Women in STEM Mentoring Programs - Methods, Measures and Impact - A Critical Review

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***Abstract*—Women mentoring programs are holistic approaches to empower women to achieve their individual objectives but also contribute to the broader movement of gender equality and representation in diverse fields. The present paper critically reviews the available literature on mentorship programs for women in STEM fields. It also lists the benefits and challenges of these programs. This paper proposes a structured mentoring framework that integrates algorithmic, heuristic, and hybrid strategies tailored to support women in STEM fields. While conceptual, the model provides a foundation for scalable mentoring initiatives and highlights areas for future empirical validation.**

Keywords—Women Empowerment, Mentor-Mentee, Women in STEM, Algorithmic Mentoring, Heuristic mentoring

I. INTRODUCTION

In the upheaval journey of life, the role of a mentor is like a ray of hope and a pillar of support. Though the concept of mentorship is thousands of years old, a formal method of mentorship originated from Greek cultures in the 18th century [1]. In all these years' individuals and organizations and communities have found it useful. The expert advice, hand-holding and moral support have helped create numerous success stories. The way of mentoring, the power of connections and potential growth opportunities have brought advancement to mentoring programs. The continued efforts of organizations, educational institutes and the community has gained momentum in initiation of a number of mentor programs.

The literature also shows the impacts of such mentoring programmes especially on women. Though modernization and technology has helped us build progressive societies, women still face challenges and exploitation. Rohana Ariffin [2] writes a number of such causes for it. The author explains the concept of exploitation of women varies based on a number of factors. Such as class systems, labor and capital, developed and underdeveloped nations, patriarchy are few of them. The UN Women [3] called for gender equal societies and have more than 50 actionable items reported for accelerating actions in this direction. These many actionable items in itself shows that barriers and biases still exist and women are facing the same in their personal and professional lives. Most parts of world saw girl education and hence social reforms for girls and women during 17th and 18th century. As a result, we can see considerable change in women literacy rate. According to Statista [4] the adult literacy rate of women is about 85 % as against 90% in the year 2023. The same was 54 and 75 in the year 2001. Though the improvement for the 2023 was encouraging, women were underrepresented in STEM (Science, Technology, and Mathematics) education. They make up only about 35%. Lack of inspiring role models peers to support, seniors to mentor and guide are few of the reasons for this underrepresentation.

Interestingly, a critical search on "Women Mentoring programs" and "Women in STEM mentoring programs" returned results as in Table. 1. The results were compiled based on the search from popular database like Science Direct by Elsevier, IEEE Xplore and JSTOR. A review of academic databases over the past 20 years shows significantly fewer studies on "women in STEM mentoring" compared to general "women mentoring" programs. This highlights a critical research gap in understanding and supporting targeted mentoring initiatives for women in STEM fields.

TABLE I. KEYWORD SERACH RESULTS ON DATABASES.

Average Articles published for the keywords	**Academic Research Databases**		
	Elsevier's Science Direct	***JSTOR***	***IEEE Xplore***
Women Mentoring	25475	17394	218
Women in STEM Mentoring	4865	3787	70

As expected, the documented literature also showed that "women in STEM" mentoring results were very less. Therefore, it was planned to do a critical literature on the available sources in the areas of "Mentoring for Women in STEM" programs. The four focus areas chosen were STEM faculty member mentoring programs, STEM student level mentoring programs and mentoring programs for Women in STEM from Industry and corporate backgrounds. Other categories such as community mentorship programs are also considered in the last section. The focus of literature review remained on understanding the programs, methods, measures and the impact created.

The remainder of the paper is structured as follows: Section II presents a literature review; Section III discusses and proposes a conceptual model for mentoring women in STEM; and Section IV provides the conclusions.

