Women leaders in STEM: shaping role models

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Abstract

Increasing vocations is one of the challenges for the School of Engineering, Science and Technology at universities. And a major challenge is to increase female vocations in STEM programs traditionally considered for men. One of the strategies used by different universities are role models, women engineers, scientists, professors, professionals, who share their passion for the discipline, their achievements and trajectory, as well as their barriers and driving forces. The purpose of this research is to share the distinctive elements that these role models present by comparing the profiles of outstanding women in different fields and recognized nationally and internationally. The research questions to be answered: What common characteristics do women who are recognized for their careers and achievements have? What factors inspire women to pursue a STEM career? What strategies can be derived from these findings to promote the successful development of more women in STEM careers? The methodology is mixed approach, consisting of the following phases: research plan, description of the awards to be used for comparison (one national and one international for Latin America), analysis of the professional and personal development of the winners, the design and implementation of a survey of women recognized as role models, in-depth interview of a sample of them, a comparative analysis and the generation of conclusions and recommendations . Preliminary findings show in common a passion for their discipline, clear decision making, commitment to their learning and the creation of a supportive community dependent on circumstances. There are differences in contexts, in the career selection process and limitations and perceptions regarding the perspective of gender barriers. However, they all agree on the desire to share their life experience, to motivate and encourage more young people to study STEM careers as a life choice, setting aside biases and taking advantage of opportunities and support from a community of both men and women. Identifying common characteristics provides the opportunity to define strategies to reach more girls and young women, to share STEM careers as a life choice, which will guide them to transform not only their lives but other lives, organizations and societies.

Introduction

For several decades, and especially since the establishment of the Sustainable Development Goals (SDGs), there have been efforts to enhance gender equity in the educational, business, and societal sectors. Universities have been keenly aware of the underrepresentation of women in STEM (Science, Technology, Engineering, and Mathematics) fields, prompting initiatives to understand the contributing factors and implement concrete actions to increase women's interest in these fields and reduce the impact of these factors. Actions taken to promote and retain interest in STEM include workshops in elementary, middle and high school, mentoring programs to guide career choices and strengthen interest in higher education, events and conferences, webinars, student groups, awards recognizing outstanding

women at various stages of their professional careers, and more [1].

One of the main initiatives to promote the participation of more women in STEM fields is to promote female role models, which consists of promoting women who serve as examples to follow in the fields of science, technology, engineering, and mathematics [2],[3]. These women can inspire and motivate others to pursue careers in these areas by demonstrating success and leadership.

The gender gap is still present in STEM environments. Among the factors affecting this reality are behavioral, personal, and environmental factors. Personal factors include characteristics of the family in which a girl grows up, such as gender stereotypes and biases that impact her from an early age. Societal gender biases play an important role in environmental factors, considering that certain activities are considered appropriate for men and others for women. Behavior is the student's self-perception of her ability to do something and whether these biases and stereotypes affect her motivation and interest [2],[4]. Given the various factors that affect women's stages of development and growth, it is crucial to dispel these stereotypes and biases from an early age and across all areas. Some of the initiatives being carried out to reduce the impact of these factors include exposing girls to more STEM-related activities and bringing them closer to female role models who inspire and motivate current and future students.

In STEM careers, there is a greater likelihood that women will not persist in their studies, and one of the causes that has been studied as having an impact is the lack of women as role models, whether as colleagues, teachers, researchers, mentors, or managers [5]. Promote interaction among female students with female role models allows [5],[6]:

1. High school students to be exposed to women who are pursuing STEM careers and who can share their experiences in studying and practicing their profession.

2. Allows them to identify with female role models and even resolve doubts regarding discipline and personal development as professionals and as women.

3. Strengthens an identity with discipline and a sense of belonging both in the academic program and in the institution and community.

These interactions can take place through ongoing relationships with female stem professors and female stem students in higher grades. For example, high school students can interact with students in STEM programmes, and students in STEM programmes can interact with graduates of these programmes. Through mentoring programs or participation in STEM events such as conferences, workshops, company visits, etc., these connections can be made, not only directly in the life of the institution where the students are studying [7],[4]. There are studies on the impact of male role models and female role models, and it has been found that male role models have no impact on girls' perceptions of STEM careers, while the impact of female role models is more visible, although

the weight of existing stereotypes in STEM areas is questioned [8],[9],[10],[11].

