

Women in science: achievements and ambitions

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International Women's Day will be celebrated on 8 March 2021. Much has changed in the modern world, but it is still a fact that women are underrepresented in many sectors; this is especially true in science and research. Colleagues from the Oxford Brain Health Clinical Trials Unit reflect on the historical contribution of women in STEM and what future challenges and success may lay ahead.

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Jane Austin wrote in *Pride and Prejudice*:

'It is a truth universally acknowledged, that a single man in possession of a good fortune, must be in want of a wife.'

For centuries, women have been establishing the foundations of modern-day society, and work conducted by women has inspired scientific, medical, political and environmental movements, leading to many new discoveries. However, it has often taken centuries for scientific discoveries made by women to be recognised to the same degree as their male counterparts.

In the last two centuries, the foundation of women's colleges, the women's movement and the job market offering more equal opportunities has led to an increase in the number of female scientists (Kohlstedt, 2004). Despite this, even in the twenty-first century, persistent and unequal representation within the sciences exist, especially in the fields of engineering, physics, surgery and medical technologies. While there are more female science graduates than ever, these numbers are vastly lower in senior positions. To understand this better, it is vital to look towards the past, recognise the progress made thus

far and identify the barriers that still exist in the scientific community.

A brief history lesson

Until recently, it was impossible for female scientists to obtain similar jobs as their male counterparts. The very few that attained such a role often faced intense criticism and overwhelming obstacles. A key example of this would be Hypatia of Alexandria, Egypt, one of the first female mathematicians. Hypatia gave lectures in mathematics and even led the local school of philosophy in 400 AD. Unfortunately, her writings and teachings were mistaken as political, and she experienced an untimely death at the hands of a militant religious mob in 415 AD (Charpentier, 1977). It would take a further 2000 years before another female scientist, Elena Piscopia Cornaro, received a doctoral degree. Elena received her Doctor of Philosophy in 1678 after first being denied to study theology.

However, despite this early female representation, women remain the minority in the highest positions in mathematics at universities. In the UK, only 6% of mathematics professors are women (Eggins, 2017), with the first female mathematician, Anne Davis, being appointed a professor of Applied Mathematics at the University

of Cambridge only as recently as 2002 (Barrow-Green, 2018). Beede and colleagues (2011) reported that women with science degrees are still less likely than men to follow a research career in science. Organisations such as the Women in Science and Engineering (WISE) UK report that female participation in science, technology, engineering and mathematics (STEM) drops during the A-level stage of UK education (usually completed at the end of high school), and declines exponentially from there onwards. In 2019, only 24% of all STEM-associated jobs in the UK were held by women, although this was an increase from 13% in 2012; it is anticipated that, by 2030, this will further increase to 29% (WISE, 2019). Of course, this is a positive step and is a predicted phenomenon not constrained to the UK, but the pattern is not uniform across countries. In 2016, it was reported that 29.3% of the scientific workforce were female, with the lowest representation of women in South and West Asia (18.5%) (UNESCO Institute for Statistics, 2019). According to Eurostat, the proportion of female scientists and engineers in the UK is 40%, ranking 20th out of 28 EU member states. In Lithuania, Bulgaria and Latvia, over 50% of scientists and engineers are women, in comparison to the proportion in Luxembourg, which is reported to be 25% (Eurostat, 2020).

There are various organisations across the world that focus on promoting equality for women in workplaces, although, in the modern era, this should be the norm without the need for advocacy. Some employers use a quota-based system to merely showcase they do have female scientists and senior staff on paper, which may not reflect true equality of access to such positions. Another added complication is that, while the

