Women in Engineering: A Review of the 2019 Literature

SWE's assessment of the most significant research found in the past year's social science literature on women engineers and women in STEM disciplines, plus recommendations for future analysis and study.

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The past few years have, in some ways, been discouraging for advocates of gender diversity in engineering. The share of engineering jobs held by women has not increased significantly in the most recent period, and one continues to read headlines describing the ongoing controversies over the experiences of women in the digital economy. There has also been pushback against efforts to take positive steps to increase the numbers of women in engineering and science, with the federal government now joining efforts to eliminate scholarships and other supports that target female recipients.

Nevertheless, interest in understanding why there continue to be relatively few women in engineering and what can be done to change that remains strong. This year, for the annual SWE Literature Review, we read almost 200 peer-reviewed articles, plus books and papers from a variety of social science disciplines devoted to these issues. Our review summarizes the major findings published this year in the hope that practicing engineers will find them useful, both in understanding their own experiences and in helping to facilitate the entry of more women into the profession.

The research we reviewed varies in quality and in methodological approach: from quantitative analyses of large data sets to small, qualitative studies of a single workplace or a few individuals. As always, we have tried to focus attention on studies that are based on extensive research and the best scientific methods (both quantitative and qualitative), as well as those that offered new insights into established research questions or that pointed to important possible new directions for research.

Perhaps unsurprisingly, given that research on women in engineering has been ongoing for decades, our review of this year's literature revealed few significant new research directions. Although there was important new research published this year, most of it focused on familiar research questions, confirming or challenging findings from previous years and/or adding nuance to what is already known. Some of the more notable characteristics of this year's research include:

- A continued focus on the reasons girls and young women are not attracted to engineering. As evidence has accumulated that the low numbers of women in engineering are not the result of inequalities in aptitude or preparation in foundational skills such as math, researchers have focused increasingly on attitudinal and psychological variables: the "fit" between engineering and women's career goals and interests, women's self-concept and confidence in engineering-related skills, the effects of stereotype threat, sense of belonging, etc.
- A relative neglect of the reasons women leave engineering at various points along the career track, despite previous research establishing that the number of women in engineering careers is considerably lower than the number who earn engineering degrees. Researchers *are* conducting studies of factors such as the climate of engineering programs and workplaces and of work/life conflict, but we read very little research this year that explored how they led to women's departure from engineering (why did they leave, where did they go?), nor

did we read any research on women who had left engineering.
- Better balance between research on academic engineering and research on engineering practice. While there continues to be a significant amount of research devoted to engineering students and to female faculty, this year we found more research on engineering practice than we had in previous years.
- An international focus. For the past several years, we have noted the existence of a rich and growing literature on engineers outside the United States. This year was no exception, as we read many studies of engineers in a wide range of countries in both the developed and developing worlds. Some of this research is explicitly comparative, trying to understand how national culture affects the position of women in engineering. Some of it, however, is not, as we read studies conducted outside the United States, but published in American journals, that said little or nothing about how the national context in which the research was conducted was relevant to its findings. Of possible concern is the fact that the studies that paid least attention to national context were studies of engineers in North America, Europe, and Australia. One can ask whether researchers are at risk of treating the cultures of those countries as all the same and irrelevant to the experience of engineers. One can also ask whether they are unconsciously making the experience of the developed world the reference case, with comparative research effectively becoming a contrast between the developed and developing countries.
- A continued focus on intersectionality. Researchers continue to explore the interactions between sex, sexual orientation, race, and ethnicity and to build awareness that not all women engineers are the same.
- An ongoing focus on evaluating interventions. Researchers continue to be interested in discovering what can be done to increase the numbers of women in engineering and to improve their experience, in evaluating what works and what doesn't. As we will discuss in the concluding section of this review, the interventions being assessed differ in whether they are designed to "fix the women" or to change engineering in some fundamental way.

Finally, we were again struck this year by the fact that almost all of the research on women in engineering is conducted by women. There has been considerable interest within organizations such as the Society of Women Engineers in understanding the importance of male allies in efforts to diversify engineering. Perhaps that discussion should be extended to the research on which those efforts are based — does it matter that interest in understanding the underrepresentation of women in engineering seems to be concentrated largely among women themselves? We do note that we read several studies this year that explored masculinities in engineering, and/or that made a conscious effort to compare the experiences of men and women within the profession. It is possible that research of this type will broaden the group of researchers interested in exploring the lack of diversity in the engineering profession.

WHY AREN'T MORE GIRLS AND YOUNG WOMEN ATTRACTED TO ENGINEERING?

This year's literature review revealed ongoing interest among researchers in understanding why relatively few young girls and women are attracted to engineering programs and careers. One focus of interest continues to be in girls' experiences with math and in their spatial abilities, but there is a clear shift away from research on differences in aptitude or achievement to research on attitudes toward math, and on how others' perceptions of girls' abilities affect their interest in pursuing engineering or STEM careers.

Two studies we reviewed this year, however, *did* report differences in math achievement for girls and boys. Gomez Soler et al. (2019) reviewed national data on math achievement in Colombia, finding that boys outscored girls on standardized tests of math and that the gender gap *increased* after students entered university (they have no data to explain these findings). Marsh et al. (2019) reviewed longitudinal data on a national survey of Australian youth as well as outcomes on the Programme for International Student Assessment exam, finding that girls had lower math and science test scores than boys (as well as higher reading scores).

Of course, these are studies from outside the U.S., and we know from American data that gender gaps on standardized tests of math don't predict success in math courses, where girls outperform boys, at least in the U.S. Perhaps more importantly, several studies we reviewed this year, including the Australian study by Marsh et al., find that attitudes, rather than math scores, were the key to determining whether girls gravitated toward STEM and engineering programs.

Marsh et al. (2019) found that, despite differences in math test scores, girls were equally likely to be in STEM courses in the last two years of high school (which in Australia is critical to being admitted to a postsecondary STEM program). However, girls were much less likely than boys to enroll in STEM courses in college, primarily because of psychological factors, including math anxiety, lower self-efficacy in math, as well as self-concept, interest, and utility value in relation to math. Marsh et al. also interviewed a subsample of students who had taken STEM courses in their last two years of high school and found that those who opted out of STEM in college generally did so less because they were making a negative judgment of STEM, and more because they evaluated alternatives more highly.

Jungert et al. (2019) used data on almost 1,600 high school and junior college students in Sweden and Quebec, Canada, to examine the gender gap in STEM achievement and persistence. They found that a cognitive style known as "systematizing" indirectly predicted STEM achievement and persistence by way of intrinsic motivation, learning anxiety, and self-efficacy. Although boys and girls in their study had similar levels of academic achievement, boys were more likely to be classified as systematizing (and thus to be intrinsically motivated toward STEM and to have low learning anxiety in that area), which explained their greater persistence in STEM. Jungert et al. argue this

Backlash?

What is discrimination on the basis of sex? For years in STEM fields, discussion of sex discrimination has focused on the low numbers of women majoring in fields such as physics, engineering, and computer science. Organizations such as SWE have labored for decades to try to increase the numbers of women entering these male-dominated technical fields. As this literature review (which has been published for nearly two decades) reflects, researchers have struggled to identify the reasons for the continued underrepresentation of women in many STEM disciplines. Federal programs such as NSF ADVANCE, as well as a range of efforts initiated by professional associations, educational institutions, and others, have devoted significant resources to attempting to encourage more women to enter these fields and creating conditions under which they persist and are successful.

In a development reminiscent of the backlash against affirmative action programs in general, a counternarrative has emerged in arguing that *men*, not women, are the victims of sex discrimination in academic science and the tech sector more broadly. A 2015 suit against Yahoo, claiming the company discriminated against male employees, and the circulation of a memo by a Google employee arguing that the low numbers of women in tech were *not* the result of discrimination, were early examples of this counternarrative. Publication of experimental research at Cornell concluding that women were actually *favored* in academic searches led to claims that there no longer is evidence of discrimination against women in academic hiring. Most recently, in a major shift of emphasis, the U.S. Department of Education (DOE) has initiated a series of investigations into universities that offer female-only scholarships, awards, development workshops, and engineering camps.

The DOE's move has been stimulated, in part, by the publication of a study by the nonprofit agency Stop Abusive and Violent Environments (SAVE), which found that most of the 220 universities studied offered single-gender scholarships targeting female students, often in STEM fields. SAVE labels these scholarship programs as "discriminatory" or, at best, "borderline." The organization, which describes itself as an advocate for gender equity on college campuses, also calls for greater equity in the handling of sexual harassment complaints. It argues, among other things, that sexual harassment grievance procedures risk becoming too cognitive style can be taught, so the gender gap in STEM achievement and persistence is not the result of innate differences between boys and girls.

Seo, Shen, and Alfaro (2019) analyzed data from the 2002 Educational Longitudinal Study regarding adolescents' beliefs about math ability and their relationship to STEM career attainment. The data set allowed them to analyze a sample of more than 15,000 10th graders in 2002, with follow-up data both two and eight years after those students completed their secondary educations. They found that youths' belief in their math abilities predicted later STEM career outcomes, and that there were significant gender gaps in that belief among white and Latinx students, with girls having lower beliefs in their math abilities. There was no gender gap for black and Asian students, but black students did not reap the full benefits of their beliefs in their math abilities.

The study also found that a growth mindset about math — the belief that one can become better at math — predicted high school math achievement, college STEM achievement, and eventual STEM career attainment for all groups. White adolescents had lower levels of growth mindset than the other groups studied; and, there was a significant gender gap among white adolescents, with girls significantly less likely to have a growth mindset. This study is an important demonstration both of the role of psychological variables in shaping young people's choice of major and career *and* of the importance of attending to intersectionality.

Zawistowska and Sadowski (2019) analyzed the gender gap in pursuing a high-stakes math exam in Poland, using national data from the 2016 exam. The results on this exam are the main criterion for admission to education for the majority of technical occupations in Poland. Women are significantly less likely to take the exam (and thus are less likely to pursue technical careers), but this was not the result of skill differences. Zawistowska and

"victim centered" and that the ways in which, under Title IX, complaints of harassment are being handled are not effective in defending the rights of the accused.

