

From Gender-STEM Stereotypes to Structural Inequality

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Abstract. This review examines how explicit and implicit gender stereotypes contribute to structural inequality for women in science, technology, engineering, and mathematics (STEM). Drawing on psychological research across educational and workplace settings, the article focuses on the gender-STEM stereotype that men are naturally good at or interested in STEM, also called "STEM = men" stereotype. Research suggests that gender–brilliance stereotype is built as early as ages six or seven, depending on the cultural environment, and can decrease girls' interests, self-efficacy, and learning behaviors about STEM. This gender-STEM stereotype continues into higher education and employment, creating a systematical inequality in resources/opportunities, hiring, salary, evaluation of competence. Teachers and employers' implicit bias can produce disparity in expectations, evaluations, and actual treatment in STEM areas. Among coworkers, the implicit bias can generate social exclusion of women from informal social networks, even acknowledging their competence. This social exclusion limits women's access to social support, collaboration, valuable information, and opportunities. In conclusion, these disadvantages accumulate across educational and professional stages. This culturally shared stereotype is validated and produces structural inequality. To reduce women's underrepresentation in STEM, interventions on the early educational stage prevention, institutions level to standardize evaluation procedures and resource allocation, and promotion to create an equal inclusive environment is needed.

Keywords: Gender stereotypes, STEM, bias, structural inequality, social exclusion

1. Introduction

Although women's participation in Science, Technology, Engineering, and Mathematics Education (STEM) areas increased, gender inequality still exists in education and workplace opportunities. These disparities are often explained as causes of gender differences in interests or abilities. However, psychological research suggests that gender stereotypes and social environments play an important role in shaping women's choices and achievements: children's interests and self-efficacy, teachers' evaluation and the amount of support, and distributions of job opportunities and other resources.

One particularly influential stereotype is the association between STEM and men: the "STEM = men" stereotype. It suggests that men are born with higher scientific ability, "brilliance" that allows men to master in STEM, and more interests about STEM areas than women. This stereotype can be

expressed explicitly through consciously endorsed beliefs, or implicitly impact one's choice and behavior through the automatic associations. Because implicit stereotypes may affect judgments without deliberate awareness, inequality can exist even when individuals and institutions explicitly support gender equality. Even minor differences in attitudes, evaluations, supports, and resource accesses may accumulate across women's education and careers and lead to great disparity in outcomes.

Understanding the impact of explicit and implicit bias on gender inequality in STEM allows a better achievement of equality systematically. The underrepresentation of women in STEM has cultural and structural contributors rather than just individual discriminations or personal choices. It cannot be addressed simply by asking women to become more confident or interested in STEM. The environments that construct ability, opportunity, and belonging must also be taken into account.

By reviewing and connecting relevant psychological research, this article examines how explicit and implicit gender stereotypes affect individuals and institutions and, over time, reproduce structural inequality for women in STEM.

2. Conceptual framework

2.1. Definition of stereotypes

Stereotypes are generalized beliefs or associations about the characteristics or expectations of a category. Although stereotypes can be used as cognitive shortcuts to build understanding and gather information of the category quickly, they often ignore individual differences and lead to biased judgments. Based on individuals' conscious awareness and the ability to report these beliefs, stereotypes are commonly divided into explicit and implicit. Explicit stereotypes are consciously accessible beliefs that individuals can recognize and express through language, while implicit stereotypes are unconscious beliefs or automatic associations that one may behave based on without deliberative reflection. However, the automatic associations are not equivalent to a person's endorsements or intentions to behave discriminately. Researchers commonly assess explicit stereotypes through self-report methods, such as questionnaires, interviews, and rating scales. Implicit stereotypes are often accessed through Implicit Association Test (IAT) and eye tracker, measuring the reaction time as the indicator of strength of automatic associations. One major limitation of self-report methods is that participants may conceal their actual beliefs concerning social desirability and criticism, even when the data are collected anonymously.