statistics may indicate the existence of a problem, understanding causation is more complex. For example, the official Nobel Prize Foundation (2020) reports that 113 Nobel prizes in Physics have been awarded to 209 men and 3 women. Metrics are only marginally better in medicine, where Nobel prizes have been given to 207 men and 12 women. Although Nobel prize laureates are a small portion of the scientific community, the low number of women laureates is indicative of the underrepresentation of women in higher academic positions, where they would have the resources, such as office space, laboratories and financial support, to work on research that could lead to important breakthroughs. In scientific fields where the majority of students are female, there is a disparity between the female and male senior staff. Within the biomedical sciences, from 2011-2012, 61% of bioscience postgraduate students were female, while only 15% of professors were female (Biology, 2013). In the same field, while 58.4% of the graduates in the US were female, but only 20.2% of biomedical scientists in academia are women (Ceci and Williams, 2010). Even within the undergraduate arenas, there are still lower percentages of female graduates, although some disciplines, such as mathematics, are faring better than others. The female graduates of STEM subjects were 25% in 2015, 24% in 2016, 25% in 2017 and 26% in 2018, demonstrating a small and unstable increase. In the workforce, an average of 22% were female employees in the years between 2016 and 2018 (WISE, 2018). However, the metrics in science, where women comprise 42% of the workforce, are far better than engineering, where only 10% of employees are women (STEM Women, 2020). The low representation of women in science and engineering is a complex issue. There appear to be obstacles from childhood that persist until adulthood. To understand the roots of underrepresentation, we will first start by examining the 'nature versus nurture' debate in relation to women's abilities in STEM.

Background

For 30 years, the differences men and women in academic science has been explained using the 'leaky pipeline' metaphor (Berryman, 1983; Alper, 1993). Researchers have proposed how specific factors, such as cognitive abilities, discrimination and areas of interest, can explain these sex differences (Ceci et al, 2009). These interconnecting factors could cause 'leaks' along the career pipeline at various points and, therefore, lead to an underrepresentation of women in more senior positions.

Although evidence of sex differences in promotion in STEM fields are scarce, there are often sizable differences in salaries in these fields. A survey conducted by Brynin and colleagues (2019) demonstrated that women in science earn significantly less than men across almost all job categories (Brynin et al, 2019). An annual report from the American Association of University Professors (AAUP), which often includes salary comparisons by sex, consistently shows that men earn more than women, despite having the same roles and responsibilities. However, the AAUP does not control for age or STEM field that could explain these gaps. Therefore, it is important to note that it is quite difficult to make direct comparisons of salaries between the sexes. Different fields pay different salaries; to date, women and men tend to work in different academic fields, and men are more prevalent in fields with higher salaries (Ceci et al, 2014). The best way to compare gender pay salary differences is to look at those in the same fields and academic rank in similar institutions. This could be cumbersome and a highly sensitive piece of research, given the ethical limits and employee regulations that protect discussions about pay from being a public matter.

Furthermore, Babcock et al (2004) claimed that sex differences when negotiating salary may perpetuate this discrepancy (Babcock and Laschever, 2004). Babcock demonstrated a tendency for women to not ask for higher pay or believe they deserve it, which could further drive pay gaps between female and male employees.

Therefore, it could be suggested that, in academia, women not asking for comparable starting salaries could lead to a salary disparity. However, Blackaby et al (2005) demonstrated that, even if women ask for salary raises or adjustments, their increases may not equate to that of their male counterparts. If you control for productivity, female economists in England were less likely to get external offers and received lower returns compared to men (Blackaby et al, 2005). It should also be noted that institutional policies may lead to sex differences in salaries in some parts of the world. Manchester et al's (2013) study demonstrated that, for both men and women, if you were to stop the progression to tenure, it had no significant impact on the probability of being promoted at a major university, but it did show a reduction in salary (Manchester et al, 2013). This is a complex area that needs further exploration, and the relevant historical trajectory should also be considered.

Gender disparity and science

Historically, it could be argued this disparity was predominantly due to social and cultural constructs, but stating that the disparity is due to women's exclusion by discrimination or misogyny is too simplistic. Instead, understanding the social, cultural and historical factors, as well as dissecting the 'normal constructs', is important. For example, it is well documented that, during World War I, women replaced men in factories and public services; however, female scientists obtained essential roles in laboratories, but were not so publicly visible. One explanation for this could be that stereotypical descriptions of science tend to portray women's work as ancillary: women were perceived as 'assistants' and thus less vital to the standalone and descriptive ideologies of science. Hartley et al (2015) found that female lab technicians were more prone to minimise the significance of their contribution to the research undertaken in their laboratories.