Universities have already begun to respond to the DOE's scrutiny. At the University of Minnesota, Mark Perry, Ph.D., an alumnus now teaching at the University of Michigan-Flint, filed complaints about three female-only faculty research awards. In response, the DOE launched an investigation into possible Title IX violations against men in August 2019; the university is now considering how to respond. It had already modified several women-only awards and scholarships a year earlier in response to complaints filed by Dr. Perry. Clemson University has also had to respond. Again, in response to complaints by Dr. Perry, Clemson came under investigation by the DOE for possible Title IX violations against men. The investigation was closed when the university agreed to open a series of female-only pre-college STEM programs to male students.

Efforts to increase the numbers of women in disciplines such as engineering, physics, and math continue across the United States. And, despite progress in some areas (e.g., improved outcomes for women in math) women continue to be significantly underrepresented in these fields at all levels, from undergraduate students to academics and practitioners. Thus, more needs to be done if sexual equality in STEM is to be achieved. However, continued efforts to take positive steps to increase the numbers of women in fields such as engineering may be in jeopardy if the counternarrative claiming there is discrimination against men continues to take root.

Sources:

Clabough, R. (2019). "Study Finds Women-only STEM College Programs/Scholarships Amount to Male Discrimination." The New American. *Aug. 23, 2019.*

Poff, J. (2019). "Clemson Opens Female-only Programs to Everyone to End Federal Investigation." The College Fix. *Aug. 15, 2019.*

Snow, J. (2019). "UMN Women-only STEM Awards Come Under Fire." Minnesota Daily, *Sept. 4, 2019.*

Stop Abusive and Violent Environments. http://www.saveservices.org

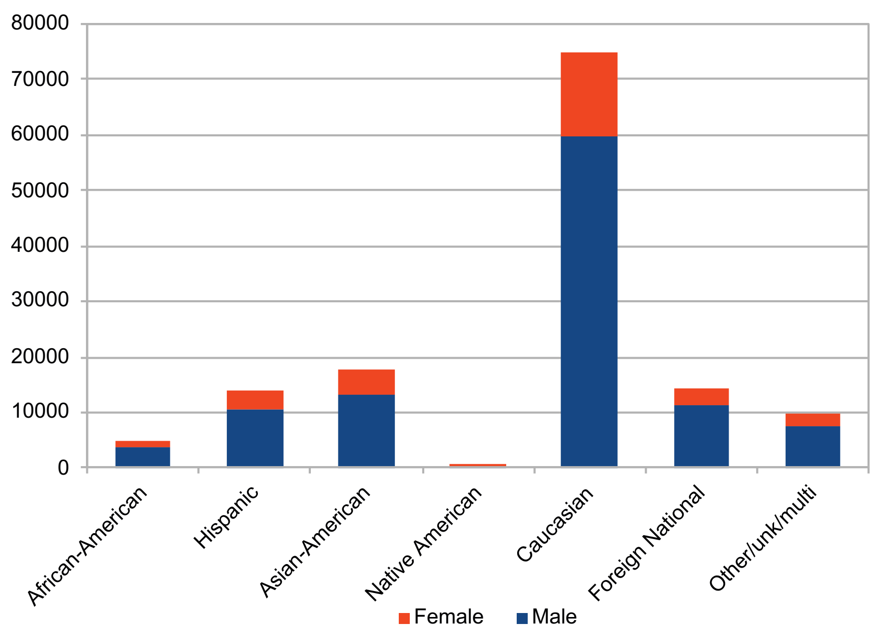
Watanabe, T. (2019). "Women-only STEM College Programs Under Attack for Male Discrimination." Los Angeles Times. *Aug. 20, 2019.*

Sadowski found that girls are less likely to take the exam when compared with boys with similar math scores and/or who attended similar schools. They conclude that the Polish technical educational system is at greater risk of losing math-talented girls than math-talented boys, in part because high verbal skills are more likely to draw women away from pursuing math-based educational programs.

Other researchers focused attention on how students' choices are affected by the judgments of others. For example, Muenks et al. (2019) surveyed 117 high school students and their parents in the mid-Atlantic region to examine how parents' beliefs about their children's spatial abilities affect students' STEM career intentions. They found that the parents of boys believed their children had higher spatial abilities, even after controlling for actual spatial abilities. Parents who believed their children had higher "mental manipulation abilities" were more likely to encourage their children to pursue STEM careers, and their children were more likely to have STEM career intentions. Beliefs about spatial visualization and navigation abilities did not have a similar effect; the researchers speculate that parents may not believe these abilities are important to success in a STEM career.

Studies that present at least indirect evidence of the influence of others on young women's attitudes to engineering include Hodgkinson, Khan, and Braide's (2019) small-scale study of a dozen undergraduate engineering and navigation students in the United Kingdom, which found that their respondents had been drawn to their programs of study because they were good at math and science, but that many of them reported not having been presented with engineering as an option in school; and that family members had often been important influences on their decisions to pursue those programs of study. Dicke, Safavian, and Eccles (2019) analyzed data on 744 participants in the Michigan Study of Adolescent and Adult Life Transitions, which followed participants over a 30-year period from age 11 to age 42, and found that women who had been brought up to have "traditional" attitudes about work/family-related gender roles (e.g., the belief that the man should be the achiever outside the home and the woman should take care of home and

Engineering Bachelor's Degrees by Gender within Race/Ethnicity, 2018



Source: Roy, Engineering by the Numbers, American Society for Engineering Education, 2019

family) had lower levels of educational attainment and a significantly lower probability of being in STEM-related careers, particularly in the physical sciences and engineering.

Previous research has explored the idea that women self-select away from or are steered away from fields in which people believe that "brilliance" is a required characteristic. Disciplines such as physics are culturally linked to brilliance, and brilliance tends to be defined as male, so girls are unlikely to enter. Galvez, Tiffenberg, and Altszyler (2019) demonstrate that the stereotype of male brilliance remains prevalent in contemporary culture. They analyzed transcripts of more than 11,000 English-language films made between 1967 and 2016. Using "natural language processing techniques" to look for associations between gender pronouns and high-level cognitive ability-related words (genius, clever, intelligent), they found that the stereotypical association between genius and masculinity persisted throughout the period they studied, and that it was also present in the subset of children's films they examined.

Deiglmayr, Stern, and Schubert (2019) conducted research in Switzerland designed to explore the connection between beliefs in brilliance and women's feelings about belonging in STEM. They surveyed almost 1,300 STEM students (18% of whom were female) at a technical university, finding that respondents associated brilliance with more math-intensive fields (physics, math) and that women reported higher levels of belief in brilliance than men. A small, but significant portion of the gender difference in uncertainty about belonging in STEM was explained by the belief in brilliance. However, the same study also reported that female enrollment in math and physics was higher than in engineering, a field that respondents did not associate with brilliance. So, it may be that beliefs in brilliance do not explain the underrepresentation of women in engineering after all.

The question of whether girls have different substantive and career interests than boys and, if they do, whether this affects their interest in pursuing engineering careers, continues to be examined by researchers. Some of the research we reviewed this year, however, cast doubt on whether this is the key factor limiting the numbers of women in the field.

Several studies did offer support for the view that women have different interests and orientations that may affect their choice of career. Lakin, Davis, and Davis (2019) surveyed 996 undergraduates enrolled in a pre-engineering course at a large public research-oriented university in the United States, finding that female students showed greater value for altruism while men showed greater value for status. Ertl and Hartmann (2019) conducted a quantitative analysis of data on almost 13,000 first-year students in Germany; they found that STEM fields with low proportions of female students tended to me more "things-oriented," while those with higher proportions of female students were more "people-oriented." Swartz et al.'s (2019) survey of just over 500 students enrolled in five engineering classes at the Colorado School of Mines and the University of Colorado Boulder concluded that female students have a greater understanding of and appreciation for the value of nontechnical knowledge, suggesting that female students more readily understand the importance of drawing from a diverse pool of stakeholder perspectives when they begin careers as engineers. And Barco et al.'s (2019) pilot study of a small group of female high school robotics students in New Zealand found that the students' motivation to study robotics was higher when social applications were used in the class.

Studies such as these, which confirm earlier research exploring the different interests of young men and women, point to the conclusion that these different interests explain gendered career choices. But is that, in fact, true? Lakin, Davis, and Davis (2019) question this in several ways. Although they found evidence of women's greater interest in altruism, they argue that the differences were significantly smaller than were found in other studies. More importantly, they note that the commitment to remain in engineering was lower for respondents who valued status most highly and who perceived engineering as providing it. This finding raises questions about the degree to which career commitment and career values are closely linked.

Ertl and Hartmann's (2019) research raises similar questions. Although they report that women were concentrated in the more people-oriented

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2019 Outstanding Women in Engineering

American Indian Science and Engineering Society (AISES) Awards

PROFESSIONAL OF THE YEAR AWARD

Wendy F. Smythe, Ph.D., University of Minnesota Duluth

TECHNICAL EXCELLENCE AWARD

Otakuye Conroy-Ben, Ph.D., Arizona State University

BLAZING FLAME AWARD

Sheila Lopez, Intel

American Society for Engineering Education (ASEE) Awards

WILLIAM ELGIN WICKENDEN AWARD

Chandra Turpen, Ph.D., University of Maryland, College Park

CLEMENT J. FREUND AWARD

Patricia D. Bazrod, retired, Georgia Institute of Technology

SHARON KEILLOR AWARD

Jenna P. Carpenter, Ph.D., Campbell University

AnitaB.org ABIE Awards

TECHNICAL LEADERSHIP ABIE AWARD

Fei-Fei Li, Ph.D., Stanford University

STUDENT OF VISION ABIE AWARD

Jhillika Kumar, Georgia Tech

EMERGING TECHNOLOGIST ABIE AWARD

Natalya Bailey, Ph.D., Accion Systems

SOCIAL IMPACT ABIE AWARD

Nimmi Ramanujam, Ph.D., Duke University

EDUCATIONAL INNOVATION ABIE AWARD IN HONOR OF A. RICHARD NEWTON

Yamilée Toussaint Beach, STEM From Dance

National Academy of Engineering (NAE) Awards

NEW FEMALE MEMBERS

Joanna Aizenberg, Ph.D., Harvard University

Penina Axelrad, Ph.D., University of Colorado Boulder

Mary Baker, Ph.D., P.E., ATA Engineering Inc.

Gilda A. Barabino, Ph.D., The City College of New York

Ana P. Barros, Ph.D., Duke University

Linda J. Broadbelt, Ph.D., Northwestern University

Wei Chen, Ph.D., Northwestern University

Hariklia Deligianni, Ph.D., retired, IBM Corp.

