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Women's participation in STEM from 1900s to 2000s

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ABSTRACT

This research paper examines the historical trajectory of women's participation in STEM fields, focusing on Mathematics and Sciences from the 1900s to the 2000s. It analyzes data across various stages of women's educational and professional lives, highlighting prevalent barriers such as biases and stereotypes. Case studies are utilized to illustrate these barriers, along with proposed methods to address them.

Keywords: *Women's Participation, STEM, Gender Inequality, Computer Science*

I. INTRODUCTION

In an era marked by rapid technological advancement, the Information Technology (IT) industry has experienced profound evolution. Despite the increasing importance of programmers and computer scientists, the representation of women in this field has regrettably declined. Government projections emphasize the promising job prospects for individuals with Computer Science (CS) degrees, prompting initiatives such as the Ontario government's aim to double the CS pipeline. Given the pivotal role of computer technology across diverse sectors, the underrepresentation of women not only signifies a substantial societal gap but also reflects a missed opportunity for innovative contributions. This disparity begins at the foundational level of education and persists throughout various stages of professional development.

II. STATUS OF FEMALES IN STEM

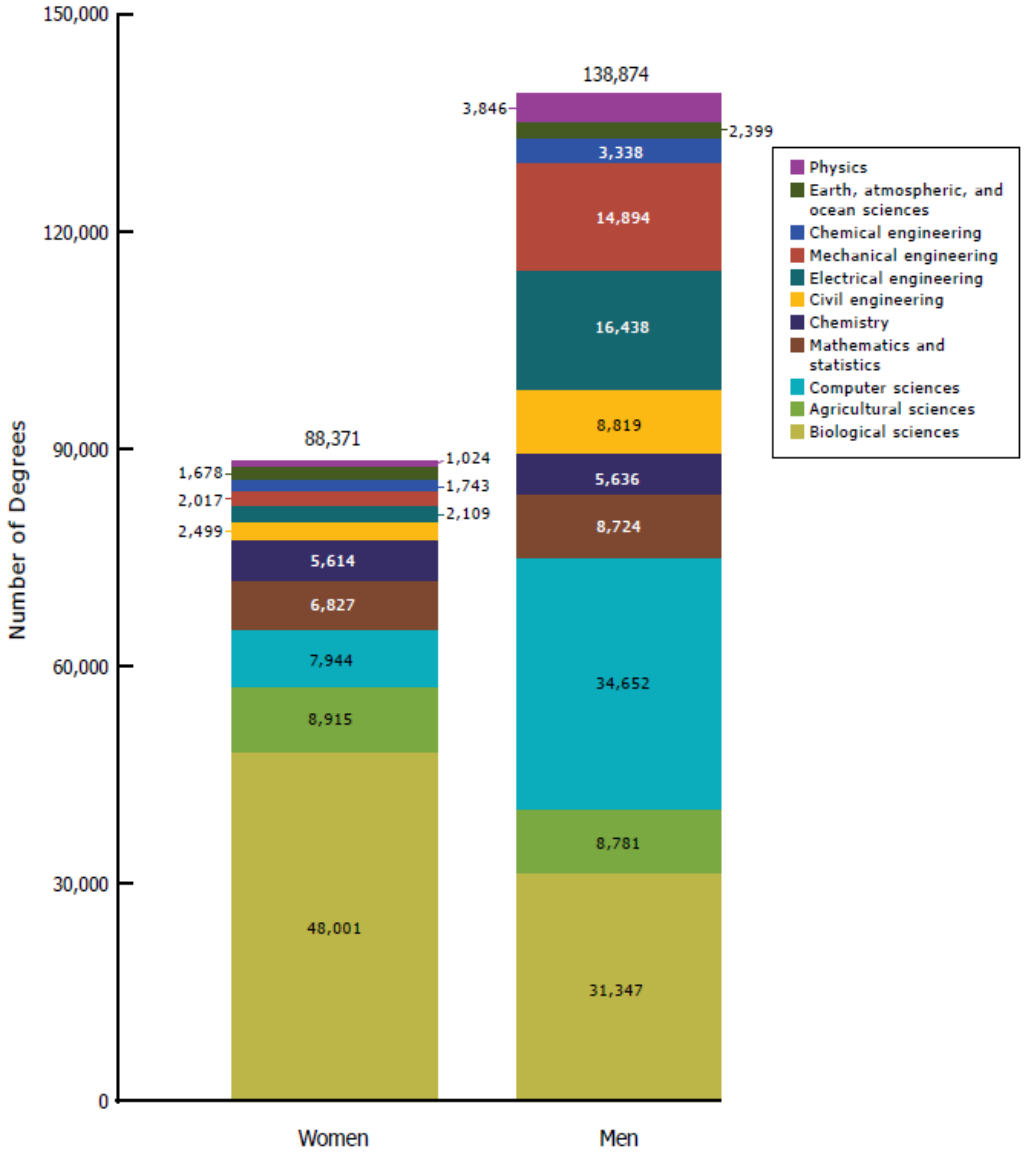
Schooling

