What bibliography says about women in STEM fields

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Introduction

"Only 17 women have won a Nobel Prize in physics, chemistry or medicine since Marie Curie in 1903, compared to 572 men. Today, only 28% of all of the world's researchers are women. Such huge disparities, such deep inequality, do not happen by chance.

Too many girls are held back by discrimination, biases, social norms and expectations that influence the quality of education they receive and the subjects they study. Girls' under-representation in science, technology, engineering and mathematics (STEM) education is deep rooted and puts a detrimental brake on progress towards sustainable development. We need to understand the drivers behind this situation in order to reverse these trends …, to improve the interest, engagement and achievement of girls in these fields.

Science, technology and innovation are also key to the Sustainable Development Goals (SDGs): in how we address the impact of climate change, in how we increase food security, improve healthcare, manage limited freshwater resources and protect our biodiversity.

Girls and women are key players in crafting solutions to improve lives and generate inclusive green growth that benefits all. They are the greatest untapped population to become the next generations of STEM professionals – we must invest in their talent…. We need to stimulate interest from the earliest years, to combat stereotypes, to train teachers to encourage girls to pursue STEM careers, to develop curricula that are gender-sensitive, to mentor girls and young women and change mindsets".

Irina Bokova, 2017
UNESCO Director General
Cracking the code: girls' and women's education in science, technology, engineering and mathematics (STEM)
Education 2030

Black sheep effect

According to Subjective Group Theory, people derogate socially undesirable in-group members (fraternities, sororities, etc) relative to out-group members. The former are characterized as deviant and they are considered and accused of giving an inappropriate or bad image of the in-group and jeopardize group's social identity and status. Individuals in a group tend to upgrade likeable/desirable in-group members and deviate from unlikeable/undesirable group members, making them a separate out-group.
As a result, concerning highly qualified members of the in-group, the rest are more likely to evaluate them more favorably than the less qualified. .However, when an in-group member is average or less qualified is likely to be evaluated much lower than out-group members with the same or equivalent qualifications. In the case of women in stem fields, established women is more likely (than established men) to help early career women who display sufficient qualifications, but on the contrary, is less likely (than men) to help early career women who display insufficient qualifications

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Doi: 10.1007/bf01499374

Marques, J.M., Yzerbyt, V.Y., Leyens, J.Ph. (1988). The black sheep effect: Judgmental extremity towards ingroup members as a function of ingroup identification. *European Journal of Social Psychology*, *18*(1), 1–16
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Pinto, I.R., Marques, J. M. & Abrams, D. (2010). Membership status and subjective group dynamics: Who triggers the black sheep effect? *Journal of Personality and Social Psychology, 99*(1), 107–119
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Taylor, T.S., & Hosch, H.M. (2004). An examination of jury verdicts for evidence of a similarity-leniency effect, an out-group punitiveness effect or a black sheep effect. *Law and Human Behavior, 28*(5), 587–598
Doi: 10.1023/b:lahu.0000046436.36228.71

Comparative advantage

Women are considered to have a high or superior performance in language, reading and (generally) linguistic tasks, so even if their performance in mathematics has not a large deviation from man's performance, their preferences and academic engagement and, as a result, their upcoming, future professional and career options and choices are more likely to be towards humanities-related field

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Doi: 10.1073/pnas.1905779116

Marsh, H. W., & Hau, K.T. (2004). Explaining paradoxical relations between academic self-concepts and achievements: Cross-cultural generalizability of the internal/external frame of reference prediction across 26 countries. *Journal of Educational Psychology*, *96*(1), 56–6 7
Doi: 10.1037/0022-0663.96.1.56

Nagy, G., Garrett, J., Trautwein, U., Cortina K.S. (2008). Gendered high school course selection as a precursor of gendered careers: The mediating role of self-concept and intrinsic value. In, H. M. G. Watt, J. S. Eccles (Eds), *Gender and occupational outcomes: Longitudinal Assessments of individual, social, and cultural influences* (pp. 115–143). Washington, DC: American Psychological Association
Doi: 10.1037/11706-004

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Doi: 10.3102/0002831211435229

Discriminations

Women in STEM fields is detected to be more likely to experience discriminations and sidelines in their workplaces due to their gender. This may concern their rewards for the same job and the same qualifications (biased evaluation) or overt and covert barriers to their success and professional evolution or, the worst, may lead to being mocked or insulted because of their gender. Studies indicate that evidences of discriminations against female candidates (and ethnic minorities as well) are spotted when applications for administrative or positions concerning consulting and managing in STEM fields are being processed. But, sometimes, the observed underrepresentation of women in the STEM fields and/or professional ranks is not attributed solely to sexist hiring, promotion, and remuneration