With the aim of raising the profile and recognizing women in STEM fields, awards are given in different categories and for different characteristics. The aim is to identify female role models who inspire girls, young women, and women, who are real, achievable models linked to different aspects of women's professional lives and who have an impact on their environment. In this research, two awards with national impact and another with international impact were selected. Each one is described below to understand the characteristics that define these awards. The Mujer Tec Award is a national award offered by a Mexican multi-campus university. The purpose of this award is to recognize and highlight the careers and achievements of women who are or have been part of the university community, as well as the impact their work has had on society [12]. And the "Inspiring Models in Science, Engineering, and Technology" Award, from the Matilda Latin American Open Chair and Women in Engineering, aims "to highlight and celebrate the outstanding contributions of individuals, groups, and institutions that promote gender equality in STEM fields by driving cultural change in their educational, professional, and institutional contexts" [13]. Both awards seek out female role models so that they can be known, inspire, and motivate other women, showing that it is possible to achieve their goals.

When considering theoretical frameworks related to gender and social theories, two emerge as particularly relevant: (a) social learning theory, in which learning arises from observation and imitation; and (b) social cognitive theory, in which learning occurs through connections that arise from an internal process enriched by feedback and reflection [14]. This is supported by the search for female role models in STEM fields whose careers, decisions, and learning experiences cannot be imitated but rather invite reflection and connection with young female students learning about their stories and interacting with them in programs such as workshops, mentoring sessions, and informal conversations.

Purpose

This research aims to highlight the unique qualities of these role models by comparing the profiles of exceptional women who have achieved recognition at the national and international levels in various fields. Another aim of this study is to explore the experiences, challenges, and influences on the professional careers of women in STEM fields. We will accomplish this by conducting a survey, which will allow us to identify role models in different areas. The research questions are as follows: What common characteristics do women who are recognized for their careers and achievements have? What factors inspire women to pursue a STEM career? What strategies can be derived from these findings to promote the successful development of more women in STEM careers?

Methods

The research approach is mixed [15], using a comparison between awards that seek to highlight and recognize outstanding women in different fields and applying a survey to women in Latin America in STEM areas, focusing on the fact that the aim is precisely to increase vocations

and retention of women in these areas. The awards to be compared are the Inspirational Models in Science, Engineering, and Technology Award (Award 1) and the Tec Woman Award (Award 2), where categories and characteristics will be compared to identify those of a role model. And conducting a survey of women in STEM fields in Latin America that allows us to visualize role models and their characteristics. Using these two approaches, qualitative and quantitative, the analysis is carried out using comparative tables and statistical data to answer the research questions. The qualitative analysis involved comparing the categories used by both awards, as well as the characteristics required to be recognized in each category. The comparison of the awards is presented in a descriptive approach. The aim was to determine the profile that these awards generally seek to recognize outstanding women in different areas for their leadership.

A total of 155 women participated in the research, which was conducted using a quantitative approach, using an online questionnaire entitled "Empowering Women in STEM: Distinctive Characteristics of Successful Female Engineers and Scientists." This technique involves the distribution of a set of questions to the participants, in this case, women identified as role models.

A structured questionnaire was developed, as exploratory instrument, subdivided into five sections: general information, influences and motivations, challenges and barriers, personal and professional characteristics, and strategies and recommendations. The questionnaire was designed to measure specific outcomes and therefore incorporated into a variety of question types, including multiple-choice and open-ended questions. The efficiency of the online questionnaire is attributable to its capacity for non-invasive data collection, thereby enabling participants to respond at a pace that aligns with their individual requirements.

The survey items were grouped into specific competencies through an iterative process that involved reviewing existing literature and consulting with subject matter experts. The objective of grouping items related to similar skills within the same competency was to facilitate comparative analysis and correlation. In several cases, multiple items targeting the same competency were combined to create a composite index with greater analytical robustness. For illustrative purposes, items pertaining to "Innovation" and "Creativity" were aggregated under the competency of "Innovation and Creativity," given the close relationship between these two skills.

The process of determining the correlation between items and competencies entailed a meticulous, multi-step procedure. Initially, a comprehensive literature review was conducted to identify key skills and competencies. Subsequently, a panel of experts was convened to validate these competencies and to deliberate on the relevance of the proposed items. In certain instances, this approach has resulted in the amalgamation of items into composite indices, with the objective of enhancing analytical robustness. In addition, iterative reviews were conducted to ensure the accuracy and relevance of the items within each competency.