Sharon C. Glotzer, Ph.D., University of Michigan, Ann Arbor

Dorota A. Grejner-Brzezinska, Ph.D., The Ohio State University

Linda P. Hudson, The Cardea Group

Sara Kiesler, Ph.D., National Science Foundation

Jessica E. Kogel, Ph.D., National Institute for Occupational Safety and Health

Monica S. Lam, Ph.D., Stanford University

Kathryn A. McCarthy, Ph.D., Canadian Nuclear Laboratories

Laura J. McGill, Raytheon Missile Systems

Mahta Moghaddam, Ph.D., University of Southern California, Los Angeles

Mary Pat Moyer, Ph.D., INCELL Corp. LLC

Sharon L. Nunes, Ph.D., IBM Corp.

Stephanie L. O'Sullivan, U.S. Office of the Director of National Intelligence

Rosalind Picard, Sc.D., Massachusetts Institute of Technology

Kimberly A. Prather, Ph.D., University of California, San Diego

Nadine B. Sarter, Ph.D., University of Michigan, Ann Arbor

Margo I. Seltzer, Ph.D., Harvard University

Heidi Shyu, Heidi Shyu Inc.

Wanda A. Sigur, Lockheed Martin Corp.

Jane McKee Smith, Ph.D., U.S. Army Corps of Engineers

Kay M. Stanney, Ph.D., Design Interactive Inc.

Jean W. Tom, Ph.D., Bristol-Myers Squibb

Claire J. Tomlin, Ph.D., University of California, Berkeley

Susan Trolier-McKinstry, Ph.D., The Pennsylvania State University

Christine A. Wang, Ph.D., MIT Lincoln Laboratory

Margaret M. Wu, Ph.D., ExxonMobil Research and Engineering Co.

New International Members

Kiran Mazumdar-Shaw, Biocon Limited, Bangalore, India

Nicola A. Spaldin, Ph.D., ETH Zürich, Zürich

Molly Stevens, Ph.D., Imperial College London, U.K.

National Society of Black Engineers (NSBE) Golden Torch Awards

OUTSTANDING WOMAN IN TECHNOLOGY

Cynthia Pierre, Ph.D., BP Cherry Point Refinery

ENTREPRENEUR OF THE YEAR

Tarolyn Buckles, Onyx Enterprise Inc.

PROFESSIONAL MEMBER OF THE YEAR

Luneta Louis, John Deere

Society of Hispanic Professional Engineers (SHPE) Awards

JAIME OAXACA AWARD

Diana Ortega, General Motors Company

DR. ELLEN OCHOA AWARD

Ellen Ochoa, Ph.D., NASA

RUBÉN HINOJOSA STEM AWARD

Sylvia Acevedo, Girl Scouts USA

ADVISOR OF THE YEAR

Carrie Robinson, Ed.D., Arizona State University

EDUCATOR OF THE YEAR–HIGHER EDUCATION

Monica Palomo, Ph.D., California State Polytechnic University, Pomona

MANAGER OF THE YEAR AWARD

Karen Siles, IBM Corporation

PROFESSIONAL ROLE MODEL

Laura Valencia Fritsch, Eaton

Yamille Perez, Caterpillar

STUDENT ROLE MODEL

Lucila Campos, Utah State University

Susana Campos, The University of Texas Rio Grande Valley

Daisy Cueto, University of Illinois at Chicago

Giannina Duran, Florida Atlantic University

Alina Garcia Taormina, Ph.D., University of Southern California

Society of Women Engineers (SWE) Awards

SUZANNE JENNICHES UPWARD MOBILITY AWARD

Endowed by Northrop Grumman Corporation

Carol Malnati, Medtronic

RESNIK CHALLENGER MEDAL

Meg Abraham, DPhil, The Aerospace Corp.

WORK/LIFE INTEGRATION AWARD

Roble Alanis, John Deere

ADVOCATING WOMEN IN ENGINEERING AWARD

Blythe Gore Clark, Ph.D., Sandia National Laboratories

Katherine J. Herrick, Ph.D., Raytheon Company

Jennifer Howland, IBM Corporation

Marilyn Tears, ExxonMobil

Marilee J. Wheaton, F.SWE, The Aerospace Corporation

GLOBAL LEADERSHIP AWARD

Tamara Hedgren, Deere & Company

Tami Heilman-Adam, Dow

Elisabeth C. Martin, The Boeing Company

GLOBAL TEAM LEADERSHIP AWARD

Liza Phase 1 Project Team, ExxonMobil

Global Team – Standardized RFID System for Medical Device Implant Tracking, Johnson & Johnson Supply Chain

Islands Energy Program, Rocky Mountain Institute

PRISM AWARD

Karen Devine, Ph.D., Sandia National Laboratories

Lynda Grindstaff, F.SWE, McAfee

Kayleen L.E. Helms, Ph.D., Intel

Colleen O'Shea McClure, The Boeing Company

Susan B. Orr, Medtronic

SPARK AWARD

Stacy Kalisz Johnson, Keysight Technologies

Reiko A. Kerr, Los Angeles Department of Water and Power

Leslie L. Oliver, Solar Turbines – A Caterpillar Company

Karen Tokashiki, Northrop Grumman

Mary C. Verstraete, Ph.D., F.SWE, The University of Akron, Retired

EMERGING LEADER

Elif Ertekin, Ph.D., University of Illinois at Urbana-Champaign

Britta Jost, Caterpillar Inc.

Jamie Krakover, The Boeing Company

Jennifer LaVine, Sikorsky Aircraft – A Lockheed Martin Company

Jessica Mattis-Carolan, General Motors

Kate Maxwell, Raytheon Company

Alexis McKittrick, Ph.D., IDA Science & Technology Policy Institute

Heather A. Spinney, Ph.D., Dow Inc.

Orietta Verdugo, Intel Corporation

Kristen White, Keysight Technologies

SWE DISTINGUISHED NEW ENGINEER

Alya Elhawary, Lockheed Martin

Katharine Brumbaugh Gamble, Ph.D., U.S. Government

Anne Maher, Medtronic

Kimberly Miller, Cereal Partners Worldwide

Sarvenaz Myslicki, American Express

Sowmya Nagesh, Caterpillar Inc.

Elaine Reeves, Microsoft Corporation

Megan B. Schulze, P.E., Dewberry

FELLOW GRADE

Cindy L. Dahl, P.E., ONAMI Inc.

Jonna Gerken, Pratt & Whitney, a United Technologies Company

Rachel A.B. McQuillen, P.E., CME Associates Inc.

Michele O'Shaughnessy, U.S. Department of Energy, Savannah River Site

Deborah Stromberg, Intel Corporation

Frances Stuart, Retired

Carol J. Weber, Caterpillar Inc.

DISTINGUISHED SERVICE AWARD

Mary Higgins Studlick, P.E., F.SWE, ExxonMobil, Retired

OUTSTANDING FACULTY ADVISOR

Helene Finger, P.E., Cal Poly, San Luis Obispo

OUTSTANDING SWE COUNSELOR

Maira Garcia, Honeywell Aerospace

OUTSTANDING COLLEGIATE MEMBER

Haley Antoine, Cornell University

Megan E. Beck, Northwestern University

Carolyn Chlebek, Cornell University

Shelby Ann Freese, California State University, Chico

Cecilia Klauber, Texas A&M University

Kathryn Lockhart, Bradley University

Shwetha Rajaram, University of Michigan

Meredith Lucy Richardson, University of Illinois at Urbana-Champaign

Mujan Seif, University of Kentucky

Stephanie Tu, Rutgers University

Women in Engineering ProActive Network (WEPAN) Awards

WEPAN/DISCOVERE INTRODUCE A GIRL TO ENGINEERING DAY AWARD

University of Illinois at Chicago, Introduce a Girl to Engineering Day

INCLUSIVE CULTURE AND EQUITY AWARD

Susan E. Walden, Ph.D., The University of Oklahoma

WIE INITIATIVE AWARDS

California State Polytechnic University, Pomona, Women in Engineering Program

The Pennsylvania State University, Engineering Mentoring for Internship Excellence

INDUSTRY TRAILBLAZER AWARDS

Aicha Evans, Zoox

Cynthia Murphy-Ortega, Chevron

BETTY VETTER RESEARCH AWARD

Joyce B. Main, Ph.D., Purdue University

FOUNDERS AWARD

Julie Martin, Ph.D., Clemson University

WEPAN PRESIDENT'S AWARD

Lesia Crumpton-Young, Ph.D., Tennessee State University

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STEM fields, they found that the congruence between individual interest profiles and vocational aspirations was generally low in all STEM fields, and particularly small in those with low proportions of women. In other words, many of the students they studied were choosing to pursue careers in STEM fields that did not align with their stated interests.

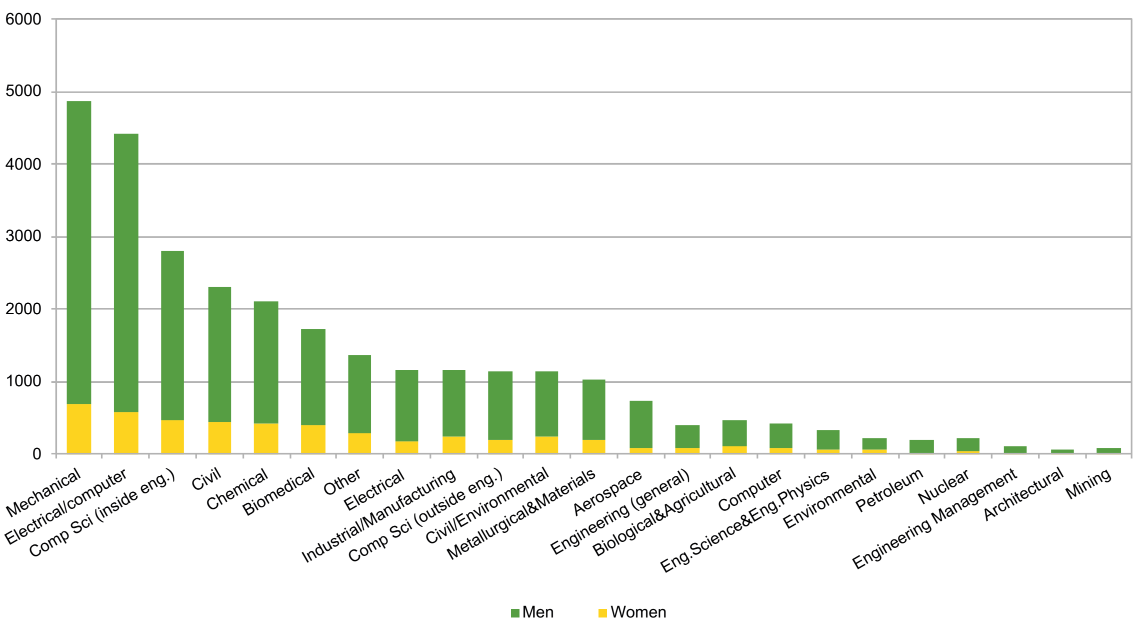
Bielefeldt and Canney (2019) surveyed 450 engineering graduates from 16 U.S. institutions to explore whether engineers were satisfied with their ability to help people and society in their jobs. The study needs to be considered with caution, since the sample appears skewed toward younger engineers and those who had engaged in service activities. The response rate to the survey was also relatively low (14%), and the sample overrepresents women (40%). Nevertheless, the study found no significant gender differences in levels of satisfaction with opportunities to help others.

