A U.S. Perspective on Women in Chemistry

Celeste M. ROHLFING Retired Chief Operating Officer at the American Association for the Advancement of Science

Nearly every woman who has pursued a career in chemical research can cite Marie Sklodowska-Curie, born 151 years ago, as an inspiration. So too women working in physics, since Curie was the first double Nobel Prize winner, in chemistry and physics. Female Nobel laureates in chemistry number only four beyond Curie, including her daughter Irene Joliot-Curie, and excluding Nobel Prize winners in Medicine or Physiology for biochemical discoveries. When I earned my doctoral degree in the mid-1980's, women represented less than 20% of the chemistry Ph.D.'s awarded that decade, and U.S. academic chemistry faculties averaged one female professor per department, with many having none at all. Role models were scarce, and for those women who had been successful in chemistry research careers, their stories were not widely known to undergraduate and graduate students. Where are the female Nobelist role models for the next generation of women chemists? Two so far this century is a promising start, but it is far from representative of the scientific advances made by women to the field of chemistry in the past several decades.

To provide further background, it is informative to examine the statistics on U.S.-awarded science and engineering degrees from the U.S. National Science Foundation (https://www.nsf.gov/statistics/2017/nsf17310/;curated data is available through 2014). About 50% of chemistry bachelor's degrees are awarded to women, and have been at that level for ten years. Compare this to engineering and computer science at about 20%, and mathematical sciences at just over 40%. Employment opportunities, while sensitive to the prevailing health of the economy, are usually robust for bachelor's degrees in all of these disciplines. About 40% of chemistry doctoral degrees are now earned by women, an increase from 33% ten years ago. Compare again to engineering and computer science at 20%, and mathematical sciences at just under 30%. Progress toward gender equity in these disciplines is slow, but chemistry is and has been more successful at attracting women than engineering and computer science, and it leads mathematics as well. A Curie effect, perhaps?

Gender equity at the bachelor and doctoral levels is of course not a guarantee of continuing equity in employment sectors and career paths, especially advancement opportunities. The degree data do however set the initial conditions of the pool available for hire. The so-called "pipeline" is less of an issue for chemistry than other science disciplines, at least through to the end of the formal education process. Industry is the largest employer of chemistry doctorates, but solid data on gender differences through career stages are lacking. However, the number of senior women at the top in chemistry-related industries — on corporate boards and in senior executive positions — is just under 20% (https://cen.acs.org/articles/95/i36/Women-chemical-industry-2017.html). Statistics exist for the representation of women in chemistry faculties and, while not a substitute for other employment sectors, the data does highlight the lack of progression toward equity. The most recent numbers for the top 50 U.S. chemistry departments (http://oxide.jhu.edu/2/Gender_2014-15;curated data is available through 2015) show that females comprise 26% of assistant professors, 30% of associate professors, and 14% of full professors. While more women hold faculty positions than ever before, the percentages still significantly lag the pool of female Ph.D.'s that exists at each level. True inclusion at the senior ranks remains an elusive goal in both industry and academia.

The status of women in chemistry of course sits within the larger context of cultural issues of employment of women in science and technology, and indeed in other traditionally male-dominated professions such as medicine and law, as well as the principal role presumed of mothers in the raising of children. Women in many workplaces face outright sex discrimination, as well as the full spectrum of sexual harassment from verbal to physical, and even violent assault. While these are prohibited civil or criminal acts, with legal recourse, the hurdles in proving such a case can be onerous for the victim. Additionally, it is crucial to recognize the subtler yet still insidious impediments to women's progress toward equity. These include the concepts of implicit or unconscious bias, microaggression, imposter syndrome, stereotype threat, and the accumulation of disadvantage, all of which are subjects of scholarly research in the social sciences (https://pubs.acs.org/doi/abs/10.1021/bk-2018-1277.ch001).