II. RELATED LITERATURE

A. Mentrong programs for Women in STEM

Women remain underrepresented in academia, particularly in leadership roles, affecting career advancement and diversity in STEM fields. Mentorship programs serve as a key strategy to address these challenges, offering professional and personal development support. Various studies have explored mentorship models and their effectiveness in fostering career growth for women in academia and STEM. Farkas et al. [5] assessed mentorship programs in academic medicine, identifying dyadic, peer, and facilitated peer mentoring as common models. These programs enhanced scholarship and career progression, though small sample sizes and short-term follow-ups limited long-term impact assessments. Rockinson-Szapkiw and Wendt [6] explored peer mentoring in STEM, finding it positively influenced self-efficacy, career aspirations, and professional engagement. Their study, conducted at historically Black institutions, emphasized the importance of recognition, mentorship engagement, and a sense of sisterhood. Peer mentoring provided emotional and academic support, helping female students navigate challenges unique to STEM fields. However, time constraints, institutional limitations, and technological barriers hindered broader implementation, suggesting the need for structured mentorship frameworks with improved accessibility and institutional backing.

Dennehy and Dasgupta [7] conducted a longitudinal study on female engineering students transitioning to college. Women with female mentors exhibited higher confidence, stronger academic engagement, and increased retention in STEM fields. Files et al. [8] examined a facilitated peer mentorship pilot program in medical academia, reporting higher publication rates and career advancements among participants, though its small sample size limited broader applicability. Brizuela, Chebet, and Thorson [9] evaluated a global mentorship initiative for early-career female researchers, highlighting its effectiveness in fostering professional networks, albeit with online accessibility challenges.

Chowdhury et al. [10] studied mentorship among female STEM students in India. A survey of 52 professionals in a 'Foundations of Data Science' course at BITS Pilani revealed that mentorship significantly improved confidence, career satisfaction, and professional advancement. The barriers such as limited access to female mentors and societal biases stayed. Author has [11] analyzed gender differences in STEM education in India using data provided by the All India Survey on Higher Education [12]. The female enrolment was high in biological sciences and growing in IT-related fields that representation is remained low in mechanical, civil, and electrical engineering because of deep-rooted societal gender biases.

Mentorship programs play a crucial role in addressing the challenges that supporting career development and promoting inclusivity in academia and STEM. However, diverse mentorship models have shown promise, challenges such as technological barriers, small sample sizes, and societal constraints persist. Future research should focus on scalable and inclusive mentorship frameworks to ensure supported professional growth for women in academia and technology.

B. Mentoring Methods for Women in STEM

Literature shows a number of mentoring methods.

- One-on-One Mentoring: This traditional and extensively employed paradigm involves the allocation of a mentor to an individual mentee. This framework facilitates tailored guidance and support, which empirical evidence has demonstrated to significantly improve career satisfaction and research productivity among female professionals in academic medicine [13-14]. Nevertheless, research has also underscored obstacles such as the scarcity of appropriate mentors and the potential for inequitable access to mentorship opportunities [15] [16].

- Peer mentoring involves a group of individuals who act as mentors. This approach has been effective in promoting a importance of community and collaboration. For example, a facilitated peer mentorship program for women in academic medicine resulted in increased academic activity. It also includes published papers and promotions in academic rank [17]. The peer mentoring has been shown to benefit early-career women researchers in sexual and reproductive health and rights (SRHR) by providing professional skill-building and networking opportunities [18].

- Group mentoring models, where multiple mentees are paired with senior facilitators, have also been explored. A study on women internal medicine subjects found that approach not only provided guidance but also encouraged collaboration and a sense of belonging among participants [19]. This model has been particularly beneficial for women in surgery, where access to mentors with shared gender and racial identities has been shown to provide unique levels of support [20].

- Strategic Collaboration models have been implemented to handle the limitations of traditional mentoring programs. This approach helps to build a networks and relationships instead of relying solely on individual mentor-mentee dyads. A case study of a university-based mentoring program found, the model helped women faculty overcome professional isolation and achieve career advancement [21].

C. Measures of Mentorship programs for Women in STEM

- Objective Measures: Mentoring program effectiveness usually include career outcomes like promotions, research productivity, and leadership roles. As an example, a systematic review of mentoring programs in academic and medicine found that women who participated in the programs. They were more likely to receive promotions and demonstrate greater research productivity [22]. A study on women in STEM fields found that mentoring programs contributed to increased self-confidence and career progress [23].