Just as people's choice of career may not be directly related to their interests (whether these are gendered or not), it is also possible that people's sense of the fit between themselves and their careers is malleable. Dunlap and Barth (2019) note this possibility in their study of the relationship between people's perceptions of the "fit" between themselves and the fields in which they work. They interviewed 117 heterosexual couples, 55 of which included a woman majoring in a STEM field. They found that both men and women in STEM fields tended to see strong associations between their chosen fields and their own genders — in the case of women, this obviously involved counter-stereotypical associations. Significantly, however, Dunlap and Barth do not attribute causality to their findings:

> *"Whether women majoring in STEM choose to do so because of their counter-stereotypical association or whether those associations develop as a result of their career choice remains to be seen."* (557)

This year's research on the factors shaping young women's decisions about whether to enter engineering and STEM focuses attention clearly on the role of psychological and attitudinal factors: Are young women confident in their math abilities? Do they feel that they "belong" in engineering? Do they believe they can pursue their interests with a career in the field? It is important to emphasize, however, that this is ***not*** the same thing as saying that women

Engineering Faculty by Discipline and Gender, 2018



Source: Roy, Engineering by the Numbers, American Society for Engineering Education, 2019

have a negative view of engineering and engineering careers. On the contrary, there is a growing sense in the literature that women choose not to enter engineering and other STEM fields not because they have a strongly negative view of STEM, but because they find other fields more appealing.

Reskin and Roos (1990), in their classic analysis of the dynamics of occupational gender segregation, showed that as more women entered the labor force in the latter part of the 20th century, they tended to enter occupations in which they were interested and that were open to them. They might have had an interest in other occupations, but there were sufficient men to fill them, so women made other occupational choices. Pearlman's (2019) analysis of declining gender segregation in the 21st-century labor force implies that something similar may be occurring in the case of engineering. She argues that the declining probability that college-educated women will be in gender-segregated occupations (such as engineering) is related not to changes in the gender composition of historically male-dominated (or female-dominated) occupations, but to the growth in employment in more gender-integrated occupations such as management. It may be, in other words, that college-educated, math-talented women are choosing to enter management and other gender-integrated careers, rather than trying to make their way into historically male-dominated professions such as engineering. Women may not have an entirely negative view of the field, but entering engineering involves overcoming gender stereotypes and barriers; plus, they have options. So, one must ask whether increasing the numbers of women in engineering is simply a matter of addressing psychological and attitudinal factors among women themselves — e.g., increasing women's math confidence or sense of belonging in engineering. Doing so may also involve eliminating the barriers that women who are already attracted to engineering may be encountering.

THE STUDENT EXPERIENCE

What happens to young women who develop an interest in engineering and enter an engineering program in university? Research reviewed in previous years finds that women do not leave engineering programs at higher rates than men. But, there remains concern that engineering programs are not as welcoming to women as they could be and that this is part of the reason some female graduates don't continue to engineering careers.

The literature we reviewed this year offers contrasting views on whether the experience of being a female student in an engineering program is a positive one. Salehi, Holmes, and Wieman (2019) analyzed responses from students in two introductory mechanical engineering courses at Stanford University to determine whether gender affected students' perceptions of their peers, something that had been found to be the case in previous research on biology classes. They found no evidence of gender bias; students "nominated" as good students both male and female peers, typically other students they knew and who had good grades.

Similarly, Denis and Heap (2019) analyzed 2004-2008 data from faculty and students at three central Canadian universities with higher than average female undergraduate enrollment in engineering. They reviewed various aspects of the student experience at these universities, finding very few gender differences in descriptions of what the student experience was like, although female students at the "large" university in the study were more likely than the male students to say that the climate there favored male students.

On a more negative note, Tao and Gloria's (2019) study of 224 female STEM doctoral students at a Midwestern university found that some of them suffered from "imposterism" — a feeling of not being good enough, of being exposed as lucky or as a fraud — and that this led to lower self-efficacy and a negative view of their field. These feelings were not specific to engineering — students in all the STEM fields studied experienced them. However, Tao and Gloria do not indicate that women are more likely than men to experience these feelings, nor do they indicate how common they are among their respondents. And, they note that other factors reduced the feeling of imposterism for some respondents — e.g., having ample opportunities to engage in meaningful research with like-minded others.

Casad, Petzel, and Ingalls (2019) surveyed 579 female STEM undergraduates at two U.S. public universities to examine whether they experience a threatening environment and, if so, how that affects them. They found that women in STEM experienced a negative campus climate and that this predicted lower academic engagement and self-esteem. Women in male-dominated majors such as engineering reported a more negative campus climate, and women who were members of racial minorities reported greater stigma consciousness, as well as more math and science disengagement, than white women did.

Leaper and Starr (2019) surveyed a group of undergraduate women to assess their experience of gender bias and sexual harassment. Most of their respondents reported experiencing bias or harassment in the past year and that these experiences were associated with reduced STEM motivation and career aspirations. Support from others, particularly friends, partially counteracted these negative effects. Leaper and Starr's sample consists of biology majors, so these results cannot be assumed to apply to engineering programs (particularly in light of Salehi, Holmes, and Wieman's research, discussed above). Nevertheless, the study documents the reality that some STEM students experience bias and harassment and points to the need for more research on engineering students to determine if Salehi, Holmes, and Wieman's findings pertain beyond Stanford.

Jensen and Deemer (2019) studied 363 female undergraduate STEM students at a Midwestern land-grant university. Their sample excluded students in the biological sciences. They found, unsurprisingly, that experience of a chilly climate led to higher levels of emotional exhaustion and cynicism and that this was related to higher levels of academic burnout. Chilly climate did not lower women's academic efficacy; the authors speculate that a hostile environment may motivate women to complete their goals.

Whether female engineering students' experiences are positive or negative, several studies we reviewed this year consider practices that might help to make their experiences better. Jackson et al.'s (2019) survey of almost 400 first-year STEM students at a public university in California found that female students with a low to average science identity showed greater science interest over time if they felt that others understood and encouraged their interest in science. Fisher et al. (2019) surveyed almost 500 graduate students in STEM programs in California (biological sciences were not included). Most of the students surveyed were women or members of underrepresented minority groups or, in some cases, both. The female students in the survey reported higher distress rates than their male peers, but the researchers found that feeling prepared for graduate classes, feeling accepted, and receiving clear expectations were positively associated with student publication rates and with subjective well-being. These findings should be treated with caution, however, as the sample is confusingly described and the researchers don't appear to have analyzed differences between women of different racial backgrounds, or between black and Latinx students. Nevertheless, the research suggests that relatively simple steps (such as making expectations clear) can significantly improve female students' experience.

Wylie (2019) reports on a very interesting ethnographic study of an engineering research lab at a medium-sized U.S. public university between 2016 and 2018. She describes this lab as unusual because part of the learning process in it involved hearing about "disaster" stories in which the lab director and her student assistants told stories about failures. Wylie argues that these stories differed from the usual "war stories" of competition and were characterized by self-deprecation and the encouragement of mutual trust and inclusion. She speculates that there may be a lesson here for those interested in the experiences of women in engineering:

> *"It is possible that this self-deprecating, inclusive discourse style common in Kate's lab originates with how Kate's identity and reception as a woman shape her worldview, including how she thinks about her research group. Kate's experience as a woman engineer may also explain why her lab has more women students than most engineering communities."* (834)

Syed et al.'s (2019) study of 502 current or recently graduated undergraduate STEM students found that research experience, instrumental mentoring, and involvement in a community of scientists were positively linked to engineering/science self-efficacy and identity, which in turn was linked to commitment to a STEM career. These relationships existed for both male and female students. Unfortunately, the researchers do not report on the likelihood that female students will have these experiences, pointing to a direction for additional research.

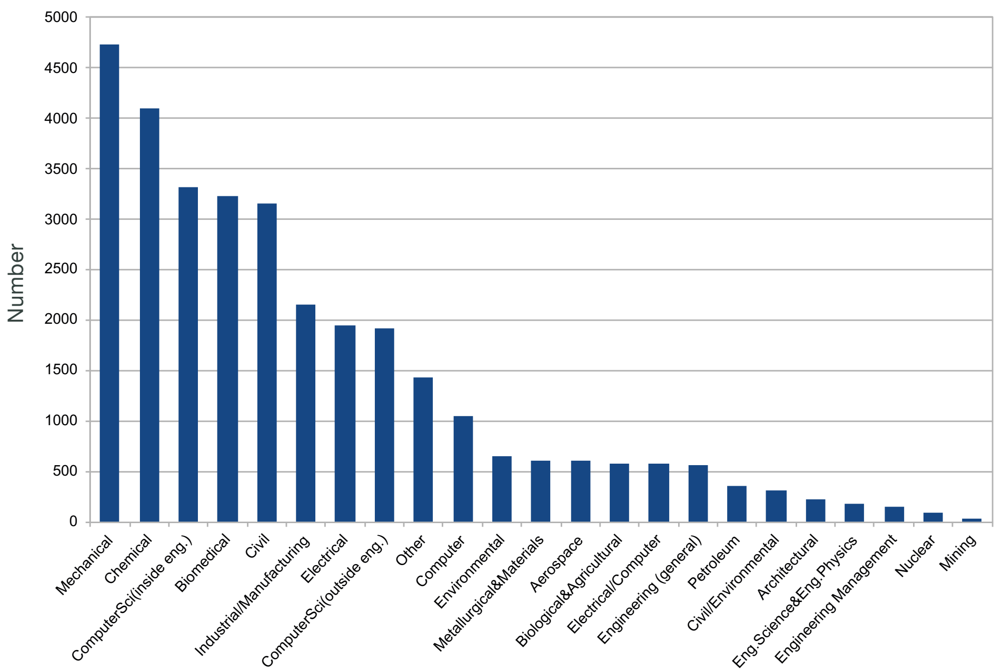
Jarboe et al. (2019) compared the characteristics of chemical engineering departments (a relatively high gender diversity engineering discipline) to electrical engineering (in which gender diversity is low). They examined Integrated Postsecondary Education Data System (IPEDS) data on more than 80,000 graduates of 95 universities for the period from 2010-2016. Surprisingly, the authors found no relationship between the gender diversity of faculty and the diversity of degree recipients, a finding at odds with some previous research. Gender diversity among EE graduates was significantly decreased when a separate degree in computer engineering was available. In contrast, there was no significant impact on gender diversity of ChE graduates when a biology-associated degree was available. Perhaps the most important finding in this study is that state variations in funding of K-12 education at the level of instructional staff support significantly impacted the gender diversity of graduates in both fields. Perhaps increasing the numbers of women enrolling in university engineering programs depends, in part, on increasing the availability of resources to primary and secondary schools!

