs", "female mentoring", "women mentoring", "peer mentoring", "faculty mentoring", Mentoring, Tutoring, "mentoring programs"
C	Absence of mentoring or general mentoring	Students without gender-specific mentoring or with non-differentiated mentoring	"no mentoring", "control group", "general mentoring"
O	Academic permanence or retention	Changes in program continuity	"student retention", Retention, "academic persistence", Persistence, Dropout, Attrition
C	Engineering education	Universities or institutions of higher education in engineering	"engineering education", "higher education", "STEM education", "technical education"

The Comparison element was not included because most studies on female mentoring do not use experimental designs with an explicit control group. Including terms such as "control group" or "no mentoring" would have unnecessarily reduced the sensitivity of the search, excluding relevant descriptive, correlational, or qualitative research that analyzes student retention without establishing formal comparisons.

Likewise, the Context component was not used as a mandatory filter in the initial equation, as many studies conducted in engineering programs do not explicitly use terms such as "engineering education" in their metadata. Incorporating it as a restriction could limit the retrieval of relevant evidence.

The PIO model was used to structure the research question and search strategy (Population–Intervention–Outcomes).

C. Sources of information and search strategy

The literature search was conducted in the Scopus and Web of Science databases, selected for their international coverage and academic indexing standards.

The search strategy was structured according to the PIO (Population–Intervention–Outcomes) model and executed using Boolean operators AND and OR, combining terms related to women in engineering, mentoring programs, and academic retention.

In Scopus, the equation was applied in the TITLE-ABS-KEY fields, according to the following structure in Table II:

TABLE II
SEARCH EQUATION - SCOPUS

Search equation
(TITLE-ABS-KEY ("female students" OR "women engineers" OR "engineering students" OR "women in engineering" OR "undergraduate engineering" OR "engineering students" OR "women in engineering") AND TITLE-ABS-KEY ("mentoring programs" OR "female mentoring" OR "women mentoring" OR "peer mentoring" OR "faculty mentoring" OR Mentoring OR Tutoring OR "mentoring programs") AND TITLE-ABS-KEY ("student retention" OR Retention OR "academic persistence" OR Persistence OR Dropout OR Attrition))

Table III shows the equation used in Web of Science. The structure uses equivalent values in the TI (Title), AB (Abstract), and AK (Author Keywords) fields:

TABLE III
SEARCH EQUATION – WEB OF SCIENCE

Search equation
((TI=((("female students" OR "women engineers" OR "engineering students" OR "women in engineering" OR "undergraduate engineering" OR "engineering students" OR "women in engineering") AND ("mentoring programs" OR "female mentoring" OR "women mentoring" OR "peer mentoring" OR "faculty mentoring" OR Mentoring OR Tutoring OR "mentoring programs") AND ("student retention" OR Retention OR "academic persistence" OR Persistence OR Dropout OR Attrition))) OR AB=((("female students" OR "women engineers" OR "engineering students" OR "women in engineering" OR "undergraduate engineering" OR "engineering students" OR "women in engineering") AND ("mentoring programs" OR "female mentoring" OR "women mentoring" OR "peer mentoring" OR "faculty mentoring" OR Mentoring OR Tutoring OR "mentoring programs") AND ("student retention" OR Retention OR

"academic persistence" OR Persistence OR Dropout OR Attrition))) OR AK=((("female students" OR "women engineers" OR "engineering students" OR "women in engineering" OR "undergraduate engineering" OR "engineering students" OR "women in engineering") AND ("mentoring programs" OR "female mentoring" OR "women mentoring" OR "peer mentoring" OR "faculty mentoring" OR Mentoring OR Tutoring OR "mentoring programs") AND ("student retention" OR Retention OR "academic persistence" OR Persistence OR Dropout OR Attrition)))

The application of these equations allowed for the maximization of the retrieval of relevant studies related to female mentoring and student retention in engineering education. Subsequently, the records obtained were subjected to a process of refinement and selection in accordance with the established eligibility criteria.