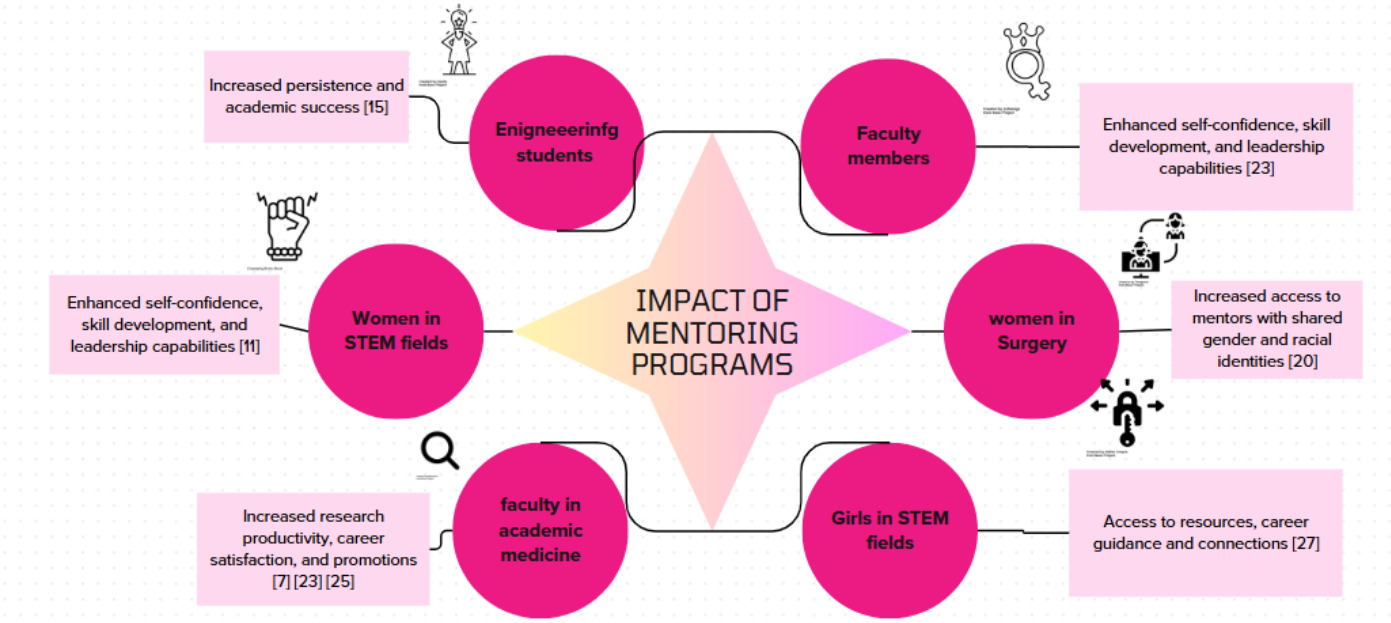

Fig. 1 Impact of Mentorship for women in STEM

- Program evaluation is a critical component of mentoring initiatives. A scoping review of healthcare faculty mentorship programs identified the need for consistent use of evaluation methods that includes objective outcomes and career satisfaction measures [24-25]. Other analysis emphasized the importance of ongoing feedback loops to refine program design and implementation [26].

D. *Impact of Mentoring Programs*

- Career Development- Mentoring programs have been shown to positively impact in the career development of women in different specialisations. For instance, a research investigation concerning female professionals within the fields of academia and medicine revealed that mentorship was positively correlated with enhanced research output and greater job satisfaction. Similarly, a study on women in STEM fields found that mentoring programs enhanced skill development and leadership capabilities.
- Psychosocial Support- The key area of impact is psychosocial support provided by mentoring programs. A qualitative study found that women in STEM appreciated the emotional support provided by mentors and guidance supplied by their mentors. Similarly, a study on women in medical highlighted the importance of mentors who could provide a sense of belonging and reduce feelings of solitariness.
- Leadership Advancement-Mentoring programs have also been shown to promote leadership advancement among women. A study on women in academic medicine found that mentoring was associated with increased leadership roles and promotions. Similarly, a study on women in STEM fields found that mentoring programs contributed to increased confidence and leadership development.
- Challenges and Barriers : Despite the positive impacts of mentoring programs, several challenges and barriers have been identified. These include the lack of available mentors, particularly for women from minority backgrounds and the potential for unequal distribution of mentorship opportunities. However, the programs support mentees immensely; mentors time and efforts remain voluntary excluding very few programs where mentors also receive funds and recognition [27-29].
- Additionally, studies have highlighted the need for more structured and inclusive mentoring programs that address the unique needs of diverse populations [30].