2.2. Gender-STEM stereotypes: "STEM = men"

This research focused on the gender-STEM stereotype that "STEM = men", which refers to the natural association of the STEM field and scientific ability more strongly with men than with women. This stereotype can be presented as believing that men are naturally better or fitted in the STEM domain than women, or have higher intellectual ability/interests in STEM. These associations may be expressed explicitly through conscious perspectives or implicitly exist in automatic cognitive associations. The "STEM = men" stereotype shapes expectations about the characteristics and roles considered appropriate for both women and men, discouraging girls and women from perceiving themselves as capable of or suitable for STEM while also pressuring boys and men to conform to stereotypical masculine ideals of high interests or competence in STEM. In both genders, this gender-STEM stereotype can hinder self-exploration and the establishment of self-efficacy. The formation and influence of it will be discussed detailedly in the following sections.

2.3. Gender inequality

Gender inequality is defined as the structural and systemic disadvantages that cause inequality between specifically two gender - women and men. This gender inequality usually leads to unequal opportunities and outcomes in education and workplaces, which appear in many forms, including disparities in wage, occupation or education opportunities, discriminate perspectives or treatments in social environments, etc. In addition, the systematic discrimination and exclusion in both workplace/academic institutions and in-official socialization reinforces the biased social norms that disvalues women's interests and abilities in STEM, influencing their professional recognition and success. This article examines how gender stereotypes develop and operate through educational and organizational decision-making and social networks, and considers possible interventions for reducing the inequality.

3. From gender-STEM stereotypes to structural inequality

3.1. Cultural origins of gender-STEM stereotypes (cross-cultural similarity)

Nowadays society perceives high level intellectual ability, which is also believed as an inborn trait that almost cannot be influenced by nurture, as one crucial requirement for achieving high performance in the STEM domain. This "brilliance = males" stereotype often discourages females from engaging, learning, and even attempting to learn, because they are told that they lack the "talent" and that they can do nothing to change it. The gender stereotype suppresses women's interest, limits their choices on college major and occupation, and creates a negative feedback loop for women who have the interests in STEM.

Believing young children's career aspirations are shaped by this gender stereotype, Bian et al. examined the existence and the developmental trajectory of it, using two samples: the first sample contained 96 children from age 5 to 7, and the second sample used to repeat the study contained 144 children from age 5 to 7. The research asked children to do several tasks associating genders with smartness or careers and averaged them into an "own-gender brilliance score" for examination. The result showed that at age 5, children did not show a significant difference in perception of gender brilliance: both boys and girls perceive their own gender group as the smarter one [1]. However, girls at age 6 and 7 showed a decreased tendency of associating brilliance with their own gender, while the own-gender brilliance score increased in boys at age 6 and 7 [1]. This change of perception also showed no significant influence by the perception of school performances: girls tended to associate girls with having the top grades; older girls were more likely to make this association [1]. Thus, it is suggested that the gender stereotype that "brilliance = males" and thus males belong in STEM is learnt at a young age, around age 6. Moreover, Bian et al. did a test about the gender-brilliance belief's effect on children's interests and found that girls at age 6 and 7 showed less interest in the game "for smart kids" than boys [1]. This difference of interest also presented a change at age 6, matching with the belief of gender brilliance.

While the research by Bian et al. mainly focused on the middle-class White children in America, Kim et al. examined this gender-brilliance stereotype and its association with children's motivation among Korean children from age 5 to 7 [1, 2]. Kim et al. took a similar research method as Bian et al.'s study. The result showed Korean children established this "brilliance = men" stereotype considering both Asian and White children around age 7, which is slightly later than the formation in the western culture [2]. The similarity of the early formation shows the generalization of gender-STEM stereotype development across different cultural contexts. The influence of gender-brilliance

stereotype on interests about "smart game" and "try-hard game" showed an intriguing pattern: the Korean girls' interest about the "smart game" dropped from a positive level similar to the boys at age 6 to a quite negative level at age 7. This decrease of interest toward the "smart game" after gaining the stereotype is much larger for Korean children than American children [1, 2]. In addition, Korean children of both genders decreased their interests in the "try-hard game" at age 7 [2].