D. Eligibility criteria

In order to ensure methodological consistency and alignment with the research questions, inclusion and exclusion criteria were defined prior to the screening process.

1) *Inclusion criteria*: The eligibility of studies was defined based on the objective of the review and the PIO structure used in the search strategy. Scientific articles that directly addressed female mentoring in the field of engineering and analyzed results related to retention, persistence, academic continuity, or student dropout were

considered relevant. Thematic relevance was verified by reviewing titles, abstracts, and, subsequently, the full text when necessary.

2) *Exclusion criteria*: During the identification and screening phases, the following were excluded: CE1: The documents are Books or Book Chapters or Theses or Systematic Review Articles or Bibliometric Reviews; CE2: The articles are more than 6 years old; CE3: The articles are not written in English; CE4: The full text of the article is not available; CE5: It is a short paper (less than 10 pages long) and CE6: The articles are not unique.

E. Study selection process

The initial search yielded 275 records in Scopus and 80 in Web of Science. Subsequently, a refinement process was applied that included removal of duplicates, screening by title and abstract, and evaluation of full text according to eligibility criteria.

The complete process of identification, screening, eligibility, and inclusion is presented in Figure 1, prepared in accordance with the PRISMA 2020 diagram.

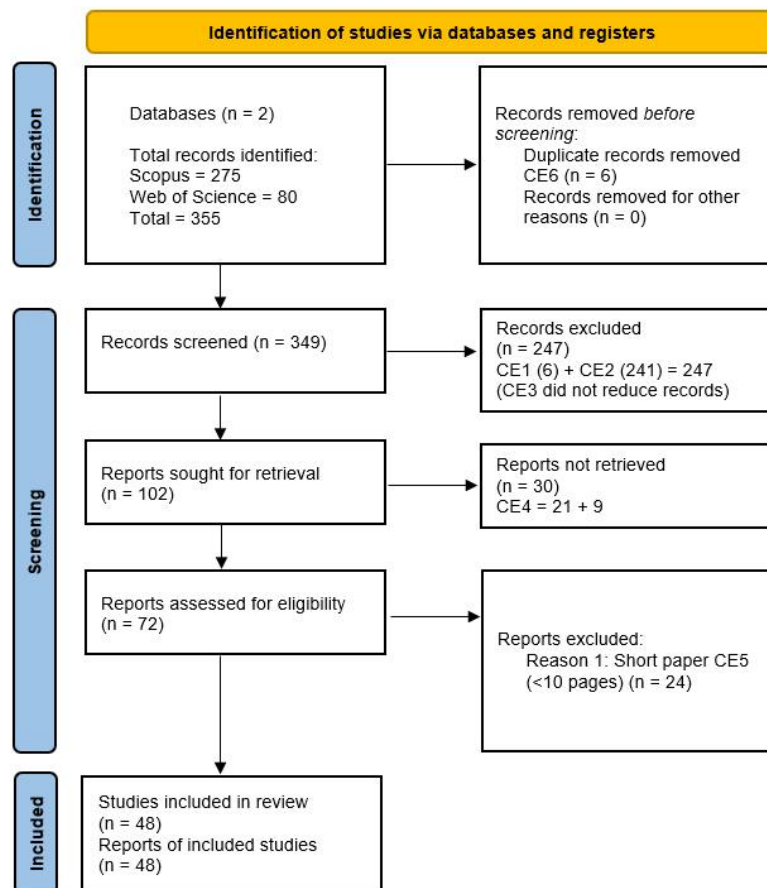


Fig. 1 PRISMA 2020 flowchart of the study selection process.

F. Data extraction and analysis

Once the final set of studies included in accordance with the PRISMA 2020 flow had been defined, relevant information was systematically extracted using a structured analysis matrix. This matrix recorded variables associated with the characteristics of female mentoring programs, the results reported in terms of academic retention or persistence, the explanatory mechanisms identified, the conditions of implementation, and the gaps pointed out by the authors.