Gelles, Villanueva, and Di Stefano (2019) conducted a small, exploratory study of faculty and graduate students at a Western public university. Their findings emphasize the potential positive value of "ethical" mentoring, rooted in six guiding principles: beneficence, nonmaleficence, autonomy, fidelity, fairness, and privacy. The authors also note the importance of being aware of the power imbalance in mentoring relationships and that mentors need to be aware of the unique characteristics of the students with whom they work.

Finally, Haynes (2019) describes a set of interviews she conducted with a small group of students who participated in an engineering living-learning

continued on page 18

Number of BS Engineering Degrees to Women by Discipline, 2018



Source: Roy, Engineering by the Numbers, American Society for Engineering Education, 2019

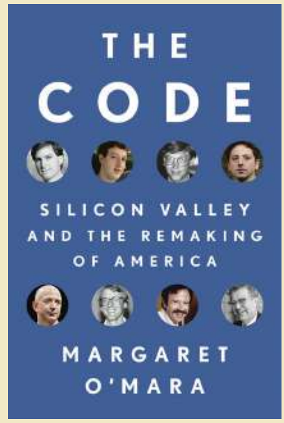
Women and the Tech Economy

A significant reason for the continued underrepresentation of women in STEM in general, and engineering in particular, is the reality that there are so few women in the sectors that have been growing fastest — computer science, computer engineering, information science; i.e., the sectors that make up the digital economy.

As social scientists and journalists have turned their attention to understanding why, we are beginning to learn a great deal about how the digital economy got to be so male dominated. It wasn't always that way, as the first "computers" were largely women; but as the work became more prestigious and better paid, and as the search for new employees came to focus on people who fit the emergent stereotype of the nerdy but brilliant male, women were gradually displaced. We have also learned much about the male culture of high tech, as books such as Emily Chang's *Brotopia* (discussed in last year's review) reveal the ways in which sexual harassment and toxic masculinity combine to make it an uncomfortable place for women to work. Two new books published this year offer additional insights into the culture of digital industry. Neither is intended specifically to be a book about gender and the tech sector. But, each points to an aspect of the sector's culture and mode of operation that helps to explain why few women find their way into it and why some of those who do eventually leave.

The Code: Silicon Valley and the Remaking of America, by Margaret O'Mara, Ph.D., tells the story of the rise of the Silicon Valley, from its origins in the aftermath of World War II to its current dominant position in the global digital economy. Her primary concern in the book is to dispel the myth that the rise of the Silicon Valley was purely the result of entrepreneurial independence. While she acknowledges that this was indeed a crucial element in the Valley's success, she emphasizes that government played a central role, from creating a legal context in which entrepreneurship and venture capital could flourish to directly funding many of the ideas that eventually became today's tech behemoths.

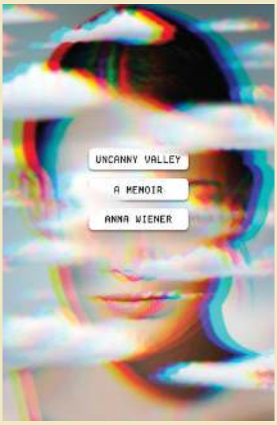
In detailing the history of the various enterprises that arose within the Silicon Valley, Dr. O'Mara makes clear that this is largely a history of men. She does make a point of focusing on a few women who played important roles in the Valley's development, but, in doing so, she reveals that some of the most important women were in non-technical positions. For example, she emphasizes the important role played by Mary Meeker, a Morgan Stanley stock analyst whose knack for picking the right internet companies in which to invest led to her being called the "Queen of the Net." The few women she describes who fulfilled important technical roles encountered discrimination and a hostile male culture in their work. For example, she follows the career of Ann Hardy, who began at IBM, then moved to Tymshare, where she played a central part in developing technology that allowed multiple simultaneous users on a single computer, but where she was not given the stock options given to men. When Tymshare was acquired by McDonnell Douglas in 1984, she became the company's only female vice-president, but was quickly pushed out, eventually founding her own company, which subsequently failed in the dot-com bust of 2001.



One of the reasons Dr. O'Mara identifies for the success of the Silicon Valley also helps to explain why women have been largely on the margins. She emphasizes that a key element in the tech industry's ability to grow large and powerful was the maintenance of tightly coiled networks of influence and investment:

> *"The Valley power players knew the tech, knew the people, and knew the formula that worked. They looked for "grade A men" (who very occasionally were women) from the nation's best engineering and computer science programs, or from the most-promising young companies, and who had validation from someone else they already knew… Keeping the networks tight and personal was a critical part of Silicon Valley's ability to keep the flywheel turning, to move from chips to micros to dot-com to the next Web without dropping the pace."* (pp 399–400)

While she holds out hope that a new generation of tech workers is emerging that may reject the tra-



ditional culture of the Silicon Valley, Dr. O'Mara also notes that women who have been active in efforts to foster change are skeptical that the tight networks that have fostered that culture are likely to break down in the foreseeable future.

Anna Wiener's *Uncanny Valley: A Memoir* provides a different insight into the male domination of tech. Wiener, a liberal arts graduate, became frustrated with her young career working in publishing in New York, so moved to Northern California to work for a data analytics firm. One of the few women employed by the company, she worked there for a year or so, but grew fed up with the pressure to work long hours, the "boys club" atmosphere, and the highly personalized managerial style, which made it difficult to know how one was doing or how to get ahead. Eventually, she left the company for an open-source start-up, which promised, and to an extent provided, a more relaxed work atmosphere.

Wiener notes that since she worked largely in customer support, she was "around tech" rather than in it. Nevertheless, she describes work environments in which women are not treated equally (e.g., are offered less or no opportunity to acquire equity in start-ups) and suffer from exposure to a kind of casual, toxic masculinity and incidents of more explicit harassment. While attending a conference on women in computers, she discovers that, if anything, women in technical roles suffered more from these problems than she did:

> *"Everyone I knew in tech had a story, first- or secondhand. That week, I heard new ones: the woman who had been offered an engineering job, only to see the offer revoked when she tried to negotiate a higher salary; the woman who had been told, to her face, that she was not a culture fit. The woman demoted after maternity leave. The woman who had been raped by a "10X" engineer, then pushed out of the company after reporting to HR. The woman who had been slipped GHB by a friend of her CEO. We had all been told, at some point or another, that diversity initiatives were discriminatory against white men; that there were more men in engineering because men were innately more talented."* (p. 178)

This aspect of Wiener's account will sound familiar to readers of other books about the male character of tech. Her description of the work itself, however, adds something new to our understanding of why the sector is so homogeneous. She argues that despite its self-presentation as disruptive and potentially revolutionary, and despite its counter-cultural veneer (casual dress, casual sex, drug use, communalism, etc.), the work in which she was involved was unsatisfying and not really radical at all:

> *"It seemed to me that whatever I had, that the men of Silicon Valley did not, was exactly what I had been trying to sublimate for the past four years. Working in tech had provided an escape from the side of my personality that was emotional, impractical, ambivalent and inconvenient – the part of me that wanted to know everyone's feelings, that wanted to be moved, and that had no apparent market value... The novelty was burning off; the industry's pervasive idealism was increasingly dubious. Tech for the most part wasn't progress. It was just business."* (p. 260)

Wiener acknowledges there are people (most of the ones she met were men) for whom this was enough. They enjoyed building systems; were drawn to power, wealth, and control; and "saw markets in everything" (p. 262). But this work tends to select for a particular kind of person, to produce a homogeneous culture and workforce. Combined with the sexism that thrived in that environment, this may help to explain why it is difficult to stimulate diversity in the tech sector.

Sources:

O'Mara, Margaret. 2019. The Code: Silicon Valley and the Remaking of America. *New York: Penguin Press.*

Wiener, Anna. 2020. Uncanny Valley: A Memoir. *NY: Farrar, Strauss and Giroux.*

continued from page 15

community at a U.S. university. This is a small, exploratory study, but it adopts the interesting approach of trying to learn about the positive metaphors female engineering students used to describe their experiences. She reports how the students describe one another as a support system, how they found the living-learning program to be both a starting point and a neighborhood, and how they tried to emphasize that being different is "normal." These findings point to the conclusion that creating a welcoming environment for female engineering students is helped by having female peers, by feeling a sense of community, and by the acceptance of difference.

CAREERS

In last year's review, we discussed several studies that explored the transition from engineering school to work, a transition during which some female engineering graduates leave engineering altogether. We did not read any studies of this transition this year, but we did find several studies of engineering workplaces, both academic and within the larger economy.

ACADEMIC ENGINEERING

Much of the research on female faculty and researchers we reviewed this year described problems and challenges. Cech and Sherick (2019) summarized results of a 2018 survey of 720 engineering faculty, all of whom were members of the American Society for Engineering Education (ASEE). Women faculty surveyed reported greater levels of marginalization and devaluation than male faculty. These differences were greater in departments in which the culture involved a strong commitment to "depoliticization" — i.e., the belief that social concerns such as inequality should be stripped from engineering to maintain its objectivity.