To understand the disparity, the social environmental factors, such as various education systems, cultural beliefs, and parenting styles, should be taken into account. A possible explanation may be the cultural belief about "hard-working". In the Korean cultural context discussed here, trying hard may sometimes be interpreted as a sign of lacking natural brilliance. In addition, the Asian education system and society may disparage making mistakes or having questions, while western culture may encourage learning through trial and error. Different cultural contexts may affect the extent of acceptance of the gender-brilliance stereotype and specifically how it can influence people.

3.2. Biased self-perception and educational viewpoint leading to educational inequality

The previous research indicates that the "STEM = men" stereotype was established at age 6 or 7, just around the age children entering primary school. It suggests that the education system may also play a crucial role in forming this stereotype.

There is adequate research around teachers' gender bias and educational and relevant influences on women students in school environments. The research by Master et al. suggested an extensive stereotype exposure from age 6 to adolescents across multiple race and ethnic groups (Black, Asian, Latinx, and White) [3]. The gender stereotype studied by Master et al. focused particularly on the belief that males have higher interests in computer science and engineering than females [3]. This biased perception damaged the sense of belonging and the actual interests among female students. In addition, the extent of this negative influence increases with the extent of endorsement that one girl personally holds about this stereotype. Master et al. compared the acknowledgement extent of the stereotype that "Men are more interested/capable in computer science and engineering areas" and found people believed the "interest" one more [3]. As a result, when an activity or learning is labelled as "only men's interest", it discourages girls from engaging in it, due to social expectations, their own biased self-perception, and lacking a sense of group belonging [3].

In addition, teachers' stereotypes affect students' performance and self-perception significantly. The study by Carlana, M. used Gender-Science Implicit Association Test, suggesting that increasing teachers' "STEM = men" bias extent causes both female students' performance and interests in this subject to decrease [4]. Teachers' implicit biases may influence their education quality and attitude, which then may impair female students' self-efficacy, leaving them less interested and confident to learn or work in the STEM domain.

The gender-STEM stereotype exists in the entire development process of children and continues from primary school to higher educational institutions, such as college and university, leading to discrimination and unequal treatments. Kube et al. conducted a group concept mapping (GCM) study, which included women university professors and staff in STEM areas from Germany, suggesting the existence of sexism, structural power inequality, etc [5]. The gender-STEM stereotype is only not an issue of personal belief, but can reproduce and reinforce the structural inequality in education institutions, hindering women from success in STEM.

3.3. Workplace inequality in STEM for women

Gender–STEM stereotypes continue to shape workplace practices and professional research environments in STEM fields. In such circumstances, gender inequality in STEM is not produced only by apparently discriminate attitudes or behaviors that explicitly exclude women from succeeding, but can also permeate through organizational decisions and interpersonal interactions which are produced by managers and colleagues with inside biases. Under the influence of gender stereotypes, disparities in hiring evaluations, salary offers, work expectations, and mentoring opportunities can jointly create disadvantages for women across multiple stages of STEM career development.

One important mechanism is the gendered evaluation of perceived competence: identical qualifications may be interpreted differently depending on whether they are attached to a male or female applicant. The classic research by Moss-Racusin et al. examined it with a randomized experiment with a sample of 127 faculty members from biology, chemistry, and physics departments at research-intensive universities in the United States [6]. Each participant evaluated identical application materials for a laboratory-manager position; the only manipulated variable was whether the applicant was given the male name "John" or the female name "Jennifer." The materials with different names were randomly assigned. Moss-Racusin et al. found that there was a discrimination by gender: "John", the male applicant was rated as more competent and hireable, offered a higher starting salary, and offered more mentoring [6]. In addition, male and female faculty members displayed a similar extent of bias [6]. The finding suggests that gender–STEM stereotypes may operate as shared cultural assumptions rather than as prejudices held only by male evaluators. Taking the cultural development and formation process of the stereotype into account, this result suggests that culturally endorsed and shared stereotypes can be internalized and exhibited by members of different social groups. Moreover, evaluators may not consciously endorse the belief that women are inferior in STEM but still can be influenced by implicit automatic association. The evaluators may sincerely believe that they are applying objective academic standards while nevertheless interpreting the same evidence differently depending on the applicant's gender.

