Women's Representation at Elite Levels in Science, Technology, Engineering and Mathematics in the United States

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Abstract

This paper establish a statistical theory to explain the so-called "underrepresentation" of professional women working at elite levels of achievement in the Science, Technology, Engineering and Mathematic occupations in the United States (hereafter referred to by the acronym STEM.) The popular hypothesis is that the women are underrepresented among the high achievers in the STEM occupations because they are victims of invidious discrimination in their education and employment and because of cultural biases discouraging women from entering those occupations. The theory developed in this paper develops an alternative hypothesis: Women are not underrepresented at the highest levels of achievement in the STEM occupations. The theory in this paper implies that differences in the statistical incidence of men and women who are extraordinarily high achievers in STEM is mainly the result of differences in the parameters of sex-linked probability density functions governing the congenital aptitudes for scientific achievement at the highest levels.

Keywords: women in STEM, probability, cognitive aptitude, discrimination

"*In every great* [achievement] *part is the gift of nature, part the contribution of accident, and part, very often not the greatest part, the effect of voluntary election and design."*

Samuel Johnson, LLD, *The King of Prussia*, essay appearing in the **Literary Magazine**, London, 1756

1. Introduction

This essay addresses the question of whether professional women workers are "underrepresented" at elite levels in the occupations of Science, Technology, Engineering and Mathematics in the United States, collectively referred to by the acronym STEM. Here is a recent statement of the President of the United States in which he expressed his belief:

> *One of the things that I really strongly believe in is that we need to have more girls interested in math, science, and engineering. We've got half the population that is way underrepresented in those fields and that means that we've got a whole bunch of talent…not being encouraged the way they need to."*
>
> *-- President Barack Obama, February 2013*

A cursory search of the internet will discover dozens, perhaps hundreds, of similar expressions of concern focused on the participation of women in the STEM occupations in the United States. Among those persons and institutions who announce their opinions publicly, there seems to be a nearly universal consensus that women are underrepresented in those occupations. The government of the United States has allocated taxpayers' money to address the so-called "*needs*" of these *"…way underrepresented…*" women.

The Federal *Office of Science and Technology Policy*, in collaboration with the **White House Council on Women and Girls,** is dedicated to increasing the participation of women and girls — as well as other so-called "underrepresented groups" — in the fields of science, technology, engineering, and mathematics by increasing the engagement of girls with STEM subjects in formal and informal environments, encouraging mentoring to support women throughout their academic and professional experiences, and supporting efforts to retain women in the STEM workforce.

This essay addresses a parochial question: what is the "correct representation" of women working at the elite levels of achievement in the STEM occupations? The statement of the President of the United States (as well as many other public commentators) suggests that the correct representation is about one-half of STEM workers. I think otherwise.

2.The Relevance of Galileo's Trial to a Theory Explaining the Representation of Women Working at Elite Levels in Stem

There is an anecdote about an exchange between the astronomer Galileo and churchmen who interrogated him at his trial on a charge of heresy. It is worth relating in the context of this essay because it illustrates a pernicious pseudo-scientific attitude that apparently continues to flourish more than three hundred years after Galileo's death. That attitude inhibits the search for a cogent theory to explain the participation of professional women at elite levels in the STEM occupations.

As is well known, Galileo Galilei (1564 - 1642) was an Italian scientist and philosopher. Galileo (as well as Kepler and Copernicus) established as a fact the heliocentric theory of our planetary system — the fact that our earth revolves around its sun. He also used his telescope to discover that the planet Mars has moons revolving around it. His scientific observations directly contradicted the theory of the universe embodied in Church doctrine - namely the Ptolemaic theory - which asserted a geocentric universe.

Sooner or later Galileo was bound to fall afoul of orthodoxy. His publications were viewed (rightly) by officials of the Roman Catholic Church in Italy as a direct attack on Church doctrine. Galileo's findings made it impossible for any intelligent and educated person who understood them to accept the Church doctrine that asserted the absolute centrality of man in the cosmos. The Church responded to the perceived threat to its authority by accusing Galileo of heresy and bringing him to trial in a forum consisting exclusively of clergy; The Office of the Holy Inquisition.