To complement the qualitative analysis, the Bibliometrix package in the R environment was used, which allowed descriptive bibliometric analyses of the selected corpus to be performed. This tool was used to analyze indicators such as the temporal distribution of publications, productivity per author, co-authorship networks, most frequent keywords, and emerging thematic trends. The use of Bibliometrix allowed for the systematic structuring of scientific production and strengthened the quantitative dimension of the review.

Subsequently, a thematic analysis guided by the research questions was developed, classifying the findings into categories corresponding to reported evidence, intervention components, mechanisms of action, institutional conditions, and gaps identified in the literature. This combination of descriptive bibliometric analysis and qualitative thematic analysis allowed for a comprehensive understanding of the current state of knowledge on female mentoring and student retention in engineering education.

III. RESULTS AND DISCUSSION

A. Descriptive overview of the selected studies

Before addressing the research questions, a descriptive bibliometric analysis of the selected corpus was conducted in order to characterize the evolution, distribution, and thematic structure of the literature on female mentoring and student retention in engineering education. This preliminary analysis provides contextual grounding for the subsequent thematic synthesis and allows for the identification of publication trends, dominant research areas, and emerging topics within the field.

The quality appraisal showed methodological variation across the 48 studies included in the review. Overall, 17 studies (35.4%) were classified as high quality, 28 studies (58.3%) as medium quality, and 3 studies (6.3%) as low quality. High-quality studies were generally characterized by clearer methodological designs, adequately described samples, and stronger outcome measurement procedures, including longitudinal, mixed-methods, quasi-experimental, randomized, or large-scale survey designs. Medium-quality studies contributed relevant evidence but often presented partial limitations related to sample justification, intervention description, or outcome measurement. Low-quality studies

were mainly limited by insufficient methodological detail, small or unclear samples, and weakly defined outcome measures.

Therefore, the synthesis gave priority to patterns consistently supported by high- and medium-quality studies, while findings derived primarily from low-quality studies were interpreted as exploratory, as shown in Table IV. This distinction was important because the reviewed corpus includes different study designs, institutional contexts, and outcome definitions, which may affect the strength and comparability of the evidence.

TABLE IV
SUMMARY OF QUALITY APPRAISAL RESULTS

Overall quality level	Score range	Number of studies	Percentage	Interpretation
High quality	8–9	17	35.40%	Stronger methodological support
Medium quality	5–7	28	58.30%	Relevant evidence with partial limitations
Low quality	3–4	3	6.30%	Exploratory evidence with methodological limitations
Total	—	48	100%	Included studies

As shown in Figure 2, the three-field plot displays how the most frequent concepts expressed in titles (TI_TM) connect with the authors' chosen keywords (DE) and the dominant terms in abstracts (AB_TM), revealing the conceptual "spine" of the corpus. The strongest flows concentrate around mentoring, retention/persistence, and undergraduate engineering, indicating that the literature consistently frames female mentoring as a programmatic intervention tied to students' continuity in engineering pathways [13], [14], [15]. The map also highlights psychosocial and explanatory constructs—most visibly belonging and motivation-related language—positioned as bridges between mentoring and retention outcomes, suggesting that retention is frequently discussed through mediating processes [5], [7], [11]. In parallel, context-loaded nodes such as community college appear as distinct pathways, implying that part of the evidence base is institutionally concentrated and that implementation conditions vary by setting [16], [17]. Overall, the figure suggests a consolidated thematic core (mentoring–retention in undergraduate engineering) alongside differentiated explanatory and contextual strands, which is methodologically relevant for organizing subsequent results across evidence, components, mechanisms, and implementation conditions.