The application materials were identical and only the perceived gender varied, suggesting that the systematic evaluation gap can reasonably be attributed to gendered perception rather than to differences in qualifications. The participants perceived the abilities and achievements as less valuable and competent when they belong to females than male. Male applicants may receive a consistent and substantial advantage in STEM workplaces, including higher hireability ratings, stronger salary offers, and greater access to mentoring opportunities that can generate long-term career benefits. When female applicants are perceived as less competent and receive a lower salary that is offered at the beginning of their careers, these initial disadvantages may accumulate through reduced bargaining power, slower salary growth and promotion, and weaker access to future opportunities. Meanwhile, limited mentoring can restrict access to professional knowledge, research opportunities, recommendations, and future advancement.

The participants rated applicants with the female name with lower competence scores, suggesting perceived competence helped explain differences in hiring, salary, and mentoring decisions. This pattern illustrates how stereotypes can be presented in organizational decision-making. Without explicitly stating that women should be paid less, decision-makers may justify lower salaries or fewer mentoring opportunities by framing them as responses to lower perceived competence.

Friedmann and Efrat-Treister showed that bias can occur in the criteria that power-holders use to make decisions [7]. 213 male and female STEM managers from America and the United Kingdom

were asked to evaluate male and female candidates for STEM managerial positions. The researchers focused on two attributes: problem-solving ability and ability to work long hours. Problem-solving ability is directly related to performance in STEM work, while the ability to work long hours reflects the "ideal worker" expectation that they should be continuously available and place the work above other responsibilities in life, which concerns gender roles. The "long-hours" standard can disadvantage employees with caregiving responsibilities, especially women who are more often expected to provide family and household care, because it converts socially assigned domestic responsibilities into workplace disadvantages.

Friedmann and Efrat-Treister found that, when evaluating a female candidate, male managers considered more heavily on her perceived ability to work long hours [7]. In contrast, female managers valued the problem-solving ability more. This criteria disparity was not found when evaluating male candidates. In this research, men managers did not perceive women as less competent but made decisions depended more on an organizational requirement that women are stereotypically considered less available outside the workplace.

In conclusion, the implicit gender-STEM bias affects the power-holders and decision-makers, consequently leading to an systematically unequal treatment in STEM organizations.

3.4. Social exclusion in informal social networks and unequal social resources

Formal employment decisions constitute only one part of workplace inequality, career development also depends on informal relationships that provide collaboration, emotional support, information, and access to opportunities.

The research by Emily N.Cyr, et al. explored the cause of social exclusion in STEM workplaces to women – a "chilly climate", hypothesizing gender stereotypes play a role in it. The researchers tested both men's gender stereotypes and negative workplace outcomes for women [8]. They used Brief Implicit Association Test (BIAT), anonymous surveys, analysing the cross-gender social ties and implicit gender stereotypes that "STEM = Men". The result showed that the "STEM = men" stereotype in men was significantly stronger than women, and men with stronger implicit stereotypes reported socially including fewer women in the workplace. The researchers distinguished social relationships from respect for colleagues' work, showing that a male colleague might recognize a woman's professional competence while still being less likely to include her in informal networks. Women also received fewer incoming cross-gender social ties from male teammates than men received from female teammates. In addition, women, who received fewer social ties from men, received more social exclusion associated with more negative workplace outcomes (lower workplace engagement, self-efficacy, organizational support, social fit & higher social identity threat).

For women, having fewer social connections with men may reduce access to support and information, which in turn can weaken workplace engagement, perceived organizational support, social fit, professional self-efficacy, and sense of belonging. The weaker social inclusion is associated with a lower sense of fit for women [8]. The informal exclusion may convey that the person is in a peripheral position of the workplace, even if obtaining the formal position. Repeated experiences of being overlooked may weaken women's sense of belonging and confidence in their professional abilities. Women may experience mental health issues caused by social exclusion and spend a lot more time and effort in collaboration or self-proving, leading to less favorable workplace results.