Miner et al. (2019) conducted two studies of early-career female STEM faculty at Texas A&M University to examine the effects of a chilly climate on their well-being. Their first study surveyed 96 early-career faculty, finding that early-career women were more likely than their male counterparts to experience ostracism (being ignored or excluded by others) and incivility (rude and discourteous behavior). In their second study, they surveyed 68 female early-career faculty, finding that they reported more ostracism and incivility from male colleagues than female colleagues. The experience of a chilly climate had negative effects on feelings of well-being.

Minnotte and Pedersen (2019) used data from a climate survey at a Midwestern university to examine the effects of departmental environment on work/life conflict among STEM faculty. They found that psychological safety (the ability to express oneself without repercussions) and perceived departmental fairness in how faculty members are treated reduced feelings of work/life conflict. They found no gender differences in these relationships. Unfortunately, the researchers do not report on respondents' overall feelings of work/life conflict, so it is not clear from their summary whether their male and female respondents had similar levels of work/life conflict or simply that the predictors of this conflict worked in the same way for both men and women.

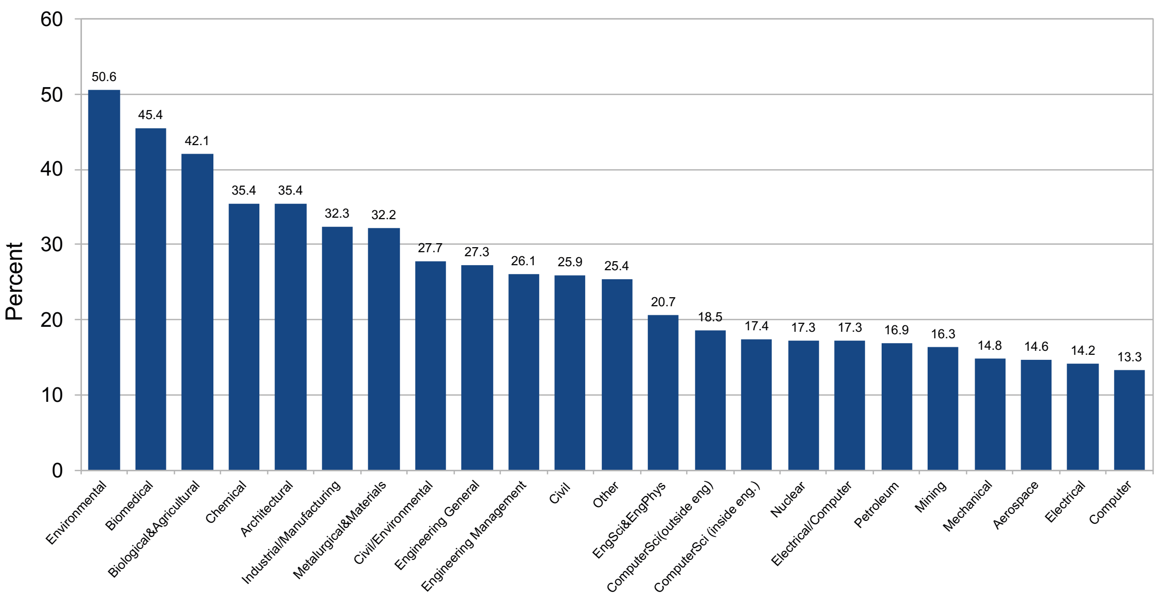
Sattari and Sandefur (2019) conducted a study of 30 male STEM faculty at two Midwestern universities. Their goal was to explore how male faculty thought about the issue of whether gender makes a difference in academic STEM disciplines, with a view to assessing how likely it is they would be supportive of efforts for change. A near-majority of their respondents saw STEM as gender blind and felt the egalitarian structure of academia did not allow gender to make a difference. Those who disagreed fell into two camps: those who acknowledged male privilege and those who argued that both men and women share challenges, but recognized that they are somewhat more significant for women. Sattari and Sandefur conclude that unless a serious effort is made to engage with male faculty on gender issues, it is not likely that they will be supportive of efforts to promote change.

Similarly, Beddoes (2019a) presented a new typology of engineering professors' "ways of not knowing" about gender in engineering and education. The typology was based on interviews with 39 engineering professors, men and women, at three universities in the U.S. Beddoes argues that understanding these ways of not knowing is important for developing future initiatives aimed at improving gender equity in engineering programs. However, this study was examining gender in the context of undergraduate education more specifically.

Several studies focused on differences between female and male faculty members' experiences of academic work. Macfarlane and Burg (2019) interviewed 30 faculty in the U.K. (half of whom were in STEM disciplines), confirming the now-familiar research finding that although both men and women prioritize research leadership, academic women are more likely than men to value the work of academic citizenship, including mentoring. They argue that this commitment to what they call "academic housework" — itself a somewhat disparaging turn of phrase — continues to hold back the careers of academic women. Zippel (2019) analyzed data from interviews with more than 100 STEM faculty and administrators at research-intensive universities in the United States regarding their ability to engage in international research collaborations. She found that it is more difficult for women to engage in these collaborations because gendered imagery creates "glass fences" that must be overcome. International collaborations were not valued highly unless they resulted in external funding or prestigious publications and/or comported with a masculine image of the researcher as "exploiter," someone who was taking advantage of lower overseas research costs or using the collaboration solely to gain access to information. Zippel argues that it is easier for male faculty to engage in collaborations that fit this pattern.

Dengate et al. (2019) found gendered differences in attitudes toward tenure criteria among Canadian STEM faculty that may be related to these gendered differences in work experience. They surveyed more than 400 STEM faculty at four Canadian universities finding that, while both felt the criteria for tenure needed to be broadened to recognize teaching and service more fully, male faculty were more likely to support the traditional model of academic success than women. Among women, there was significant, although not majority, support for what the researchers call a "progressive" model of tenure, which involved a complete revision of the value system underlying tenure, not just changing the weight given to service or teaching.

Percentage of BS Engineering Degrees Awarded to Women by Discipline, 2018



Source: Roy, Engineering by the Numbers, American Society for Engineering Education, 2019

ENGINEERING PRACTICE

As noted in the introduction, we read a larger than usual amount of research on engineers working outside the academy this year, something we have been urging for several years. As with research on academic engineering, much of this research focused on negative aspects of women's working experiences, although attention also was paid to the ways in which women cope.

Tao and McNeely (2019) analyze data from the National Science Foundation's Scientists and Engineers Statistical Data System (SESTAT) database on graduates in engineering and science to look at whether degree recipients are working in engineering. They studied those who received engineering degrees in 1993, 2003, and 2013. Overall, they found that only 59% of graduates were working in engineering occupations, with slightly lower persistence rates for women. Persistence rates for both men and women were lower for the most recent two cohorts studied, with women's persistence rates declining somewhat more. There were variations by race as well, which we discuss below in the section on intersectionality. Among both men and women, change in career interests was one of the top two reasons for leaving engineering; however,

The ARC Network: A STEM Equity Brain Trust

In 2017, the National Science Foundation (NSF) awarded almost $5 million (Award HRD-1740860) to the Association for Women in Science (AWIS) to support the ADVANCE Resource and Coordination (ARC) Network Building on the work of NSF's ADVANCE program, the ARC Network seeks to promote systemic change to address gender equity in the STEM professoriate.

Since 2001, NSF has invested almost $300 million to support ADVANCE projects aimed at increasing the representation of women in the STEM workforce. The ARC Network seeks to collect, analyze, and broadly share the knowledge created by the multitude of researchers funded by NSF ADVANCE. By connecting scholars and practitioners, the ARC Network is intentional in its efforts to improve the participation, advancement, and inclusion of diverse women in STEM. Online resources and stakeholder meetings facilitate the application and adaptation of the ADVANCE research for practical use.

To support the translation of research to practice, the ARC Network includes two components: community and research. The Society of Women Engineers (SWE) is proud to be an active ARC Network member as a representative of both the communities of practice and the research board. SWE's participation is an opportunity to help inform change efforts to improve gender equity in STEM by encouraging research-based applications in real-world contexts.

One of the major products of the ARC Network Community to date has been the development of a rich library of curated gender equity in STEM resources. The ARC Network Resource Library, including reports, white papers, toolkits, and other materials produced by researchers and practitioners, and the library continues to grow with contributions from network members. Join the community at www.EquityInSTEM.org and gain free access to these resources. Membership is free, and members have the opportunity to participate in a variety of virtual and in-person workshops and community collaborations.

Another important activity of the ARC Network is the Virtual Visiting Scholars program. Each year, members of the ARC Network Research Board select researchers to conduct meta-analysis, synthesis, and big data curation centered on STEM faculty equity. To date, five scholars have been selected, focusing on topics related to issues including mentoring women faculty of color, STEM faculty networks through an intersectional gender lens, and the effects of gender and intersectionality on citation practices.

The ARC Network also hosts a Community Convening each year, where members from higher education, industry, nonprofit, and government share research, resources, and best practices for STEM equity. You can learn more about the ARC Network, join to participate in future events, and have access to valuable research available through the online resource library at www.EquityInSTEM.org.

while men also emphasized pay and promotion opportunities, women were more likely to say they left because a job was not available. Among those who left, men were more likely than women to have moved to computer science; women were more likely than men to have left STEM altogether.

Research in the Netherlands conducted by van Veelen, Derks, and Endedijk (2019) suggests that being "outnumbered" may contribute to women's discomfort in some STEM fields. They surveyed 807 STEM graduates (of whom 177 were women) and found that feelings of gender identity threat increased the more women were outnumbered by men in their direct working environments (something that is highly likely in engineering workplaces).

Beddoes (2019b) presented findings on the biggest challenges faced by first-year practicing civil engineers in the U.S. Based on interviews with 12 women and six men, Beddoes (2019b) found that while both men and women experienced interdependence and learning new practices and material as their biggest challenges, negative interpersonal interactions in the form of harassment and being ignored were cited only by women as their biggest challenge. In fact, negative interpersonal interactions were not mentioned by any of the men anywhere in the interviews. The takeaway is that although both men and women newcomer civil engineers struggle with some of the same things, for some women there is an extra layer of challenges to navigate on top of the challenges they share with men.