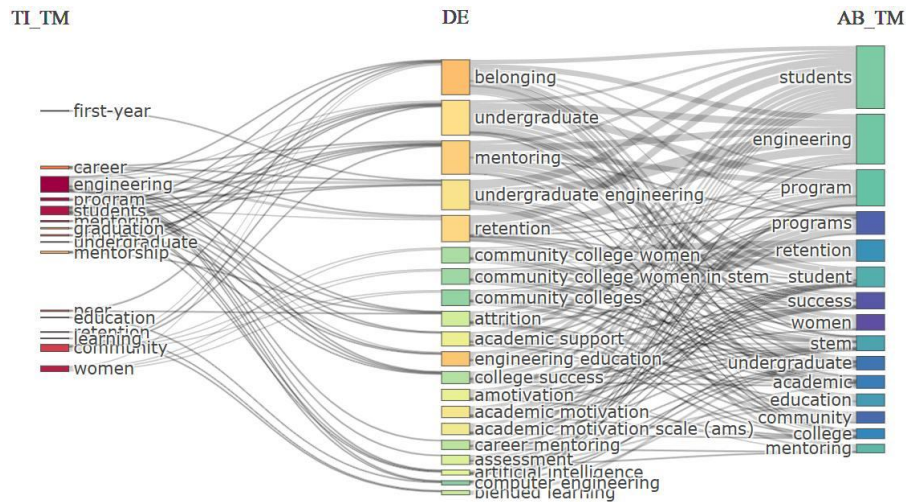


Fig. 2 Three-Field Plot Linking Title Terms (TI_TM), Author Keywords (DE), and Abstract Terms (AB_TM).

As shown in Figure 3, the geographic distribution of the selected studies reveals a strong concentration of scientific production in the United States, which accounts for 40 of the 48 analyzed publications. This dominant presence indicates that the empirical and conceptual development of female mentoring research in engineering education is largely shaped by the U.S. higher education context. In contrast, other countries demonstrate substantially lower representation: Mexico contributes 3 publications; Chile and South Africa each account for 2; and Canada, France, Germany, Saudi Arabia, and the United Kingdom contribute 1 publication each.

This asymmetric distribution suggests that the evidence base is geographically concentrated, with limited representation from Latin America (outside Mexico and

Chile), Europe (beyond isolated contributions), Africa (except South Africa), and the Middle East. Such concentration may influence the contextual framing of mentoring programs, given that institutional structures, gender policies, and engineering education models vary significantly across regions. The limited diversification of geographic contexts also highlights potential gaps in comparative and cross-cultural analyses, reinforcing the importance of expanding research beyond dominant educational systems.

Overall, the figure demonstrates that while female mentoring in engineering has achieved notable scholarly consolidation, its development remains uneven across global contexts, with a pronounced reliance on evidence generated within a single national ecosystem.

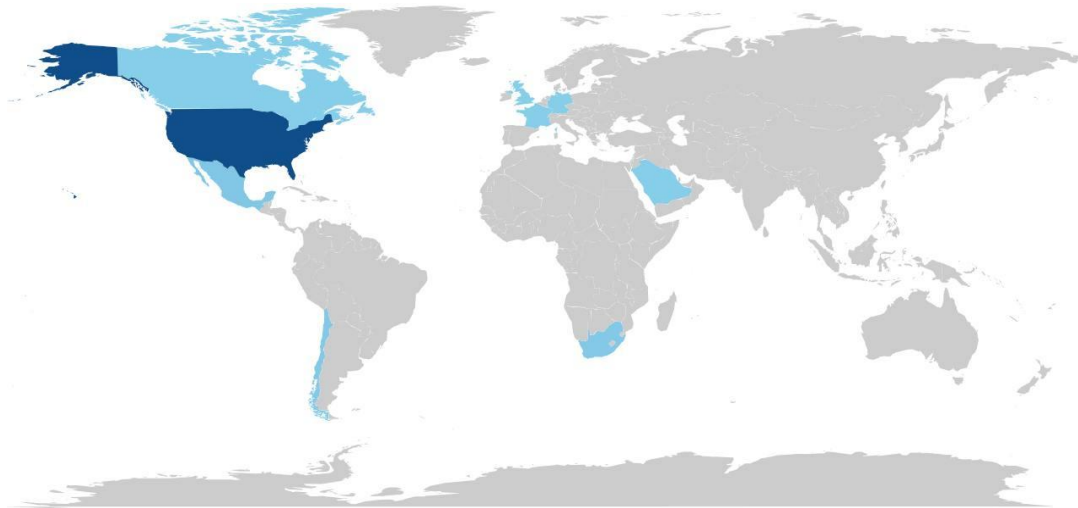


Fig. 3 Geographic Distribution of Scientific Production on Female Mentoring and Student Retention in Engineering.