・Implicit bias is a stereotype — an attitude or association toward a particular group — that is subconscious. Consequently, this bias can be exhibited even if one does not believe oneself to be prejudiced toward a group, and/or one is a member of that group. The results of the gender-science Implicit Association Test (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2705538/) demonstrate that both men and women predominately associate science with males through implicit bias.

・Microaggressions are different than overt discrimination. They are frequent behaviors, such as an offhand comment that women can't excel at mathematics or lack mechanical skills. Such comments may be uttered in a teasing or joking manner, and if frequent, contribute to a chilly climate for women in a department or research group.

・An individual experiences stereotype threat when a negative stereotype arises in an evaluation setting, creating anxiety that may confirm the stereotype. For example, females may perform worse on a math or science test if the majority of the test takers in the room are male.

・Imposter syndrome is the inability of an individual to acknowledge one's own accomplishments. Thus, a woman might perceive her success in a scientific career to be false or due to luck, and this can lead to low self-esteem and even depression.

・Accumulation of disadvantage results from a gender differential in recommendation letters, authored papers, start-up funding, laboratory space, grant submissions, and nominations for awards and prizes. Over time, these seemingly minor individual disadvantages accrue, resulting in a personal financial cost in terms of salary and promotions, in addition to impacting the advancement of women's professional careers.

A multi-prong approach is required to mitigate these numerous effects. First, there is a role for government legislation and policies, along with informed employer practices. These include strong and enforceable anti-discrimination laws, safe and harassment-free work places, guarantees for parental leave, and access to quality childcare. Second, employers can provide training in the mentoring of individuals of another race or gender, as well as the role of implicit bias in hiring, promotion decisions, and award/prize nominations. Third, within academia, family-friendly tenure policies and reimbursement of dependent-care expenses incurred during professional travel are becoming widespread, yet students are mostly uninformed about the subtle barriers that can influence their career progression.

There are many successful examples of leading change in both cultures and structures in order to minimize deterrents to women's advancement in chemistry and other scientific disciplines, but I have space to describe only a few. Two notable grass-roots efforts to address equity issues for women and other underrepresented groups began in the academic chemistry community. COACh (coach.uoregon.edu) equips individuals with knowledge and skills through career-building workshops, while OXIDE (oxide.jhu.edu) engages and educates faculty leaders to reduce inequitable policies and practices. At the National Science Foundation (NSF) Chemistry Division, I piloted the use of briefing materials for expert panels on the role of implicit bias in the research proposal review process, and in evaluation contexts in general. This practice has been widely adopted throughout the agency. Also at NSF, I assisted in the creation of the ADVANCE program (https://www.nsf.gov/crssprgm/advance/) to fund changes implemented at the institutional level to further the careers of female faculty. Recently, NSF has launched a new effort called INCLUDES (https://www.nsf.gov/news/special_reports/nsfincludes/index.jsp) to broaden the participation of women and other groups in science and engineering. At the American Association for the Advancement of Science — a scientific professional society, I organized a major forum for key academic publishers and federal funding agencies on how to minimize implicit bias in peer review and share practices that these groups found effective.

Women in chemistry have achieved substantial progress during my lifetime: from getting a foot into the door, to building a critical mass within a research group or department, to breaking quite a few glass ceilings. In my keynote address to the 2017 International Conference on Women Leaders in Science, Technology, and Engineering held in Kuwait, I urged attendees to network with each other, utilize the services of professional societies, educate themselves and others on implicit bias, but not to forget to have fun while pursuing their careers and building their research portfolios. The conference theme was "science empowers women," and I posited that women empower science, via different perspectives drawn from the female experience. In conclusion, there are still goals yet unfulfilled: women chemists equitably represented at the senior and leadership levels of industry, academia, and government; talented and accomplished female researchers in the chemical sciences realizing their full potential; and Nobel Laureate rosters filled with the names of women who will inspire future generations to pursue science.

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E-mail: ronsetsu@chemistry.or.jp