Traditionally, boys have outperformed girls in mathematics; however, in recent decades, the gender gap has narrowed considerably. Studies such as the Study of Mathematically Precocious Youth have demonstrated a notable increase in girls' interest and achievement in mathematics. Over the years, the ratio of boys to girls in this select group has declined significantly, indicating a positive shift in gender dynamics within the field (Benbow & Stanley, 1983; Brody & Mills, 2005; Halpern, Benbow, et al., 2007).

University

While females constitute a significant portion of university student populations, they are less likely to pursue majors in STEM compared to their male counterparts. Despite the presence of academically proficient women in these fields, many opt out prematurely. Although the attrition rate among males is not drastically different, the loss of women exacerbates the existing gender disparity within STEM disciplines.

Figure 7. Bachelor's Degrees Earned in Selected Science and Engineering Fields, by Gender, 2007



Source: National Science Foundation, Division of Science Resources Statistics, 2009, *Women, minorities, and persons with disabilities in science and engineering: 2009* (NSF 09-305) (Arlington, VA), Tables C-4 and C-5.

(Hill, Corbett et al.,10)

Reframing the information with a touch of expertise:

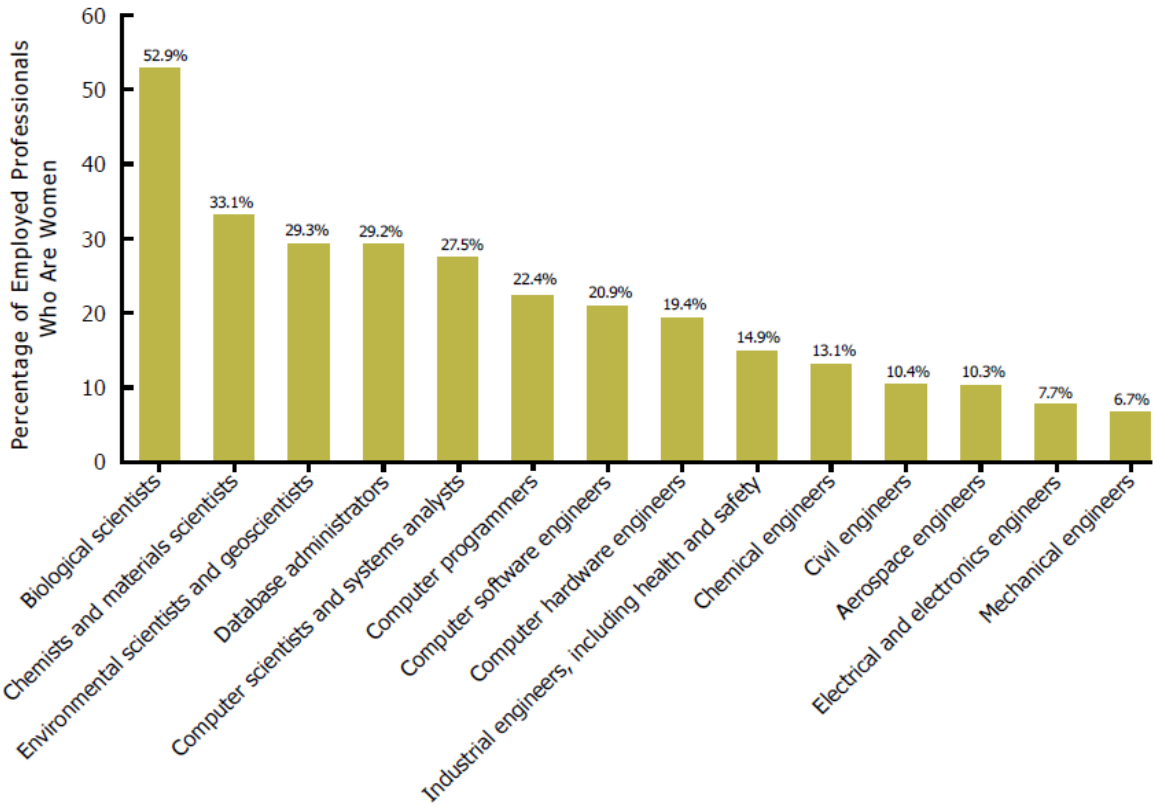
In the realm of professional landscapes, while the presence of women is progressively expanding across various sectors, a notable exception persists within the domain of computer science.