An accusation of heresy was not merely a theological *faux pas*. In seventeenth century Italy heresy could be a capital offense. If Galileo had been convicted he could have been immolated at a stake in a public square, by order of the Inquisition. That possibility was not as farfetched as a modern mind might imagine. In 1600 Giordano Bruno (a monk) was convicted of heresy and was condemned to the flames by the Holy Office. Sentence was executed in Florence.

In 1616 Galileo was condemned in a closed session of the Inquisition. But his behavior seemed to remain too unsubmissive, so in 1633 he was once more dragged before the court, this time in public. During Galileo's questioning he was asked by one of the inquisitors whether he persisted in his heretical opinion that Mars had moons. Galileo responded to this question by exhibiting his telescope to the questioner, who happened to be a politically powerful Cardinal. Galileo invited the Cardinal to look through the telescope to view the moons of Mars. The Cardinal is said to have responded to the invitation as follows: "*I need not look through your infernal device to know the truth. I know that Mars does not have moons because Holy Scripture forbids them*."

To avoid punishment Galileo publicly recanted and promised henceforth to abandon all thoughts of the earth moving. He apologized profusely and repeatedly for his errors.

What is the relevance of the historical anecdote to an understanding of the statistical representation of women workers in the STEM occupations? The relevance is this: Any explanatory theory of women's achievements in STEM which is construed to be inconsistent with feminist orthodoxy or the prevailing doctrines of political correctness is castigated in the public media as unworthy of serious consideration. Those persons who articulate the offending theory are publicly denounced as bigots and malignant oppressors of women. If that claim seems to be hyperbole, consider the experience of Lawrence Summers in 2005.

In 2005 Dr. Summers was the President of Harvard University He was invited to be a speaker at an academic conference.

The theme of the conference was an exploration of possible explanations for the underrepresentation of women faculty in the STEM occupations in the university setting. He expressed three distinct hypotheses (not mutually exclusive) which might explain why women were underrepresented. One of those hypotheses resulted in a public excoriation of Dr. Summers in the media and elsewhere. His hypothesis is amplified in this essay.

Dr. Summers hypothesized that the so-called "underrepresentation" of women in certain scientific disciplines could be explained by innate (i.e. congenital) differences in mathematical ability.

> "*There is relatively clear evidence that whatever the difference in the means* [of mathematical ability between the sexes] *—which can be debated—there is a difference in the standard deviation and variability of a male and female population."*

Thus, even if the average mathematical abilities of men and women were the same (it is not conclusively established that they are), one would expect there would be more men than women at the elite levels of mathematical ability. Dr. Summers commented:

> *''There are issues of intrinsic aptitude, and particularly of the variability of aptitude, and that those considerations are reinforced by what are in fact lesser factors involving socialization and continuing discrimination. It's talking about people who are 3 1/2, 4 standard deviations above the mean in the one-in-5,000, one-in-10,000 class. Even small differences in the standard deviation will translate into very large differences in the available pool* [of exceptionally high achievers.]'' (underlining added)

There are at least two facts that have been obscured by the public excoriation of Dr. Summers. First, he did not assert dogma. If one reads a transcript of the speech that Dr. Summers actually delivered (it was posted on Harvard's website, accompanied by his recantation and apology) one finds that he did no more than offer three tentative hypotheses, one of which produced the firestorm of public vilification. In my opinion, the treatment given to Dr. Summers' in the United States media and Galileo's trial are eerily similar.

The second fact that seems to have been ignored is that the offending hypothesis might be amenable to testing and refutation.

3. A Theory of Congenital Sex-Linked Differential Aptitudes for Work at Elite Levels in the Stem Occupations.

Here is a statement of the hypothesis examined in this paper:
The observed differences in the statistical incidence of professional men and women working at elite levels in the STEM occupations in the United States are mainly (perhaps exclusively) the result of differences in the distributions of congenital sex-linked aptitudes for high quality professional achievements in those occupations.