According to Figure 4, the thematic structure of the field is organized across four quadrants defined by centrality (relevance) and density (development). In the upper-right quadrant (Motor Themes), the cluster composed of curricula, teaching, and first-year engineering appears as both highly developed and central. This positioning indicates that research linking retention to early academic experiences and curricular structures represents a driving force within the field. The prominence of first-year engineering suggests that transitional stages are strongly associated with persistence discussions [6], [18].

In the lower-right quadrant (Basic Themes), the large cluster including students, engineering education, and low incomes, together with professional aspects, engineering program, and women in engineering, reflects foundational but less internally developed themes. These topics function as structural anchors of the literature, connecting mentoring initiatives with broader constructs such as academic identity, program structure, and socioeconomic context [18], [19]. Their high centrality indicates that they are conceptually indispensable to the field.

The upper-left quadrant (Niche Themes) contains clusters such as engineering research, STEM, and computer engineering, as well as mentoring programs, undergraduate students, and hispanics. These themes show higher density but lower centrality, suggesting specialized lines of inquiry that are internally cohesive but less integrated into the broader network. This pattern indicates focused subfields, particularly those addressing specific populations within engineering education [6].

Finally, the lower-left quadrant (Emerging or Declining Themes) includes best practices and undergraduate engineering students. Their low centrality and density suggest areas that are either in early stages of conceptual consolidation or losing prominence within the broader discourse.

Overall, the thematic configuration reveals that female mentoring research in engineering education is structurally anchored in curricular and early-stage academic experiences, while mentoring-specific discussions remain partially specialized and not yet fully integrated as a dominant motor theme. This distribution aligns with patterns identified in the reviewed studies [6], [18], [19].

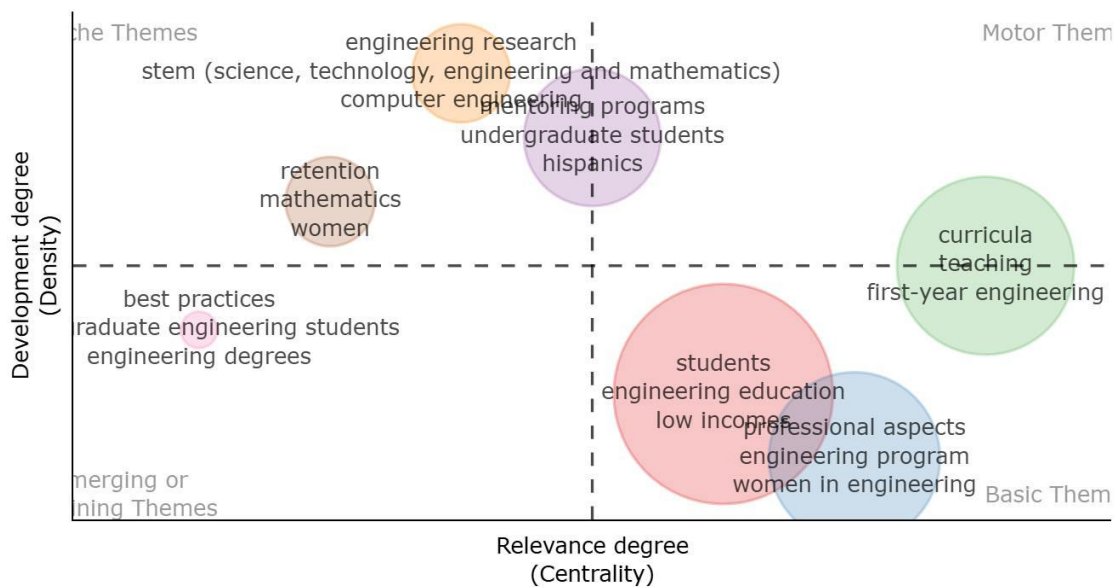


Fig. 4 Thematic Map of Keyword Co-occurrence in Female Mentoring and Student Retention in Engineering.