● Workforce Dynamics:

Within fields such as the biological sciences, women have historically held a significant presence, with statistics indicating a noteworthy trajectory. As early as 1960, women comprised approximately 27 percent of biologists, a figure that surged to 44 percent by the turn of the millennium in 2000. In stark contrast, the representation of women in engineering fields presents a contrasting narrative. Merely constituting 1 percent of engineers in 1960, women's presence within engineering circles only marginally increased to about 11 percent by 2000 (Hill, Corbett et al, 14). While this progression is commendable, it underscores

the persistent underrepresentation of women in engineering disciplines.

Figure 10. Women in Selected STEM Occupations, 2008



Note: Occupations are self-reported.
Source: U.S. Department of Labor, Bureau of Labor Statistics, 2009, *Women in the labor force: A databook* (Report 1018) (Washington, DC), Table 11.

(Hill, Corbett et al.,14)

Men distinctly dominate the number of doctorate holders in stem fields.

In the academic workforce, women's representation varies by discipline as well as tenure status. Forty percent of the full-time faculty in degree-granting colleges and universities in the United States in 2005 were women; however, women's representation in STEM disciplines was significantly lower. Women made up less than one-quarter of the faculty in computer and information sciences (22 percent), math (19 percent), the physical sciences (18 percent), and engineering (12 percent). In the life sciences, an area in which many people assume that women have achieved parity, women made up only one-third (34 percent) of the faculty. In all cases women were better represented in lower faculty ranks than in higher ranks among STEM faculty in four-year colleges and universities (Di Fabio et al., 2008).(Hill, Corbett et al, 15)

Barriers to Entry:

Passing a math test, enrolling for a physics course, starting a coding club, completing an engineering degree, working in an esteemed firm, getting promotions, winning awards, balancing family life; at every step of the way, females encounter various barriers when linking themselves with any of the STEM associated activities. Some of these barriers are:

Beliefs about Intelligence

Intelligence is defined as "the ability to acquire and apply knowledge and skills "(Oxford Language sources) . This ability with no doubt has been predominantly attributed to men throughout the journey of mankind. It is also regarded as something present by birth. So automatically when someone fails to 'acquire' something (concepts taught in a certain physics lecture, for example), or successfully 'apply' that something (passing the follow up physics test), we automatically form judgements about their level of intellect. This suggests a concept of fixed mindset (viewing intelligence as an inborn, uncontrollable trait). Individuals with a fixed mindset are susceptible to a loss of confidence when they encounter challenges, because they believe that if they are truly "smart," things will come easily to them.

If a task turns out to be challenging and requires additional efforts, they are likely to back out. A fixed mindset takes away the opportunity of creative thinking and delving deep into challenging tasks.

A study was recently conducted by Carol Dweck, a social and developmental psychologist at Stanford and her colleagues to see if motivation of seventh graders towards their grades would be affected if they were told that intelligence is malleable.This study included 91 relatively low-achieving seventh graders from a New York City public school. The students were split into two groups

for a 25-minute period once each week for eight weeks. During this time, one-half of the students were taught that intelligence is malleable, and one-half were taught study skills. The students in the intervention group were taught that learning changes the brain and they should think of the brain as a muscle that becomes stronger, developing new connections and strengthening existing ones as someone learns. As a result, the person becomes smarter. The lessons also stressed that mistakes made in the course of learning are necessary and help students learn. The lessons concluded with the message that students are in charge of this process and that being smart is a choice. (Hill, Corbett et al 31,32)

The results were impressive; students who were told intelligence can be attained saw their grades' decline reversed whereas the opposite happened in the control group where their grades fell down.
This suggests that the idea of a 'Growth Mindset' can actually benefit girls for the better.