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Doi: 10.1086/495540

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Doi: 10.1037/0033-2909.105.3.409

Stereotypes

Stereotypes in STEM fields concern how someone should look, act and behave in these fields. It many cases the established members of these fields may devalue, overlook, and in such a way, "penalize" individuals (like women) who are equally highly competent. Additionally, this behavior discourages women from engaging or continuing in STEM fields. This sounds quite rational since the stereotypical professional in STEM fields is usually thought to be male (few exceptions, like Medicine, are mentioned) and, according to the Role Congruity Theory of Prejudice, the perceived incongruity between gender and a particular role or occupation can result in negative perceptions and consequent evaluations. The stereotypic consideration is that men is expected to possess and display agentic qualities and characteristics, while women display communal ones, usually negatively related to professional or/and academic career (Social Role Theory).

Even in cases where men encounter discriminations due to their engagement in non-traditional occupations or female occupations, the forms and the consequences are distinctly different. The stereotypes do not seem to deter women to the same degree that these may deter men from pursuing non-traditional professions. Paradoxically, men may even experience certain benefits and enjoy profits in female-dominated occupations. It is described as women hit a "glass ceiling" that prevents them from reaching the top in a male-dominated occupation, while men hit a "glass escalator" that facilitates them to accede and excel in a female-dominated occupation.

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Stereotype threats

Stereotype threats spring from and are supported by the fear that ones' actions will indicate a negative sign or threaten the stereotype of the group in which belongs (in-group stereotypes). Fear creates additional stress, consumes valuable cognitive resources, rises susceptibility and underestimation of abilities during assessment, influences interest and undermines task performance in a general or in a specific academic domain (STEM fields), by lowering them.

It is mentioned that, even individuals who enjoy strong identification with a certain field, are more likely to have their performance in that area hampered by stereotype threats than those who identify less strongly with the area. This means that even highly motivated students from negatively stereotyped groups are likely to be adversely affected by stereotype threats and thus, may end up in disengagement from the stereotyped domain. On the contrary, gender differences in performance disappear if students are treated like there are and mentioned no gender differences in that. This indicates that the learning environment can greatly impact success in a course or even a field.

Nonetheless, stereotype threats has been criticized and the relevant researches' findings are attributed to the publication bias: in case of a possible publication, notification and distribution of the findings of a research, there is a tendency in favor of positive and not of negative results, something which disturbs their balance and validity.

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Flore, P.C., & Wicherts, J.M. (2014). Does stereotype threat influence performance of girls in stereotyped domains? A meta-analysis. *Journal of School Psychology*, *53*(1), 25–44
Doi: 10.1016/j.jsp.2014.10.002

Clustering and leaky pipeline

In the 1980s, Margaret Rossiter focusing on the history of women in American science, noticed that women are more likely to choose, study, teach and do research in the humanities and social sciences than in the STEM fields. This was described as a "clustering" around specific fields known as "territorial segregation" or "occupational segregation". It's about the distribution of workers across and within occupations based upon specific characteristics (gender, race,…), while the value or the prestige of their jobs are not taken into account.

This usually results in a "hierarchical segregation" of women in the lower hierarchical levels of the STEM fields. This could be better described as "leaky pipeline", which drives women dropping out of those fields at all levels of their career. This leakage may be due to, both overt and covert, discriminations or stereotypes concerning the role of women in academic or professional sectors or even within family. That keeps women from rising to the upper ranks regardless their qualifications or achievements. However, data and analyses from contemporary researches show that the state of women in STEM fields is changing. Women seem to enjoy sizable successes and gains in those fields as well as in the corresponding professional ones.

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Doi: 10.1038/523272a

Harassment

Women scientists is more likely to be targeted and harassed by their seniors and superiors in their working place, than their male peers. This harassment varies from inappropriate sexual comments to unwanted sexual conducts and assaults. Women also protest of unsatisfied outcomes when reporting their experiences and complaints. Harassment is reported to impacts negatively their personal safety, self-esteem and professional productivity, even driving women leaving science careers. On the contrary, actively enforced anti-harassment policies in their field work is associated with positive fieldwork experiences where female scientists feel safe, valued and equal.