B. Answering research questions

1) RQ (Evidence base): What evidence does the literature report regarding female mentoring as a strategy for student retention in engineering education?: Across the reviewed corpus, the evidence converges on female mentoring being reported as a retention-supportive strategy in engineering education, primarily by strengthening students' continuity intentions (persistence), academic progress (course performance/credit accumulation), and program commitment—often discussed as reduced attrition risk rather than a single “retained/not retained” endpoint. Studies

commonly frame mentoring as an organized support pathway (rather than an informal interaction), and report benefits that appear most salient during early undergraduate stages and key transition points, where students' decisions to remain in engineering are most fragile. The evidence base also suggests that mentoring effects are frequently intertwined with broader student-success outcomes (e.g., engagement, academic support utilization, and professional orientation), meaning retention is presented as an outcome that sits downstream of multiple educational and psychosocial improvements rather than as an

isolated metric [4], [5], [7], [11], [12], [15], [16], [20], [21], [22].

2) *RQ1 (Intervention components): What common characteristics and components define female mentoring programs associated with student retention?*: The interventions reported in the literature tend to share recurring design components that shape implementation and comparability across studies. First, mentoring programs are commonly described using structured formats (formal pairing or cohort models), with defined mentor roles and planned interactions (scheduled meetings, guided activities, or milestone check-ins). Second, many programs incorporate multi-layered support—combining peer mentoring with near-peer or faculty/staff mentoring—so that students receive both social integration support and academic/professional guidance. Third, a frequent component is community-building: group sessions, networking, and cohort identity activities are used to strengthen connection to engineering peers and the discipline. Fourth, several studies point to integration with academic/professional development (skills workshops, research exposure, career orientation, industry/professional identity), indicating that “mentoring” is operationalized as a package of supports rather than a single dyadic relationship. Finally, the way retention is captured varies: some programs tie outcomes to persistence intentions or progression markers, while others focus on program continuation and longer-term outcomes, which affects how components are judged as “effective.” [2], [6], [23], [24], [25], [26], [27], [28], [29], [30].

3) *RQ2 (Mechanisms of action): What explanatory mechanisms or processes are identified regarding how female mentoring contributes to retention?*: Mechanistically, the literature most often interprets mentoring as influencing retention through psychosocial and academic pathways that mediate persistence decisions. A central mechanism is strengthened sense of belonging and disciplinary identification—students feel more “legitimate” in engineering spaces, more connected to peers/mentors, and more able to navigate gendered climates. A second mechanism involves motivation and self-regulation, where mentoring is linked to goal clarity, confidence in academic capability, and sustained engagement during challenging coursework. A third mechanism is access to informational and instrumental support, including navigating institutional resources, academic strategies, and professional pathways, which reduces uncertainty and increases perceived control over progress. Importantly, the field often treats these mechanisms as interacting: belonging supports motivation; motivation supports persistence behaviors; and instrumental support translates motivation into academic progress. In this way, retention is repeatedly positioned as the downstream result of combined social, motivational, and academic support processes rather than a direct “mentoring → retention” line [3], [8], [31], [31], [32], [33], [34], [35], [36], [37], [38].