However in the presence of damaging stereotypes, attaining this growth mindset becomes very challenging. Alongside the widespread traditional perceptions of intelligence, there is a lack of awareness regarding this transition which can occur from a fixed mindset to that of a growing one. Most girls from a very early age do not have inspiring figures in their lives to motivate them towards such ''intellectually competitive" subjects and hence this becomes a major reason why girls lose interest in STEM subjects and inevitably lose confidence.

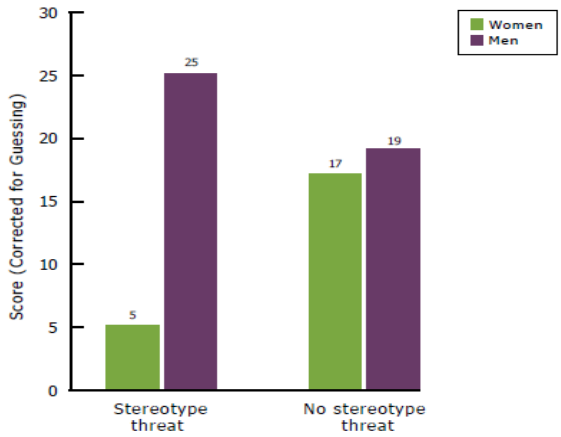
What can we do?

- ➔ Intellect can be attained
  Teach children that smartness and intelligence is not something inherent. It can be acquired through hard work and curiosity. Intellectual skills can be developed through specialized courses. Passion, dedication and discipline shape a genius capable of bringing a revolution, not simple inborn talent.
- ➔ Specialized programs for the 'extra' talented and gifted students should send out the message that they value an individual willing to learn rather than one who knows it all.
- ➔ Encourage the struggle
  Rather than setting clear standards for someone to be smart, parents and teachers should value the efforts and mistakes. Teach children the values that are at the heart of scientific and mathematical contributions: love of challenge, love of hard work, and the ability to embrace and learn from our inevitable mistakes (Hill, Corbett et al, 35)

Stereotypes

Even though impressive progress in female participation all over the globe has been made, there still remains a vast number of negative stereotypes regarding girls' abilities and women's role in work. Such stereotypes, the portrayal of a scientist being a man in children's television shows for example, are prominent everywhere and embedded in our minds since the start.
A phenomenon called "stereotype threat" is defined as the threat of being viewed through the lens of a negative stereotype or the fear of doing something that would confirm that stereotype by Joshua Aronson (social psychologist) and his colleagues Claude Steele and Steven Spencer.
In a social experiment conducted by Spencer et al. (1999) 30 female and 24 male first year psychology students from University of Michigan were recruited. All of them had a strong math background with similar mathematical abilities based on their grades and test scores. They were divided into two groups: The threat condition, where they were told men performed better than women and the non threat condition where they were told there were no gender differences in performance. They were asked to give a computerized math test.
The results of the implied negative stereotype on the students showed significantly in their test results which are as follows:

Figure 15. Performance on a Challenging Math Test, by Stereotype Threat Condition and Gender



Source: Spencer et al., 1999, "Stereotype threat and women's math performance," *Journal of Experimental Social Psychology, 35*(1), p. 13.

(Hill, Corbett et al. 40)
Clearly comprehensible from the graph, females when told that the test was outperformed by men negatively impacted their performance.
We come across such stereotypes, subtly or explicitly, on a very frequent basis. Asking about one's gender before registering for an exam might count as an instance too.
In many cases, long and repeated exposure to such threats causes the individual to eventually alienate the subject of interest. One common defense mechanism used by many female students is called 'disidentification', meaning they avoid the subject completely and regard it as something not to be associated with.

What can be done?

- ➔ Expose girls to female role models in STEM.
- ➔ Spread awareness about the stereotype threat.
- ➔ Encourage students to have a growth mindset.
- ➔ Teachers can mitigate reliance on stereotypes by making the performance standards clear.

★ Spatial skills

Spatial ability or visuo-spatial ability is the capacity to understand, reason, and remember the visual and spatial relations among objects or space (wikipedia).

So undeniably, such skills are very important when it comes to STEM subjects. While there has been no clear evidence on men winning the cognitive lottery when it comes to spatial skills, women have been evidently struggling in this area.
For instance, in 1993, when Sheryl Sorby, a professor of mechanical engineering at Michigan Technological University and Beverly Baartmans, a math educator at Michigan Tech administered the Purdue Spatial Visualization Test: Rotations (PSVT:R) along with a background questionnaire to 535 first-year Michigan Tech engineering students during orientation, the results showed a dependency of two major factors.