Prior to the completion of the questionnaire, participants were presented with a disclaimer that included the following:

• Informed Consent: The study's purpose is explained in detail, and it is made clear that

participation is voluntary and that participants have the right to withdraw at any time without repercussions.

• Privacy Policy: The following clarifications are provided to ensure full transparency regarding the handling of personal data. It is guaranteed that all information will be kept confidential and used exclusively for the purposes of research. The participants were assured that their responses would be stored securely and anonymized to protect their identity.

• Data Analysis: After the collection of all responses, the data was analyzed using statistical tools to identify significant trends and patterns. The data were grouped and analyzed according to the different sections of the questionnaire to provide a comprehensive view of women's experiences and perceptions in the fields of engineering and science.

Eleven multiple-choice questions were asked, as shown in Table 1.

Table 1
Multiple-choice questions in the online questionnaire

Questions	
1. What inspired you to pursue a career in Engineering and Science?	6. Have you faced gender barriers in your career?
2. How important do you consider passion for your discipline to your professional success?	7. Could you specify which ones?
3. How would you describe your family's support in your decision to pursue a career in engineering?	8. Have you faced specific challenges as a woman in the field of engineering and science?
4. Did you participate in STEM-related extracurricular programs during your education (such as science clubs, technology fairs, etc.)?	9. What kind of challenges have you encountered in your STEM career?
5. What other extracurricular activities, besides those related to STEM, did you participate in during your education?	10. What were the key moments in your personal and professional journey that led you to where you are today?
	11. What factors influenced those key moments? Select the three most relevant.

In response to the ranking questions, subjects were asked to rate the importance of the indicated characteristic in their professional development on a scale from 1 to 5, with 1 representing "Not important at all" and 5 representing "Extremely important."

A one-way analysis of variance (ANOVA) was applied to determine if there were significant differences between the means of the assessed competencies. After the analysis of variance (ANOVA), Tukey's multiple comparisons test was implemented, with a 95% confidence level. The grouping table generated by Minitab allows visualization of which competencies share similar performance levels, and which show significant differences; in other words, Tukey reveals which groups are different from each other.

A Pearson correlation analysis was conducted using the following ranking questions variables: "Clear decision making", "Commitment to learning", "Creating a supportive women's community", "Resilience in the face of adversity", "Innovation and creativity", "Conflict resolution skills", "Teamwork", "Work-life balance", and "Effective communication". After the collection of the data, the responses were coded numerically to facilitate subsequent statistical analysis. The Pearson correlation coefficient (r) was calculated for each pair of variables using specialized statistical software. Values close to 1, -1, and 0 were used to identify strong positive, negative, or nonexistent correlations, respectively.

Results

For qualitative analysis, the awards have their own categories, one focused on STEM areas, privileging individual, collective or institutional role models (See Table 2), and another highlighting women's contributions in social, cultural, environmental, or entrepreneurial domains. Characteristics such as being proactive, leading, implementing, researching, creating, promoting, and inspiring are present in both awards.

Table 2
Comparative analysis between recognitions of outstanding women

Type	Award 1 [13]	Award 2 [12]
Categories	3 Categories: Individual Recognition, Collective Recognition (Committees), Institutional Recognition	9 categories: Art and cultural management, Citizenship with a gender perspective, Sports and sports management, Entrepreneurship, Environment, Technological transformation, Science, Health and well-being, and Transformative leadership.
Characteristics to be recognized	Active and sustained participation in promoting a culture of gender equality in stem areas, with personal or institutional initiatives in their discipline or in gender equality, intellectual contributions in both areas, outstanding leadership with evidence, and proven inspirational impact.	Positive impact in the category they apply to, innovate in the area they apply to, stand out for leadership in activities, contribute significantly and promote initiatives, create initiatives, organizations, or business units, are leaders in the category they apply to, generate support networks.

For quantitative analysis, the survey of 155 women in STEM (Science, Technology, Engineering and Mathematics) fields provided valuable insights into the diverse experiences, influences, and challenges they face in their careers. The general information collected is displayed in Table 3, which presents a comprehensive overview of the participants in terms of age, country of residence, educational level, and years of experience.