Williams' (2019) study of the oil and gas industry points to the role employers can play in pushing women away from engineering. She interviewed 356 engineers and scientists who worked for a multinational oil company between 2014 and 2017. During an economic downturn in the industry, layoffs became inevitable. Williams found that, despite the official position that layoffs were based on skills and performance ratings, a discourse of the "deserving professional" affected layoff decisions in ways that disadvantaged women.

She discovered that managers were reluctant to lay off "deserving professionals" — native-born whites, who were under the age of 50 and were identified as the family breadwinner. Part-time workers, many of whom were women with small children, were particularly likely to be laid off.

Cech and Blair-Loy used the 2003-10 survey waves of NSF's SESTAT database on science and engineering graduates to examine the career trajectories of new parents. They found that both men and women often leave full-time STEM employment after the birth of their first child, but that women are considerably more likely to do so: 43% vs. 23%. Nonparents were significantly less likely to leave STEM employment, indicating that work/family issues continue to be a significant factor in causing STEM professionals, particularly women, to leave their jobs.

Sociologists of work, following the pioneering research of Christine Williams (1989), have long recognized that gender segregation is sometimes shaped by "glass escalators" that lead women and men out of occupations traditionally dominated by the opposite sex. Alegria (2019) interviewed 32 women engaged in tech work (the production, design, and maintenance of computer hardware, software, and networks) to determine if a glass escalator existed, moving them into managerial roles where the required "interpersonal" skills matched gender stereotypes. She found some evidence of this, although the effect was weak enough that she describes it as more of a "step stool" providing only a small lift. And, she found that it did not exist for women of color, none of whom experienced the kinds of unsolicited or unexpected promotions several of their white colleagues experienced.

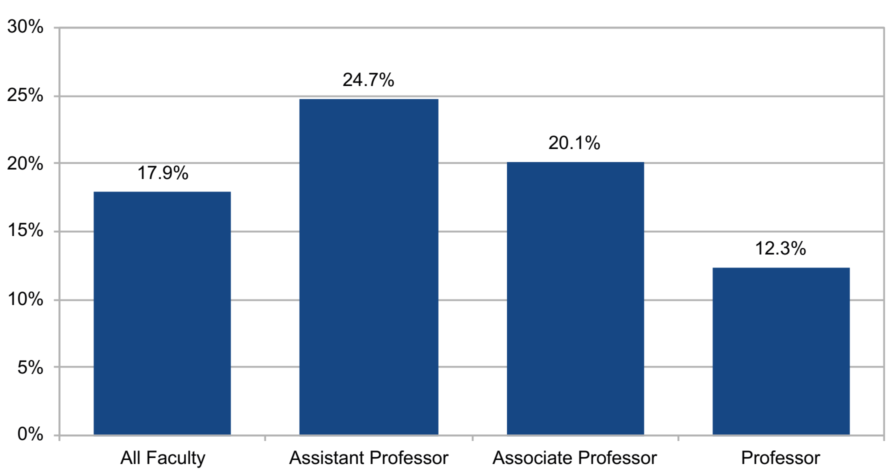
The studies reviewed above analyze women's departures from engineering jobs. Several studies we read this year focus instead on things that enable women to stay, even when they have negative experiences. Fernando, Cohen, and Duberley (2019) interviewed 50 women, at various stages of their careers, who worked at three companies in the British petroleum, mechanical, and automotive engineering sectors. Respondents agreed that female bodies attracted undue attention in their workplaces; they described the various strategies they adopted to navigate this "sexualized visibility." Some early-career women used the strategy of confirmation, positioning themselves as daughters or sisters to avoid sexual provocation, while others embraced their gender and challenged stereotypes by demonstrating high levels of competence (enhancement). Midcareer women tended to engage in avoidance, playing down their femininity to neutralize the possibility of sexual attraction, while some women at all career stages tried to "assimilate" by adopting stereotypically masculine behavior (a strategy that worked best for late-career women). The authors note that, while these strategies helped women navigate their workplaces, they tended to reinforce gender stereotypes.

Dutta (2019) reports on a study of 45 women employed as STEM professionals in Singapore. She describes how the women studied construct stories about their experiences and anticipated experiences and coping strategies to navigate obstacles they experience as women in traditionally masculine fields. The author finds that resilience is not something women develop in response to a sudden event — rather it is constructed on an ongoing basis, both in response to events and in anticipation of problems to come. The stories women develop allow them to cope with challenges as they arise and to communicate resilience to other women in the workplace.

Khilji and Pumroy (2019) also describe the strategies female engineers used to cope in male-dominated workplaces. They interviewed 10 female engineers working in a variety of industries. All described the gendered norms of their organizations and several volunteered stories about experiencing discrimination, both overt and covert. They employed various coping strategies, ranging from conforming to the rules, to negotiating to get around the rules, to defiance to establish their own rules. The authors don't offer an analysis of which strategy works best or whether there are patterns determining which women adopt which strategy. But, they make the important point that the women they interviewed were not passive in the face of organizational realities; they had "agency" and had been successful in using it to deal with the challenges they had faced.

These studies of working engineers in academic and nonacademic workplaces document the existence of gendered workplaces in which it is not always easy for women to make their way. The late-career and retired women engineers surveyed by Ettinger, Conroy, and Barr (2019) attest to the degree to which gender is deeply embedded in the interactions and social structures of engineering workplaces. Like the women in the studies describing how women "cope," Ettinger, Conroy, and Barr's respondents tended to rely on individual-level solutions, to emphasize the need to be strong, to persist, and to find a way to "just do it." As we will see in our concluding discussion of "what works," there is a case to be made that the gender integration of engineering will require more than individual solutions that focus on "improving" or "changing" women.

Women as % of Tenured/Tenure-track Faculty by Rank



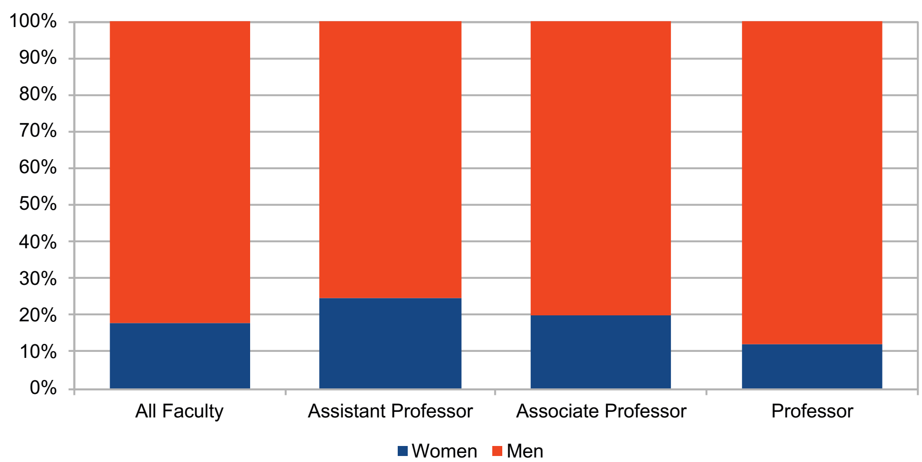
Source: Roy, Engineering by the Numbers, American Society for Engineering Education, 2019

INTERSECTIONALITY

As in recent years, we again wish to highlight studies with important new intersectional findings and/or approaches. The first such study employed an experimental design to test whether participants evaluate and pay an Asian American woman job applicant differently depending on whether her gender or race is made more prominent on the application. Rattan et al. (2019) present the results of three different experiments in which they had women and men participants (university students as well as adult nonstudents) evaluate a fake application for the positions of computer technician, tutor in computer science and English literature, and computer programmer. They found that the Asian American woman was evaluated differently depending on which aspect of her identity potential employers perceived as the most salient. Specifically, men rated the applicant as more skilled and more hireable and offered her higher pay in the computer-related positions when her race, rather than her gender, was made salient. The reverse was true as well; when her gender was made salient, men rated her less skilled and less hireable for those positions. While the studies did have some noted limitations, including small sample size and not being able to definitively determine which identity drove the different evaluations, they raise complex questions about how to reduce biases in hiring and pay decisions. Furthermore, as the authors point out, it will also be important for future research to explore these same questions for women who have identities in two negatively stereotyped groups, i.e., Latina women and African American women. Future research should also consider the complexity of racial identities as they intersect with gender. Research by Williams, George-Jones, and Hebl (2019) found that not just race but stereotypical appearance affected students' likelihood of persisting in STEM (e.g., Asian American students who looked stereotypically "Asian" were more likely to persist, while African American students whose appearance was more stereotypical were less likely to persist). This study did not consider gender, so there is an obvious need to see what an intersectional approach would find.

Another innovative intersectional study by Kargarmoakhar and Ross (2019) presents findings about four Muslim women's pathways into their chosen field and factors that affected their choices. Based on interviews with students in a computer science Ph.D. program at one public university in Florida, they found that the most relevant factors to the participants' choosing computer science were cultural factors and family impact. While the significance of family on women's STEM pathway decisions has long been documented, a new finding that emerged from this study is that the participants chose computer science, as opposed to

Engineering Faculty by Rank and % Gender



Source: Roy, Engineering by the Numbers, American Society for Engineering Education, 2019

other engineering fields, because they perceived it as a more feminine field. That contrasts with the dominant view of computer science as a masculine field in the U.S., thus highlighting how the gendering of certain fields varies by culture.

There were also several intersectional studies exploring the experiences and pathways of women of color that stood out this year, two of which came from a special issue of the *International Journal of Gender, Science and Technology* devoted to intersectionality and edited by Moncaster and Morris (2019).

The first large national survey in this group of papers was Tao and McNeely's (2019) analysis of engineering workforce pathway data (from the U.S. SESTAT database) for the 20 years between 1993 and 2013 (discussed above). They identified intersectional patterns that would not have been seen without specific attention to race/ethnicity. For example, white American men are retained in engineering careers at the highest rate, while Asian American women are retained at the lowest rate. For women specifically, white American and Hispanic American women are retained at higher rates than African American and Asian American women. The study also identified many differences in reasons for leaving among different groups of women and men, with white American women most likely to leave because of a change in career interests and family-related reasons, and African American and Hispanic American women most likely to leave due to the job they wanted not being available to them and a change in career interests.

Based on a survey of 2,104 women of color engineering students at 18 research-intensive universities in the U.S., Ro and Kim (2019) analyzed self-reported critical thinking, research,

Collaborative Network for Engineering and Computing Diversity

The Collaborative Network for Engineering and Computing Diversity (CoNECD; pronounced "connected") conference — "the only conference dedicated to all the diverse groups that comprise our engineering and computing workforce" (ASEE Education and Career Development, 2019) — was held for the second time in 2019. This year's conference brought together 326 educators and researchers for 79 sessions, up from 70 sessions last year.