First was the past experience with design-related courses as well as a keen interest in construction toys, for example legos, as a child. Second one was simply being a man. The result showed women were more than three times as likely to fail as their counterparts with 39% of females failing relative to only 12% of males.

The National Academy of Sciences states that "spatial thinking is at the heart of many great discoveries in science, that it underpins many of the activities of the modern workforce, and that it pervades the everyday activities of modern life" (National Research Council, Committee on Support for Thinking Spatially, 2006, p.1). Even though there has been no clear evidence whether spatial skills are a necessity when it comes to succeeding in any of the STEM fields, a majority of females facing problems in the same are at a huge disadvantage. This disadvantage is apparent in the number of girls attempting international mathematics competitions, which tend to be heavily male dominated. There is also a huge gender gap in the results of the logical and reasoning sections of many exams. At a higher level, this disadvantage persists in the retention rate of female engineering students which remains low.

What can be done?

- ➔ These spatial skills can be easily taught through a course.
- ➔ Explain to young learners that such skills are not innate and can be perfected through practice.
- ➔ Encourage children to play with construction toys.
- ➔ Make use of hand-made models whenever possible to enhance children's visualization ability.

Implicit Bias

Most people in today's generation have adapted to the modern beliefs on gender equality. They agree that women are just as good as men in math and science, if not better. However, certain unconscious beliefs (implicit bias) wired in our brains from our pasts can say otherwise. These unconscious beliefs might even be more powerful than the explicit comments merely because we are not aware of it ourselves.

Even if overt gender biasing may be waning, such underlying negative stereotypes still hold the responsibility for the gender gap in many places.

The Implicit Association Test (IAT) developed by Mahzarin Banaji, professor of social ethics at Harvard University, Anthony Greenwald, professor of psychology at the University of Washington, and Brian Nosek, professor of psychology at the University of Virginia, helps give key insights into the extent to which implicit biases are wired in our minds. In the test, the participants have to go through two rounds, categorizing sixteen randomly ordered words, one half consisting of gender associated words (for example: son, boy, mother, wife etc.) and the other half containing "science" and "arts" associated words (for example: physics, dynamics, history, english), in each round.

More than a half million people all over the globe have taken this test since 1998 and the results remain consistent with more than 70% of the test-takers readily associating the 'male' related words with science and 'female' related words with arts. This finding also challenges the notion of men and women being treated as equals when identifying themselves with mathematics and science.
Another experiment conducted by Banaji and her colleagues included a sample of Yale undergraduates to measure the strength of implicit attitudes towards math and science.

The results were quite disappointing where both male and female participants had negative evaluations of math and science relative to arts but the females showed a greater negative implicit attitude.

As Banaji says,
"The first effect is that our culture does not support the idea that studying math and science is a cool thing to do. That alone is something to worry about. However, girls and boys seem to know that if one or the other group is better at it, it's boys. When we look at how quickly men associate themselves with math, it's a lot easier than for women. Often we hear from girls that it's not that they can't do math; it's that they don't identify with it. And that's critical—when you don't see yourself connected to a particular path, whether it is math-science or motherhood, the likelihood is that you will steer clear of it.

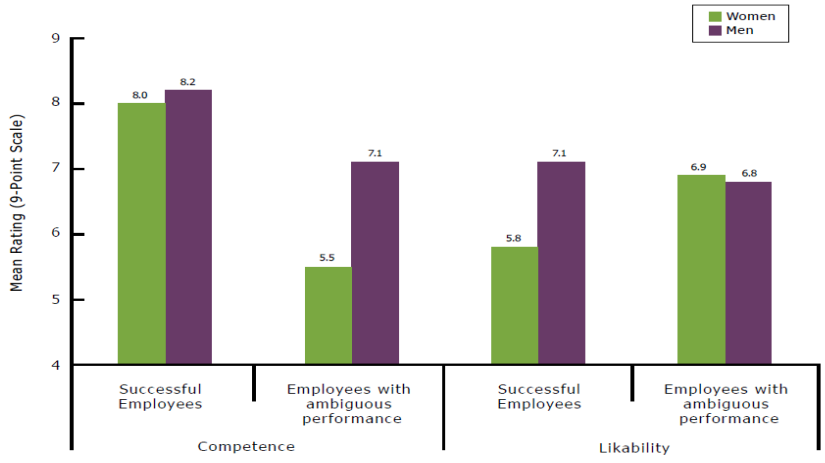
The degree to which the idea that girls aren't good at science is in the air we breathe, the more likely it is to show up in patterns of attitudes, beliefs, and performance. If you look around you and only a fraction of those doing science come from group A, what are members of group A and B to think? It doesn't take too many neurons to figure out that perhaps group A isn't so good at science." (Banaji as quoted in Hill, Corbett et al. 78)

What can be done?