A summary of the impacts created by mentorship programs isshown in Fig. 1

E. *Identified Gaps in Literature*

The following key gaps were identified through an extensive review of existing studies on mentoring programs for women in STEM:

- Lack of Integrated Frameworks- Most current models either follow an algorithmic (data-based) or heuristic (experience-based) approach, but rarely integrate both in a structured and dynamic way. This limits adaptability across diverse mentoring needs [31-32].
- Limited Contextual Differentiation- Mentoring approaches are often generalized across academic, industrial, and community contexts. There is a lack of studies that account for contextual variations specific to women in STEM [33-34].
- Scarcity of Empirical Validations- Many conceptual models exist, but few are supported by case studies, pilot

programs, or longitudinal assessments, limiting their practical credibility [35-36].

- Underrepresentation in Scholarly Databases- As shown in Table I, the volume of research specifically addressing women in STEM mentoring is significantly lower than general women mentoring programs, revealing a substantial research gap [37].

III. Discussions and A Conceptual Model

A very detailed structured approach was available from Society for Women Engineers. [38]. Success of a mentorship programs depends on the satisfaction of both mentor and mentee. As brought in the review more structured approaches create required impact. The present study proposes a conceptual model as shown in Fig.2, based on Tripod policies.

The model uses Tripod policy all across. The three concepts used are Context Setting for Mentoring Women in STEM program (MWSP), the stakeholders and the methods, measures and impact mapping

A. Context Setting for Mentoring Women in STEM program

The base for the conceptual model is based on the need analysis, goals & objectives and resource allocation. A MWSP owner will study the setting, need analysis and set the goals & objectives. The MWSP programs need time as a major resource from both mentor and mentee side. Other resources like offering platform for connecting both of them. The role of platform connects both the mentee and the mentor, provide monitoring support and supervise the progress to support accessing of the impact of the program.

B. The Stakeholders

The three primary stakeholders of the MWSP are Mentors, Mentees and the platform. The platform is an interface who will connect the mentor with mentee. It could be an organization, an individual or a community unit and can exist formally or informally. A platform can also make use of technical tools for project management, goal assessment and impact measurement.

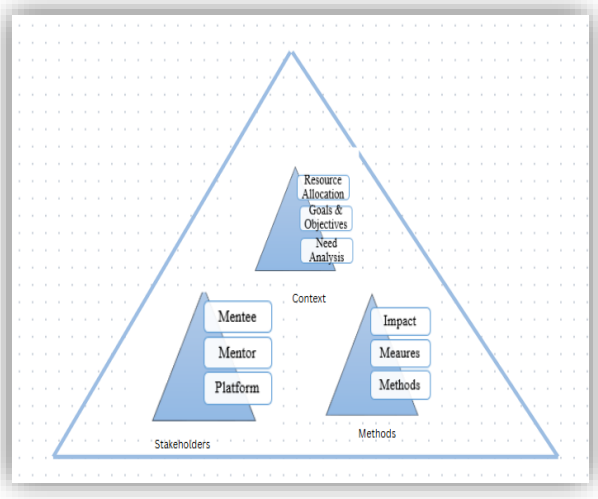

Fig. 2 A conceptual Mentoring Women in STEM Program

C. Methods, Measuremnts and Impact

Our framework introduces a unique combination of algorithmic, heuristic, and hybrid strategies tailored for women in STEM.

The present paper proses three novel approaches for mentoring.