Table 3

General information collected through online questionnaire to Role Models

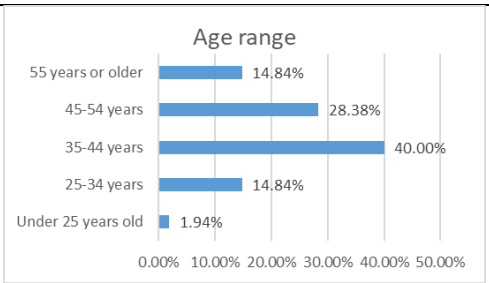
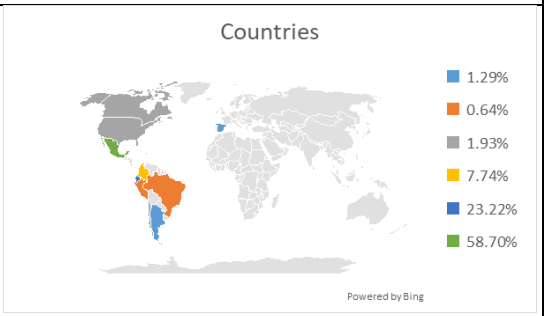
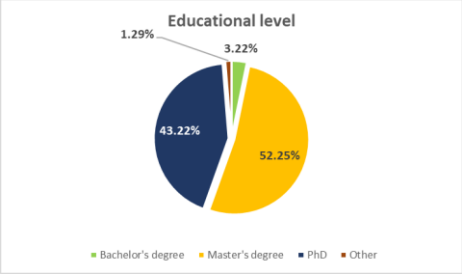
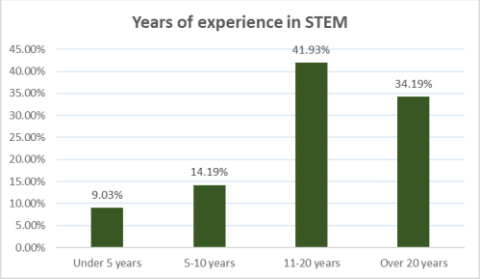
Category	Options	Number of Responses	Percentage
Age	Under 25 years old 25-34 years 35-44 years 45-54 years	3 23 62 44	
Country of residence	11 countries	Argentina 2 Brasil 1 Canadá 3 Chile 3 Colombia 12 Costa Rica 1 Ecuador 36 España 2 Estados Unidos 3 México 91 Perú 1	
Educational level	Bachelor's degree Master's degree PhD Other	5 81 67 2	
Years of experience in STEM	Under 5 years 5-10 years 11-20 years Over 20 years	14 22 65 53	

Figure 1 shows the results of multiple-choice question number 1, regarding motivations to pursue a career in engineering and science. The percentages illustrate the main sources of inspiration.

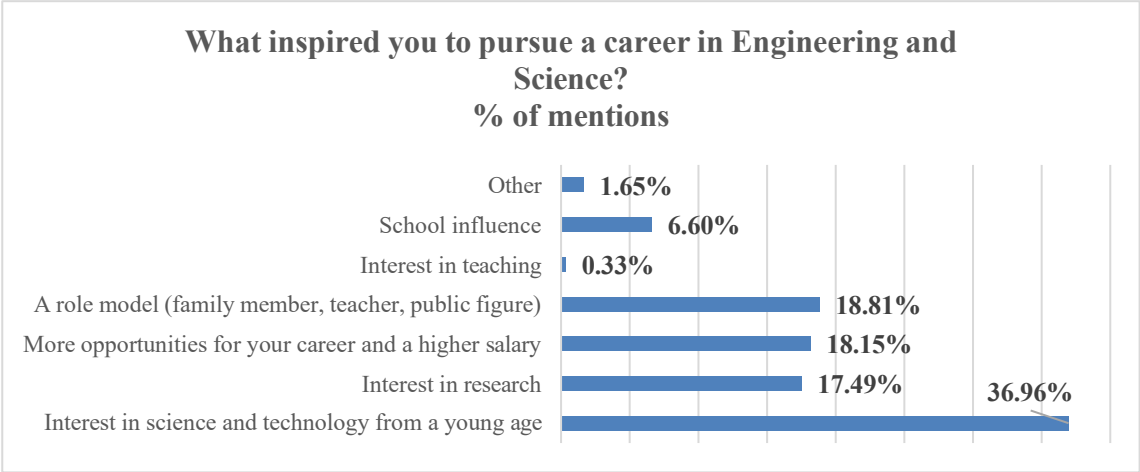


Fig. 1 Inspiring Factors for a Career in STEM

The results obtained from the online questionnaire regarding sources of inspiration for choosing a career in STEM subjects revealed several key points. Firstly, the most significant inspirational factor, cited by 36.96% of respondents, is an interest in science and technology from a young age. This finding underscores the significance of cultivating interest in these domains from an early age to promote the pursuit of STEM careers by women.