There have been several researchers who have asserted that there is an



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inherent sex bias in the research grant review process. One example of this comes from Lortie et al (2007), who concluded that sex biases function at many different levels in the scientific community and includes funding allocation, employment and publications. These researchers based their conclusions on earlier work by Wenneras and Wold (1997). In this review, the researchers discovered that postdoctoral fellowship applications to the Swedish Medical Research Council were highly prejudiced against women (Wenneras and Wold, 1997). However, this is not supported by the evidence and their work has been highly criticised (Ceci and Williams, 2011). In fact, there are no systematic sex differences in grant-funding rates; despite the fact that men may have higher grant totals, this is most likely due to the fact men are more likely to be principal investigators on bigger projects. Generally, men and women have very similar funding rates for their grant proposals (Ley and Hamilton,

2008; Marsh et al, 2009; Pohlhaus et al, 2011). Hosek et al (2005) evaluated sex differences in grants awarded by the National Science Foundation (NSF), the National Institutes of Health (NIH) and the US Department of Agriculture (USDA) between 2001 and 2003 (Hosek et al, 2005). They found no significant sex difference between the NSF and USDA grant awards, although results showed that women received smaller amounts in funding than men from NIH. Ley and Hamilton (2008) delved further into the differences in the NIH and analysed approximately 100 000 grant applications from 2003-2007. Their analysis found no differences and supported the idea of gender-neutral grant reviewing. The success rate for men and women were practically the same (32% for men and 31% for women). It should be noted that both Ley and Hamilton (2008) and a more recent study by Pohlhaus et al (2011) found that, although women were as successful in applying for new Research Project Grants (R01), they were less

likely to be funded for R01 renewals than men (Pohlhaus et al, 2011). Mutz et al (2012) also confirmed, in their review of 8500 US grants, that the decision to award grants was not related to the applicants' sex.

Publishing good-quality scientific papers in high-ranking journals is an integral part of the job of an academic, and is an influencing factor in decisions about their progression to higher positions. A significant amount of research shows that women face more obstacles to publishing in academic journals than men (Silver, 2019). This has led to significantly lower percentages of female authors, especially last authors (denoting higher academic positions held at their institutions), and fewer papers produced by women in highly ranked journals (Holman et al, 2018). A contributing factor could be the way women report the results of their studies. A study by Lerchenmueller et al (2019), looking into the gender of the first and last authors of articles, found that men

tended to present their results in a more positive light. Women may be underestimating the value of their research (Sanders et al, 2011), hence not producing as many highly-cited publications as their male colleagues.

The future for female scientists

Overall, the need to increase the representation of women in STEM poses one of the most important challenges for our society. History has shown there has been incremental progress that could, over time, lead to still bigger improvements. An example of this can be seen in the increase women in engineering roles over the last decade. Cheryan et al (2013) demonstrated that women's interest in studying computer science can be increased through a change of image of this discipline. In the UK in 2019, there was increase in girls taking GCSE core-STEM subjects, such as computer science and physics, and results showed that girls did significantly better in GCSE computer science than boys. This trend continued through to A-level, where girls were able to achieve higher grades in physics and computing than boys. This consistent growth is seen at higher education level. In 2019, women made up 29% of those getting qualifications in STEM subjects from university (an increase of 27% from 2014). This trend has also extended into the workplace, where there are approximately 350 000 more women in UK STEM than 10 years ago, with women now comprising 24% of the UK core-STEM workforce (WISE, 2019).

The career trajectory of women in STEM continues to differ to that of men, despite the fact that this is improving. Sex differences in STEM continue to be apparent in higher profile positions and in subfields of physics and computer science. While much progress has been made in the last decade to address disparities, much still has to be understood about the most effective intervention to reduce individual and organisational sex biases. Sally Gregory Kohlstedt (2004) said:

'History makes it clear that there is

no stability in the gains made in policy and practice; and awareness of that helps us from being complacent.'