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Queen Bee Effect

The Queen Bee effect is similar to the Black Sheep effect applying only to women. The phenomenon, first defined by Tavris C, Staines G.L and Jayaratne T.E. in 1973, explains why higher-status women, particularly in male-dominated professions, may actually be far less likely to help other women than their male colleagues might be. These women, satisfying their need for self-preservation, distance themselves from other, subordinate women and treat them more critically or even hinder them from rising up the ranks. As a result, female faculty members at universities may believe more strongly than male ones do, that female students are less competent, committed or satisfied with their work.

A potential negative impact of these beliefs and subsequent attitudes and behavior is that "queen bees" do not perceive their success as evidence of negative stereotypes about women, but rather as a proof that they personally are successful exceptions to the rule, perpetuating this way the negative stereotypes.

On the other hand, recent research strongly questions and contests the existence of the phenomenon because of bias (eliciting of confirming cases or localization of endogeneity issues).

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Lack of Confidence

The lack of confidence, on behalf of female students on their capabilities to the academic subjects consisting the STEM field, noticed at all levels of education, is a factor that supports and feeds the leaking pipeline phenomenon. It is attributed to biased, unqualified, ineffective and non-supportive teachers who create an unbalanced learning environment and deter girls from even engaging with STEM education or pursuing further education on that.

Male students are treated differently than their female peers: they enjoy more and more frequent opportunities while working at school with STEM or even higher expectations are attributed to them. The exact opposite treatment of female students leads to lowering or a loss of their self-esteem in STEM fields, preventing them from entering those fields and pursuing relevant professional or/and academic careers (Imposter Syndrome impacts).

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Lack of Interest

Studies researching men and women interests, show that men have more realistic and investigative interests connected close to STEM fields, while women have stronger artistic and social ones concerning humanities. Women also found to believe that studies in out-of-STEM fields match better with their interests and offer better educational and professional options for them. These perceptions switches women to non-STEM areas, even in cases of women with equal or higher corresponding abilities than their male peers.

According to these studies, the conclusions apply and are even more intensified to more "gender-equal" or egalitarian countries. This seems to be a paradox, named after "the gender-equality paradox". An explanation that has been proposed is that, more stereotypes and gendered expectations are spotted in more gender equal countries, while women in less developed or equal countries are more likely to choose STEM fields, based on the increased need for security and good pay. Others believe that deeply rooted and intrinsic gender differences are less restrained and emerge more easily in gender equal countries.

But these conclusions are challenged and the researching methods are accused of poor accuracy of the variables used, while the findings are accused of lack of validation. Independent researchers were unable to recreate the data reported and the discovered discrepancies were attributed to conceptual and empirical problems of the studies.

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Lack of Mentorship

Empirical data and research findings show that, in the STEM fields, the support and encouragement of a mentor can make a lot of difference in younger women's struggle to overcome the obstacles they encounter. Women indicate that can be decisively guided and helped in their decisions of whether or not to continue pursuing a career or/and which career, by seniors, experienced or established mentors.

However, the supportive presence of a mentor (formal or informal) is not an easy thing to happen. Most of women appreciate the crucial role of a mentor and look for a helpful mentorship from studies to workplace, but they mention a lack in relevant opportunities or resources in their working environment. Additionally, women experience harassment incidents from their male mentors making the whole issue a disappointing one.

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Lack of Role Models

The low representation of women in STEM fields is attributed, among others, to the projected negative school or social role models, concerning female students and adult women, associated with their capabilities, interests and future option to those fields. On the other hand, the introduction of positive role models is proposed as a method for alleviating stereotype threat, as well as for retaining women in STEM fields: presentation and conduct with women and female teachers enjoying successful career and high status in STEM fields, cooperation and team work with other female peers or even interventions and corrections in text books and their accompanying images.

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Lack of Support

Women who work in STEM fields (and generally) are more likely to be at risk of leaving, due to gender discriminations and lack of support: inflexible working conditions, which make their everyday demanding family and social life more difficult, a possible pregnancy and the subsequent maternity, etc. Since women are paid less in their careers, when a classical male-female family cannot afford child care, it is the mother that leaves work and career in order to stay at home with the children. For alleviating the negative consequences, supporting measures must be deployed by states and generous provisions must be offered by employers: gender-friendly or friendly-responsive policy frameworks (children facilities at the workplace, re-entry programs after taking a break to start a family etc.

In order to modify perceptions and to increase women's enrollment in STEM fields, action must be taken against gender gap since the early school years. As the unsupportive culture extends throughout time and hinders women's careers, supportive programs must be developed and closely modified and monitored for extended periods. Apart from state welfare, any kind of relevant organizations, institutions, educational institutions and companies must take action or expand and strengthen the action it has already developed.

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