It is important to note that, according to the respondents, the second most popular source of inspiration, at 18.81%, was the influence of a role model (whether a family member, teacher or public figure). This emphasizes the importance of role models in influencing career choices, indicating that individuals who have an inspirational figure in the fields of science and engineering are more motivated to pursue a career in these areas. Furthermore, 18.15% of participants identified greater career opportunities and higher salaries as decisive factors. Concurrently, 17.49% of respondents expressed a particular interest in research, indicating the appeal of exploration and discovery in these fields. Interest in teaching, school influence, and other factors were found to be less influential, with percentages of 0.33%, 6.60%, and 1.65%, respectively. These findings suggest potential areas for enhancing inspiration toward these careers.

Table 4 shows the results of the analysis of variance (one-way ANOVA). The F-value = 12.24 and the p-value = 0.000 indicate that there are statistically significant differences between the competencies analyzed. This justifies the application of post-hoc tests to identify which competencies differ from each other.

Table 4
One-way analysis of variance of questions evaluated by ranking

Fuente	GL	SC Ajust.	MC Ajust.	Valor F	Valor p
Factor	8	48.23	6.0290	12.24	0.000
Error	1386	682.44	0.4924		
Total	1394	730.67			

Tukey's multiple comparisons test was applied with a 95% confidence level. The clustering table generated by Minitab allows for graphical representation of the competencies with similar performance levels and those with significant differences. The results visualization and interval plot are presented in Figure 2.

Factor	N	Mean	Grouping
Commitment to learning	155	4.7548	A
Resilience in the face of adver	155	4.6839	A B
Conflict resolution skills	155	4.6129	A B C
Clear decision making	155	4.6000	A B C
Effective communication	155	4.5032	B C D
Innovation and creativity	155	4.4452	B C D
Work-life balance	155	4.4129	C D
Teamwork	155	4.2839	D E
Creating a supportive women_s c	155	4.1355	E

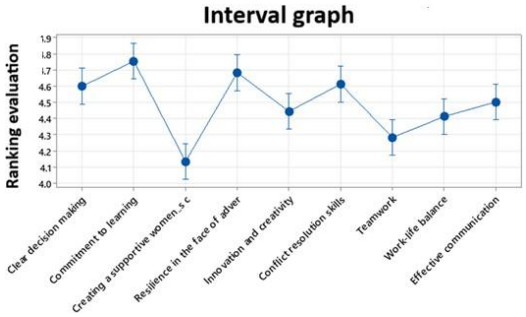


Fig. 2 Tukey comparisons and Interval Graph

Tukey's group of competencies reveals that not all skills are perceived with equal intensity. Competencies that do not share letters demonstrate significant disparities, thus enabling the establishment of clear priorities for designing institutional strengthening strategies. The analysis indicates that commitment to learning emerges as the strongest competency, with the highest means and a narrow confidence interval. This finding suggests consistency in its assessment and cross-cutting relevance across the analyzed profiles. The creation of a supportive community and the promotion of teamwork have been identified as the most effective methods of fostering these competencies. However, it is important to note that these factors are not immune to limitations imposed by contextual or institutional factors, which can impede their full development. These areas are identified as opportunities to enhance support and collaboration in STEM environments.

Commitment to learning emerged as the strongest competency, with the highest means and narrow confidence interval. Conflict resolution and resilience appeared in an intermediate range, while work-life balance showed lower but not significantly different performance.

Finally, the Pearson correlation results are shown in the correlation matrix in Figure 3.

	Clear decision making	Commitment to learning	Creating a supportive women's community	Resilience in the face of adversity	Innovation and creativity	Conflict resolution skills	Teamwork	Work-life balance	Effective communication
Clear decision making	1								
Commitment to learning	0.294695127	1							
Creating a supportive women's community	0.098333163	0.15140598	1						
Resilience in the face of adversity	0.176073248	0.153573269	0.330699267	1					
Innovation and creativity	0.343769628	0.338811792	0.274723442	0.3668121	1				
Conflict resolution skills	0.34405403	0.288931681	0.137451726	0.2405071	0.4765491	1			
Teamwork	0.121653258	0.259724919	0.337417589	0.1246299	0.2216041	0.254827	1		
Work-life balance	0.165496697	0.042502416	0.077429556	0.0165524	0.2023633	0.1260603	0.239616	1	
Effective communication	0.275884437	0.159848543	0.262942317	0.0444763	0.3063218	0.2719166	0.424051	0.3102165	1

Fig.3 Pearson correlation matrix of ranked questions.