This kind of perspective is needed for further positive changes to be made. BJNN

- Alper J. The pipeline is leaking women all the way along. *Science*. 1993;260(5106):409. <https://doi.org/10.1126/science.260.5106.409>
- Babcock L, Laschever S. Women don't ask: negotiation and the gender divide. *Southern Economic Journal*. 2004;71(2):462–483. <https://doi.org/10.2307/4135303>
- Berryman SE. Who will do science? Trends, and their causes in minority and female representation among holders of advanced degrees in science and mathematics. A special report. 1983. <https://files.eric.ed.gov/fulltext/ED245052.pdf> (accessed 27 January 2021)
- Blackaby D, Booth A, Frank J. Outside offers and the gender pay gap: empirical evidence from the UK academic labour market. *Economic Journal*. 2005;115(501):F81–F107. <https://doi.org/10.1111/j.0013-0133.2005.00973.x>
- Brynin M, Longhi S, Zwysen W. The diversification of inequality. *Br J Sociol*. 2019;70(1):70–89. <https://doi.org/10.1111/1468-4446.12341>
- Ceci SJ, Williams WM, Barnett SM. Women's underrepresentation in science: sociocultural and biological considerations. *Psychol Bull*. 2009;135(2):218–261. <https://doi.org/10.1037/a0014412>
- Ceci SJ, Williams WM. Understanding current causes of women's underrepresentation in science. *Proc Natl Acad Sci US*. 2011;108(8):3157–3162. <https://doi.org/10.1073/pnas.1014871108>
- Ceci SJ, Ginther DK, Kahn S, Williams WM. Women in academic science: a changing landscape. *Psychol Sci Public Interest*. 2014;15(3):75–141. <https://doi.org/10.1177/1529100614541236>
- Cheryan S, Plaut VC, Handron C, Hudson L. The stereotypical computer scientist: gendered media representations as a barrier to inclusion for women. *Sex roles*. 2013;69(1–2):58–71. <https://doi.org/10.1007/s11199-013-0296-x>
- Eurostat. Women in science and technology. 2020. <https://ec.europa.eu/eurostat/en/web/products-eurostat-news/-/edn-20200210-2> (accessed 4 February 2021)
- Hartley JM, Tansey EM. White coats and no trousers: narrating the experiences of women technicians in medical laboratories, 1930–1990. *Notes Rec R Soc Lond*. 2015;69(1):25–36. <https://doi.org/10.1098/rsnr.2014.0058>
- Hosek SD, Cox AG, Ghosh-Dastidar B et al. Gender differences in major federal external grant programs. 2005. www.rand.org/pubs/technical_reports/TR307.html (accessed 27 January 2021)
- Ley TJ, Hamilton BH. The gender gap in NIH grant applications. *Science*. 2008;322(5907):1472–1474. <https://doi.org/10.1126/science.1165878>
- Lortie C, Aarssen L, Budden A et al. Publication bias and merit in ecology. *Oikos*. 2007;116(7):1247–1253. <https://doi.org/10.1111/j.0030-1299.2007.15686.x>
- Manchester C, Leslie L, Kramer A. Is the clock still ticking? An evaluation of the consequences of stopping the tenure clock. *Industrial and Labor Relations Review*. 2013;66(1):3–32. <https://doi.org/10.1177/001979391306600101>
- Marsh H, Bornmann L, Mutz R, Daniel HD, O'Mara-Eves A. Gender effects in the peer reviews of grant proposals: a comprehensive meta-analysis comparing traditional and multilevel approaches. *Rev Educ Res*. 2006;79(3):1290–1326. <https://doi.org/10.3102/0034654309334143>
- Min A. The past, present and future of women in STEM. 2019. <https://edventures.com/blogs/stempower/the-past-present-and-future-of-women-in-stem> (accessed 27 January 2021)
- Mutz R, Bornmann L, Daniel HD. Does gender matter in grant peer review? An empirical investigation using the example of the Austrian science fund. *Zeitschrift für Psychologie*. 2012;220:121–129. <https://doi.org/10.1027/2151-2604/a000103>
- Pohlhaus J, Jiang H, Wagner R, Schaffer W, Pinn V. Sex differences in application, success, and funding rates for NIH extramural programs. *Academic medicine*. 2011;86:759–767. <https://doi.org/10.1097/ACM.0b013e31821836ff>
- Society of Biology. Women in academic STEM careers. 2013. https://www.rsb.org.uk/images/Society_of_Biology_response_to_women_in_STEM_careers_inquiry.pdf (accessed 27 January 2021)
- UNESCO Institute of Statistics. Women in Science. 2019. <http://uis.unesco.org/sites/default/files/documents/fs55-women-in-science-2019-en.pdf> (accessed 27 January 2021)
- Wenneras C, Wold A. Nepotism and sexism in peer-review. *Nature*. 1997;387(6631):341–343. <https://doi.org/10.1038/387341a0>
- Women in Science and Engineering. Statistics: core STEM Graduates 2018. 2018. <https://www.wisecampaign.org.uk/statistics/core-stem-graduates-2018/> (accessed 24 February 2021)
- Women in Science and Engineering. 2019 workforce statistics—one million women in STEM in the UK. 2019. www.wisecampaign.org.uk/statistics/2019-workforce-statistics-one-million-women-in-stem-in-the-uk/ (accessed 27 January 2021)