- Algorithmic approach : In this approach mentor and mentee work together towards achievable goals & objectives in a step by step manner until they achieve. These are time bound and short term type of mentoring programs. An expert and a group of mentees are the participants of the approach. The impacts could be measured both quantitatively and qualitatively.
- Heuristic Approach: In this approach mentor and mentee work towards a problem which may not have a known solution. The pair might work using a trial and error approach. The group in dyads, and a teacher student pair, a scholar supervisor pair are suitable for such an approach. The impact of such mentoring is long lasting and has impressions on both mentor and mentee.
- Hybrid Approach: In some cases, mentor and mentee might use a combination of both algorithmic and heuristic approaches.

The methods, measurements are subjective and depend on the set goals and objectives. For example, a short-term mentoring program to develop soft skills among rural girls might run as a weeklong program and can immediately provide the results. On the other hand, a long-term mentoring program may continue to work for long periods with heuristic approach in support of meeting the set goals and objectives of the mentee. For example, an all women start-up mentoring program. In most of the other cases can use a hybrid approach involving both algorithmic and heuristic mechanisms. For example, mentoring a mentee for possible promotions and moving towards the next higher position in the organization. The model can fit for the need of mentorship program of a number of tailor-made situations. Unlike traditional linear models, methods adapts based on mentee profiles and context. The algorithm ensures structured matching, the heuristic layer brings in expert judgment, and the hybrid model blends both for flexibility. This integrated approach addresses a gap in existing mentoring literature.

TABLE II. Summary Comparison of Mentoring Approaches.

Feature	Traditional Models	Community-Based Models	Proposed Framework
Matching Method	Manual or informal	Volunteer-based	Algorithm-driven
Personalization	Limited	Moderate	High – Adaptive
Focus on Women in STEM	General or indirect	Varies	Central focus
Scalability	Mostly academic	Community-specific	Cross-sector (academia, industry)
Use of Data & Feedback	Minimal	Informal	Integrated quantitative & qualitative

The proposed mentoring framework offers a more personalized, data-driven, and adaptable approach compared to traditional and community-based models. It uniquely emphasizes women in STEM and integrates structured feedback across academic, industry, and community settings as shown in Table 2.

To conduct this compressive review below structured approach was adopted.

- Database Selection: We used three major academic research databases—Elsevier's Science Direct, IEEE Xplore, and JSTOR—due to their wide coverage of interdisciplinary STEM and social sciences literature.
- Search Strategy: Keyword searches included "Women Mentoring," "Women in STEM Mentoring," "STEM Mentorship Programs," and related combinations. The search considered publications from the past 20 years (2004–2024).
- Inclusion/Exclusion Criteria: Research has included if they addressed mentoring frameworks, strategies, or outcomes for women in STEM. Articles not focusing on women or mentoring programs, or that lacked relevance to STEM disciplines, were excluded.
- Data Extraction: Research papers were reviewed for different types (empirical study, review, case study), methodology (qualitative, quantitative, mixed) and context (academic, industry, community).
- Thematic Analysis: Identified studies were categorized under four primary focus areas—academic faculty mentoring, student mentoring, industry mentoring, and community-based mentorship. Emerging patterns and gaps were thematically coded to inform the conceptual model.

IV. Conclusions

Mentorship programs for women are designed to empower them by offering guidance, support, and resources to help them thrive in their personal and professional lives. A new mentorship program for women has been proposed, with plans to develop a model based on various structural approaches. Both algorithmic and heuristic methods, along with a hybrid method, are envisioned to facilitate these mentoring programs.

The STEM mentoring models use either rigid matching or informal networks. Our multi-method approach combines data-driven precision with qualitative insight, allowing for a more inclusive and adaptable mentoring experience. While the proposed mentoring model offers conceptual contributions, empirical validation is a crucial next step. In future work, we plan to apply the framework to case studies in academic and corporate STEM settings and measure its effectiveness through predefined mentoring success indicators (e.g., retention, satisfaction, and progression metrics). This will ensure practical applicability and inform further refinements of the model.

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