The results in the correlation matrix demonstrated two moderate positive correlations. The first of these is between the "Conflict resolution skills" factor and the "Innovation and creativity" factor. This phenomenon is commonly understood to signify that as individuals' proficiency in conflict resolution enhances, there is a concomitant rise in innovation and creativity. This finding is particularly salient in professional environments, such as work teams or professional development programs, where effective conflict resolution has been shown to positively impact creativity and innovation.

The second correlation is between the "Teamwork" factor and "Effective Communication." This moderate positive correlation suggests that the women surveyed perceive that the development of effective communication skills among team members is associated with an improvement in teamwork. This finding may be particularly relevant in organizational and professional settings where teamwork and effective communication are essential for group performance and success. The ability to communicate with clarity and efficacy can facilitate a deeper level of understanding and coordination among team members. This, in turn, can improve collaboration and the achievement of common goals.

This finding suggests that stronger conflict resolution skills may accompany higher creativity, and that effective communication supports teamwork.

Discussion

The findings of this study provide evidence of the relevance of female role models in STEM education and professional development [5],[6]. Beyond the descriptive statistics, the significant differences identified through ANOVA highlight that competencies such as commitment to learning are consistently valued across profiles, suggesting that they can serve as a foundation for institutional strategies aimed at strengthening women's participation in STEM. This resonates with prior work emphasizing the importance of mentoring programs and recognition initiatives to sustain women's interest in STEM careers [1],[2],[3].

The correlations observed between conflict resolution and creativity, as well as between teamwork and communication, reinforce the idea that interpersonal and problem-solving skills are interconnected. These results align with studies that highlight how environmental and behavioral factors shape women's persistence in STEM [2],[4], and suggest that fostering collaborative environments may enhance innovation and resilience [14].

Motivational factors such as early interest in science and technology and the presence of role models were decisive in our sample. This finding supports previous research showing that female role models exert a stronger influence on girls' perceptions of STEM careers compared to male role models [8–11]. It also underscores the relevance of awards and recognition programs, such as Mujer Tec and Inspiring Models in Science, Engineering, and Technology, which aim to provide visible, achievable examples of success [12],[13].

This contribution is twofold. First, it expands the understanding of how motivational factors interact with professional competencies to shape women's trajectories in STEM. Second, it provides empirical evidence that can inform mentoring programs and institutional policies, particularly those seeking to foster resilience, teamwork, and innovation among female students and professionals. These insights respond to calls in engineering education for more inclusive frameworks that recognize the social and cultural dimensions of professional development.

Nevertheless, some limitations must be acknowledged. The sample, although diverse, was limited to women who voluntarily participated in the survey, which may introduce self-selection bias. The quantitative analysis was restricted to specific competencies and correlations, leaving other potentially relevant variables unexplored. Additionally, the interpretation of correlations does not imply causation, and future studies should employ longitudinal or mixed method approaches to deepen the understanding of these relationships.

Conclusion

The results of this research have been analyzed, and the following conclusions have been drawn. Related with the first research question, the characteristics we found in women who are recognized in the awards are a proactive attitude, leadership, high motivation, commitment to themselves and their environment, creativity and innovation, and networks of contacts and collaboration. The factors that inspire women to pursue STEM careers mainly include an interest in STEM areas from an early age, a role model in the family or close circle, and knowledge of the opportunities that the chosen career may offer. This leads to a stronger focus on identifying female role models, considering the recommendations given to us so that they are achievable and inspiring role models. Finally, strategies that can be developed to promote the development of more successful women who serve as role models for our young women and girls include encouraging the creation of communities or support networks and the development of skills such as resilience and conflict management, as well as innovation and creativity.

The impact of female role models has been proven, ensuring certain characteristics and carrying out activities at different stages of a woman's development from childhood to youth, and even in her early professional life. This may lead to future studies on the characteristics of female role models in STEM fields to facilitate women's growth in their professional lives after graduation. As girls, young women, and adult women grow, we grow our families, organizations, and societies for a more just, inclusive, and sustainable world.

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