If the hypothesis is valid, it generates at least three distinct implications:

a. Invidious sex discrimination and cultural biases cannot entirely explain the so-called "underrepresentation" of women in the elite levels of STEM occupations.
b. Government policies designed to "correct" the putative "underrepresentation" of women in the elite levels are nugatory.
c. Women are not "underrepresented" in the elite levels of STEM occupations. The observed statistical representations of the sexes at those levels is what is to be expected by reason of their differing intellectual capacities for extraordinarily high quality achievements.

Here is the theoretical foundation for the hypothesis. Consider two distinct populations: males and females. Suppose congenital aptitude for professional work in the STEM occupations can be represented as a numerical valued random variable distributed continuously in each population.[1] That aptitude is, to use Samuel Johnson's description, "*the gift of nature*." It is symbolized by X.

The range of X is each population is the semi-open interval $[0 \leq X \leq \infty)$. The hypothetical probability density functions governing the values of X in each population are symbolized by $f_M(X)$ for males and $f_F(X)$ for females.

[1] I am not suggesting that congenital mathematical (or scientific) talent can necessarily be measured as a univariate. That is a question for neuroscientists to address.

Both functions are assumed to be continuous and differentiable.

The doctrine popular among behaviorists studying sex-linked achievements is the statistical hypothesis: $f_M(X) = f_F(X)$ for all values of X. This is a mathematical transcription of the proposition that the congenital distributions of scientific aptitude in the two populations are exactly the same.

An alternative hypothesis (stated above) is equally plausible and has the advantage of being consistent with the observable data. The hypothesis in this paper proposes that the density functions $f_M(X)$ and $f_F(X)$ have different parametric properties.

I assume the solutions of equations (1) and (2) exist.

$$\frac{d}{dX} f_F(X) = 0\,, \quad \frac{d^2}{dX^2} f_F(X) < 0 \tag{1}$$

$$\frac{d}{dX} f_M(X) = 0\,, \quad \frac{d^2}{dX^2} f_M(X) < 0 \tag{2}$$

The solutions to the equations in (1) and (2) are symbolized by X_F and X_M respectively. These are the modal values of innate ability distributed in the two populations. I assume they differ as follows:.

$X_F < X_M$ (3)

Also, I assume the variances of the random variable X differ in the two populations:

$$Var_F(X) \; < \; Var_M(X) \tag{4}$$

The inequality in (4) states that the dispersion of innate scientific aptitudes in the population of men is larger than its dispersion in the population of women. Properties (3) and (4) are sufficient to generate a plausible and testable hypotheses to explain the paucity of high achieving women in the STEM occupations.

Suppose there is a specific value for X symbolized by X^*. The salient characteristic of X^* is that it identifies the minimal congenital aptitude required for any kind of professional work in the STEM occupations. Persons of either sex who are born with an aptitude not exceeding X^* may, perhaps, secure employment in the STEM occupations. However, their employment activities will be carried at the lowest levels of professional expertise, e.g. they work in the capacity of technicians who can understand and carry out clear and simple instructions.

The symbol X^* characterizes the threshold level of congenital aptitude of persons of either sex who have the capacity to do significant professional work in STEM. Persons of either sex who are born with levels of X greatly exceeding $X^*$are those who are capable of high levels of achievement in the STEM occupations.

Suppose the probability densities governing the congenital aptitudes of the populations of men and women have the property:

$$f_F(X^*) = \; f_M(X^*) \tag{5}$$

Equation (5) means that a woman randomly selected from the population of women and a man randomly selected from the men's population have an equal probability of having the threshold level of congenital aptitude for professional work in the STEM occupations.

Now consider the proportion of the population of men and women who are capable of high levels of professional achievement in the STEM occupations. For the population of women, the proportion can be represented as:

$$F(X^*) \; = \; \int_{X^*}^{\infty} f_F(X) dX \tag{6}$$

For the population of men, the proportion can be represented as:

$$M(X^*) \; = \; \int_{X^*}^{\infty} f_M(X) dX \tag{7}$$

The difference between the two proportions is symbolized by $\Delta(X^*)$ where:

$$\Delta(X^*) = \; M(X^*) - \; F(X^*) = \int_{X^*}^{\infty} [f_M(X) - f_F(X)]\, dX \tag{8}$$

If $\Delta(X^*) > 0$, the inequality constitutes statistical evidence consistent with the hypothesis. A graphic representation is displayed in Figure 1 below. That figure displays hypothetical probability distributions of congenital scientific aptitude for males and females superimposed on the same set of axes.