- ➔ Raise awareness regarding implicit bias
- ➔ Teachers should reflect upon their teaching style and encourage gender equality in classrooms.
- ➔ Parents can resolve to be more aware of the messages they send out to their children.

Workplace Bias
In the professional realm, competence and likability stand as fundamental pillars for advancement within the workplace. Madeline Heilman, an esteemed organizational psychologist at New York University, posits that individuals often perceive women in traditionally "masculine" fields as either competent or likable, but seldom both simultaneously. The delicate equilibrium between competency and likability poses a greater challenge for women, influenced by entrenched societal perceptions of the 'ideal' woman, which pervade the collective consciousness to varying degrees of explicitness.
Heilman and her colleagues followed a set of experiments in the same regard. In the first experiment, 48 undergraduates were recruited from an introductory psychology course in which a large proportion reported having significant work experience. They were made to rate the competence and likeability of the three employees (a man, a woman and a dummy man) in a 'male'-type job: Assistant Vice President (AVP). Dummy man's ratings were not analyzed since the only reason to include the dummy man in the first place was to make it not obvious to the participants that this was an experiment to judge the gender differences. The participants were split into half, one group being told that performances of men and women were unclear. The other group was told that men and women were clearly successful.
The results were summed up in the following graph:

Figure 21. Competence and Likability for Women and Men in "Male" Professions



Source: Heilman et al., 2004, "Penalties for success: Reaction to women who succeed in male gender-typed tasks," *Journal of Applied Psychology, 89*(3), p. 420, Table 2.

(Hill, Corbett et al. 84)

In terms of likeability, when success was made known, participants overwhelmingly chose the man as more likable and the woman was somewhat judged interpersonally as hostile and hence rated less likable comparatively.
In terms of competence, when performances were unclear, the participants assumingly chose the man as more competent even though there was no distinction between the man and woman's respective performances.
When a woman has shown herself irrefutably to be competent in a male-type field,
She then pays the price of social rejection in the form of being disliked. Being disliked appears to have clear consequences for evaluation and recommendations about reward allocation, including salary levels. (Hill, Corbett et al, 86) This makes one of the many reasons why women in STEM fields quit their jobs.

What can be done?

- ➔ Imposing transparency
  The process of voting and evaluation criteria should be made clearly known to all employees. When the criteria for evaluation is vague or no objective measures of performance exist, an individual's performance is likely to be ambiguous, and when performance is ambiguous, people view women as less competent than men in STEM fields. (Hill corbett et al 87)
- ➔ Raise awareness about bias against women in STEM fields
  Awareness is the primary fundamental required to bring a change in our society. Together as a community, women can counteract the social disapproval.

III. CONCLUSION

Status of the female population, not only in STEM fields but in every aspect such as quality of life, dignity, human rights, social repute etc. has seen a great improvement throughout history. From being married off as a teenager to getting a doctorate degree, from being prohibited from entering the parliament to building the constitution, women have achieved and proven their proficiency in various disciplines. But still there remains a lot of work yet to be done. Women are still being treated unequally. Having examined all of these sources, it has become evident that one can reasonably conclude that being a prominent field in STEM, Computer Science is perceived to be more agentic than communal which is why it is presumed to be a male-intended field. Just as so, intellect and acuity have always been associated contradictorily with women. Such "practical" skills are believed to be gifted to men by birth. Throughout history, women have been associated with emotions and benign behavior and even though so much advancement has taken place and so much more is yet to take place, they are still somehow expected to have similar attributes. Stereotypes and biases alongside hostile environments and a toxic rat race don't make it any easier on women to enter such male dominated fields. Even after having worked in a STEM field or completed a graduate course in the same, there still remains a huge issue of women switching their careers. Females are prone to sexual assault in many conditions. Long working hours or spontaneous attendance can become very challenging and exhausting for women with children. Throughout the educational journey, a majority of girls don't have a role model to look forward to for inspiration towards entering STEM fields. Discrimination, stereotypical comments, lack of communal effort and ignorance might seem unimportant when talking about the global representation of females but they play a huge role in the foundation of women in tech.

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