In addition, information and opportunities can be circulated through informal networks, fewer informal relationships may affect women's access to workplace resources, including advice,

feedback, information about opportunities, and collaboration. In male-dominated organizations, men may occupy a large proportion of senior, influential, or central positions, holding the resources, crucial information, and power. Consequently, exclusion from relationships with male colleagues can be especially costly because women cannot necessarily obtain equivalent access to resources exclusively through same-gender relationships. Under these conditions, unequal social networks can reinforce existing differences in organizational power.

Because social connection is often treated as a private preference, the discrimination and disadvantages can be difficult to identify. However, informal social exclusions can result in an unequal distribution of social resources even when formal policies guarantee equal access to employment.

Repeated exclusion from invitations, conversations, and collaborations can gradually contribute to structural inequality in resource distribution and reinforce unequal gender-power relations within STEM organizations.

4. Discussion and Suggestion

Gender inequality in STEM is neither produced by a single belief or decision, nor by individuals' prejudice. Instead, it operates repeatedly and structurally through cultural and social environments. Children may learn the gender-STEM stereotype from their parents and relatives, and build a firm bias during the first year of elementary school. They receive constraining beliefs about their gender and abilities, and might thus change their interests and perception about themselves. For example, a girl can thus think herself as less suitable or should not be interested in STEM, and would not attempt to learn or easily give up after having one bad grade in math. In addition, teachers' biased expectations can affect the amount of support or the attitude they hold to students with different gender but same competence. Same for the professional research evaluations and the workplaces, women's ability and competence are often underestimated or overlooked. They also gain less opportunities and resources in job applications, research fields, and social networks, etc., gradually leading to systematic inequality and disempowerment.

The gender inequality in STEM is deep rooted, with cultural and social structural causes. While the underrepresentation of women in STEM is often explained by women's own flaw: less capable, less interested in, and too sensitive to achieve in STEM. However, Schmader argues that stereotypes can weaken women's self-concept fit, goal fit, and social fit, hindering them from building interests, feeling the sense of belonging, and achieving in STEM [9]. At the workplace level, women may even receive less acknowledgement for scientific contributions in research [10]. Therefore, underrepresentation should not be explained by that women are less interested in or capable of STEM. Their decisions are shaped by an unequal environment that holds gender stereotypical social norms and structurally distributes the opportunities and resources based on gender.

To improve this situation and address the structural inequality in STEM, solutions that focus only on changing individuals or single gender groups' perspectives or behaviors are not enough. First of all, educational interventions should begin before gender-brilliance stereotypes become firmly established, before the age around 6. Teachers and parents should avoid describing scientific ability as a fixed, inborn talent or expressing the "STEM = men" bias. The parents and school should support children to explore all kinds of interests regardless of their gender. Especially to break the "STEM = men" gender stereotype, they can achieve that by providing more examples of women scientists and engineers, and ensuring girls and boys receive comparable encouragement, feedback, and opportunities to participate. Teachers should also examine whether their expectations, classroom interactions, and recommendations are influenced by students' gender.

In addition, addressing from the organizational level, institutions should establish gender-equal evaluation criteria for reviewing applications, use structured hiring standards or choose the employer with less gender bias. Salary, promotion, and mentoring opportunities should be equally allocated based on competence rather than gender, presenting the standard and procedures transparently. The informal exclusion by gender should be warned or even punished. A supervision system for gender inequality should be established, and everyone can have access and report the unequal events to it.

5. Conclusion

The review explores the development and causes of the gender-STEM stereotype and the structural gender inequality, examining the influences from education to workplace environment and discussing through the explicit and implicit bias. The studies found the gender-STEM stereotype can be formed at a young age and affect the girls' interests and self-efficacy towards STEM, which in turn leads to less attempting and learning in STEM. Teachers and the employers' implicit gender-STEM stereotype can also play great roles in women's unfavorable achievements in STEM. Moreover, the disadvantages are not produced only by individuals' discriminations and acts, but operate through the unequal structure about resource allocation, social networks, and less visible but unfair evaluation standards that favor men.

Gender-STEM stereotypes can shape the social norm and public acts that limit the life choices of both genders. Further improvements should be done to create an equal and diverse environment that allows all genders to explore their interests in STEM, access the resources fairly, and be seen by their achievements.

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