The shaded area on Figure 1 to the right of X^* is the geometric representation of $\Delta(X^*)$. It represents the proportion of men exceeding women who are capable of achieving exceptional professional success in the STEM occupations. An implication of the hypothesis is that one would expect to observe that the ratio of high achieving men to high achieving women will increase as the congenital aptitude for achievement in STEM increases, *ceteris paribus*. This expectation is consistent with observable data.

4. Recently Published of Evidence

A study published in July 2008 adduced evidence supporting the hypothesis stated in Section 3 in this paper. The authors of the study compared the scores of girls and boys in grades two through 11 on the state mathematics tests mandated by the *No Child Left Behind Act* (NCLB). They found no meaningful differences in the average performance of boys and girls. But the variability of boys' scores was 11 to 21 percent greater at all grade levels. Consequently, boys were indeed "overrepresented" in the top percentile, by a 2:1 ratio over girls.[2] That finding is consistent with the area in the diagram above. One can find similar conclusions in many other studies.

5. A Tendentious Idea

Objective evidence has a dual function: It can be harnessed to guide policy and it can also rebut invalid theories. A recent example of a particularly silly idea that has gained traction in the United States will illustrate the point.

In 2015 an opinion essay appeared in a widely distributed popular publication. Its title was "*What Really Keeps Women Out of Tech*."[3] Here is what the author wrote:

> *"To make computer science more attractive to women, we might help young women change how they think about themselves, and what's expected of them. But we might also diversify the images of scientists they see in the media, along with the decor in the classrooms and offices in which they might want to study or work."*

The implication of the idea reproduced in the paragraph above (I decline to dignify it by calling it a theory) is that women are underrepresented in "Tech" because of the way they think about themselves, because of "images" of scientists they see in the media and because their classrooms and their offices are not decorated in shades of pastel pink and furnished with posters of "*Sex and the City*"[4] and with copies of *Vogue* and *Cosmopolitan* scattered around.[5]

The silliness, even the absurdity, of the idea is manifest if success in STEM is in fact determined by congenital sex-linked differences in the aptitude for professional work in the those occupations. Trying to psychologically condition girls when they are young and providing them with copious quantities of feminine accoutrements will not increase their participation at the elite levels of the STEM occupations if their innate ability is absent.

6. Concluding Remarks

Feminist dogma and politically correct commentators claim that the so-called "underrepresentation" of women functioning at extraordinarily high levels of achievement in the STEM occupations is caused by invidious discrimination as well as by cultural biases imposed on the mentality of young girls. This essay suggests a much more benign and, I think, at least equally plausible explanation.

This essay suggests that women are not underrepresented at the elite levels of achievement in the STEM occupations. A direct implication of the theory developed in this essay is that the representation of women at the elite levels is merely an ineluctable statistical consequence of the distribution of congenital aptitudes in the population of women in the United States. If the theory is valid, it is impossible to design a government policy (other than a policy of selective breeding) to "correct" a spurious underrepresentation.

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2 Hyde, Janet S. (2008)

3 Pollack, Eileen (2015)

4 *Sex and the City* is the name of a television dramatic series broadcasted for several years in the United States. Most of the episodes dramatized the sexual activities of four white and well-to-do young professional women residing and working in New York City. The broadcasts were very popular among women.

5 *Vogue* and *Cosmopolitan* are monthly periodicals displaying advertisements and articles targeted at a female audience.

References

Hyde, Janet S. and Jane E. Mertz. *Gender, Culture and Mathematics Performance*. **Proceedings of the National Academy of Sciences of the United States of America,** Vol. 106, No. 22, doi: 10.1073/pnas.0901265106

Pollack, Eileen. *What Really Keeps Women Out of Tech*. **The New York Times**. October 11, 2015.

Figure 1