4) *RQ3 (Implementation conditions): What contextual or institutional factors influence the effectiveness of female mentoring in engineering?*: Figure-consistent with the thematic patterns, the studies highlight that mentoring effectiveness is contingent on where and how the program is embedded. Programs situated in contexts with stronger institutional scaffolding (clear governance, resourcing, and integration with first-year engineering or curricular structures) are more likely to report coherent pathways from mentoring activities to persistence outcomes. Implementation conditions frequently include mentor preparation and availability (training, workload, continuity), the degree of institutional endorsement (visibility, incentives, alignment with equity goals), and the match between program design and student population needs (e.g., first-year students, specific subgroups, or institution types). Several works also indicate that local educational ecosystems—such as resource constraints, student socioeconomic conditions, and the structure of engineering programs—shape participation intensity and the plausibility of scaling. Therefore, the field suggests that mentoring is not a “plug-and-play” solution; outcomes depend on institutional fit, delivery quality, and the surrounding support environment. [1], [15], [17], [39], [40], [41], [42], [43], [44], [45].

5) *RQ4 (Gaps and opportunities): What gaps or limitations justify the development of an integrative conceptual model?*: The evidence base repeatedly points to fragmentation that justifies an integrative conceptual model. First, retention is operationalized inconsistently (intentions, persistence, progression, graduation, attrition), limiting cross-study comparability and making “effectiveness” sensitive to measurement choice. Second, intervention descriptions vary in granularity—some report mentoring as a broad program label without sufficient specification of components (dose, structure, mentor type), which prevents clear attribution of which design elements matter. Third, mechanisms are frequently implied rather than tested (belonging/motivation/support are discussed, but not always modeled as mediators), leaving causal pathways under-specified even when outcomes trend positive. Fourth, context is unevenly represented (geographic and institutional concentration), reducing generalizability and highlighting the need for models that explicitly incorporate implementation conditions. Collectively, these gaps support the opportunity to consolidate: (i) a component taxonomy, (ii) a mechanism pathway model, and (iii) a context/implementation layer—so that future work can accumulate evidence more coherently and enable design-relevant synthesis [10], [16], [19], [31], [46], [47], [48].

This review has two main limitations. First, although a quality appraisal was conducted using a simple High/Medium/Low framework based on study design rigor, sample adequacy, and outcome measurement validity, the included studies showed methodological heterogeneity. Overall, 17 studies were classified as high quality, 28 as

medium quality, and 3 as low quality. Therefore, findings supported mainly by medium- or low-quality studies should be interpreted cautiously.

Second, the evidence base was geographically concentrated, with most studies conducted in the United States and only limited representation from Latin America, mainly Mexico and Chile. This restricts direct generalization to Latin American engineering education contexts, where institutional capacity, socioeconomic conditions, gender equity policies, and academic support structures may differ. Thus, the findings should be understood as transferable principles rather than directly generalizable conclusions. Mentoring strategies such as structured mentoring, peer support, community-building, mentor training, and early undergraduate intervention may inform Latin American universities, but they require contextual adaptation and empirical validation in the region.

IV. CONCLUSION

This systematic review examined the existing literature on female mentoring as a strategy to support student retention in engineering education. The findings indicate that mentoring initiatives are predominantly conceptualized as structured support programs embedded within undergraduate contexts, particularly during early academic stages. While retention is consistently addressed as a desired outcome, the literature demonstrates that its realization is mediated by psychosocial and academic mechanisms, including belonging, motivational reinforcement, and access to institutional support systems.

The thematic structure of the field reveals that curricular integration and first-year engineering experiences function as motor themes, whereas mentoring-specific discussions often remain positioned within specialized or context-bound clusters. This distribution suggests that mentoring has not yet achieved full structural centrality as a unifying theoretical construct within engineering education research. Furthermore, heterogeneity in intervention design, outcome measurement, and contextual framing limits cross-study comparability.

Collectively, these findings justify the development of an integrative conceptual model that articulates intervention components, mediating mechanisms, and implementation conditions. Such a framework would contribute to theoretical consolidation and support more coherent empirical evaluation of mentoring strategies aimed at strengthening gender equity and persistence in engineering education.

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