Unlike many other conferences that focus on one population in engineering, CoNECD presentations cover the experiences of "women, individuals of diverse racial, ethnic, and socio-economic backgrounds as well as varied gender identities and expressions, the LGBTQ+ community, people with disabilities, veterans, and first-generation college students" (CoNECD, 2019). Also, by accepting peer-reviewed presentations in addition to peer-reviewed papers, CoNECD provides an important venue and forum for practitioners to share practices.

In 2018, the conference tracks were focused mainly on individual identity groups (i.e., there was a Gender track and a Race/Ethnicity track), which proved to be frustrating to authors of intersectional work and their audiences. A change was made, and in 2019, the sessions were organized into five tracks and six special topics. The tracks were Pre-college; Collegiate; Graduate; Faculty; and Learning Spaces, Pedagogy and Curriculum Design. The special topics were Identity; Computing and Technology; Social Justice and Reform; Evaluation and Grant Writing; Student Organizations; and Intelligence (CoNECD, 2019).

The conference was co-hosted by the National Association of Multicultural Engineering Program Advocates (NAMEPA), the Women in Engineering ProActive Network (WEPAN), and the Minorities (MIND) and Women in Engineering (WIED) divisions of the American Society for Engineering Education (ASEE). The event's 2019 organizing committee included Darryl Dickerson, Ph.D., president, NAMEPA; Catherine (Kitty) Didion, executive director, WEPAN; Beena Sukumaran, Ph.D., past division chair, WIED; Bevlee Watford, Ph.D., immediate past president of ASEE; and Rochelle Williams, Ph.D., chair, MIND (CoNECD, 2019).

ASEE Education and Career Development (2019). CoNECD Marketing Kit. Retrieved from: https://sites.google.com/a/vt.edu/conecd/opportunity-for-sponsorship

CoNECD (2019, April). CoNECD conference program. *Retrieved from: https://cdn.ymaws.com/www.wepan.org/resource/resmgr/conference-change-forum/2019-conecd/conecd_2019_program.pdf*

communication, and professional skills, as well as the effects of curricular, pedagogical, and co-curricular experiences on those skills, for four groups of women: Asian; black and other; Latina; and white. The only differences identified were that, compared with white women, Asian women rated their skills/learning outcomes in all four categories significantly lower, and black and other women rated their critical thinking skills lower. The authors point to a continued need to over-sample women of color, including Asian women who are often not seen as a minority group, in quantitative studies so that their experiences and outcomes can be better understood.

Yamaguchi and Burge (2019) analyzed data from 93 black women who work in computer science in the U.S. to identify intersectional themes in their experiences and identify needs specific to that group of women. The data included focus groups as well as a survey, and most participants were from academia rather than industry. The four themes/needs identified were: specifically link black women's (as opposed to underrepresented groups in general) recruitment, retention, and career growth to organizational/institutional and personal accountability; provide multifaceted cultural and educational supports for black women throughout the pipeline starting in middle school; provide opportunities for leadership development in school and workplaces; and collectively produce more research and scholarship specifically about, for, and by black women in computing.

Other research we reviewed echoed this emphasis on attending to the distinctive experiences of women of color in engineering. For example, Johnson et al. (2019)'s experimental study involving 351 black female students found that respondents who read a profile of a successful black professor at a hypothetical college of science and engineering reported greater anticipated belonging and trust than students who read a profile of a successful white professor.

Finally, Kang et al. (2019) employ an intersectional lens in their analysis of data on 1,921 middle-school girls in low-income communities in Michigan, North Carolina, New York, and Hawaii. The authors are interested in how middle-school girls develop STEM identities and whether race and ethnicity play a role in this process. They found that, in general, girls' self-perception in relation to science was positively associated with experience of science at home, outside school, and in science classes. However, there were significant racial and ethnic differences in their results. Asian American girls showed the strongest identification with STEM-related careers, while African American girls showed weak identification in all domains except biological sciences. Asian American girls had the most experience with science at home, while African American girls had the least. The authors report that experience with science in the classroom alone is not predictive of identification with STEM careers; they advocate steps to expand girls' exposure to science in a variety of settings and emphasize that that exposure should be culturally relevant and context dependent.

INTERNATIONAL COMPARISONS

Many of the studies we reviewed this year considered the experiences of women in engineering and science outside the United States. As we noted in the introduction, some of these studies, particularly those focused on European countries and Australia, do not emphasize the comparative dimension — they make little effort to identify what is distinctive about the experience of women in engineering in a particular national setting, so we have discussed the findings of several of these studies elsewhere in this review. Other research *does* make a conscious effort to introduce a comparative dimension to the study of women in engineering, something we highlight in this section of the review.

Singh and Peers (2019), in their contribution to the special issue of the *International Journal of Gender, Science and Technology* mentioned above, propose a framework for classifying countries based on the involvement of women in engineering. They argue that countries can be classified into four categories:

1. Developed countries that were never communist/socialist
2. Former communist countries, plus countries in the Nordic and Levant regions
3. Developing countries at various levels of development

Diversity, Unrest, and Silicon Valley

The image of Silicon Valley firms as open, communal associations of engaged, satisfied employees has been tarnished in recent years, as allegations of sexual misconduct and a "boys club" culture made headlines. This year, the turmoil continued, with reports that the culture of open discussion at companies such as Google and Facebook were in jeopardy and that some companies were struggling with employee trust. Although the issues underlying these tensions were varied, they often intersected with the gender issues that had emerged in previous years.

In November 2019, Google fired four employees for what it said were "clear and repeated violations of our data security policies." The four had been actively involved in labor organizing at the company, leading to claims that the company was engaged in union busting. In response, in December, the National Labor Relations Board (NLRB) launched an investigation of whether Google had broken the law in firing the four employees. Later in December, another Google employee, security engineer Kathryn Spiers, said she was fired for using a company tool to notify her co-workers of their right to organize.

The effort to organize workers at Google is rooted in a range of employee concerns, including discontent with the company's involvement with the Department of Defense and concerns over its involvement with the Department of Homeland Security, which were intensified when the company hired Miles Taylor, a former member of the Department of Homeland Security staff. However, the organizing efforts also are linked to concerns about diversity and discrimination, most notably to dissatisfaction about the ways in which the company handled complaints of sexual harassment and the perception that it was protecting senior employees who had been accused of sexual impropriety. The organizing efforts follow a large-scale walkout by Google employees in 2018, protesting payouts to executives accused of sexual misconduct. The recent firings have also raised questions of gender and sexual equity — the majority of those fired were women, and at least two self-identified as LGBTQ. News media reported that some members of the company's LGBTQ community felt unsafe at Google and had received electronic threats.

Google also was in the news for its 2018 firing of a male engineer, Kevin Cernekee, allegedly for his conservative political views. Cernekee is an open, vocal Republican who spoke out internally on various occasions during his time at Google. Some of his comments are linked to the gender controversies plaguing the Silicon Valley, including James Damore, author of a widely reported memo arguing that men were better suited for tech jobs. He also posted on company sites defending a colleague who denied that there was gender bias in hirings and criticizing a feminist colleague for not being able to handle criticism. Cernekee was accused of multiple violations of company policies, but complained that his dismissal was political. His complaint received national attention, including comments by the Republican House minority leader. In September 2019, the NLRB settled the dispute with the company, calling on it to allow greater debate and more open discussion on campus. Media reports suggest that this did not create a political truce within the company, instead fueling tensions prior to the firings of the four union activists in November.

Also in 2019, the U.S. Department of Labor (DOL) brought suit against Oracle for what it said was widespread discrimination against women and people of color. The suit claims that the company systematically excluded African Americans and Hispanics in its hiring decisions and that women and people of color were paid significantly less than their white male counterparts. The company is accused of favoring Asian applicants in hiring, a group who were then underpaid (the DOL suggested that Asians' dependence on the company for work authorizations enables this underpayment). Women, African Americans, and Hispanics also were found to be underpaid, with the gap between them and white male employees growing with tenure at the company. An earlier suit, filed in 2017, estimated that the company owed employees as much as $400 million in compensation for these inequities. The new suit suggests that Oracle had not changed its practices, so the amount owed to underpaid groups of workers is now significantly more. Oracle denies the allegations, stating that it is in compliance with regulations and committed to equality. The company is reported to have sued the DOL to end the discrimination lawsuit, alleging the DOL's actions had usurped the role of the federal courts in handling complaints regarding discrimination. While the issue remains unresolved, these claims of gender and racial discrimination, the ongoing controversy over sexual harassment, and the tensions flaring up at companies such as Google present a picture of the Silicon Valley as a place where diversity has become a flashpoint for conflict.

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4. Countries of the Middle East and North African regions, plus the Levant

The authors use this scheme to note differences in women's participation in engineering. For example, they find that women's participation in category one tends to hover between 10 and 20%, while it is much higher (but declining) in many of the countries within category two. Women's participation in engineering in category four is quite high, while it is variable in category three, in part because of limited access to higher education in those countries. The authors also note that affirmative efforts to increase the numbers of women in engineering tend to be concentrated in the countries grouped in category one. There are some obvious questions one can pose to this classification scheme (the Levant appears in two places, developing countries vary tremendously, the differences between Nordic countries and formerly communist countries are significant, etc.). Nevertheless, the authors draw attention to the reality that the numbers of women in engineering vary significantly in different countries and that the variations are not related in any simple way to levels of economic development, a point made quite persuasively in research summarized in last year's review.

Several studies we read this year described the experiences of women in Middle Eastern countries, which, as Singh and Peers' review makes clear, are countries in which female engineers are relatively common, despite strongly patriarchal cultural settings. Al-Aawi et al. (2019) review the situation of women engineers in Bahrain, where 43% of engineering graduates are women. Although Bahraini cultural stereotypes create barriers, and while employers prefer not to hire married women with children, and while most respondents agreed that employers prefer to hire male engineers, women represent a significant portion of the engineering workforce. They are 35% of public sector engineers, 21% in the private sector, and respondents expressed a high degree of confidence in their ability to succeed as engineers.

Not all Middle Eastern countries appear quite as open to working women engineers, however. Mozahem et al. (2019) interviewed female engineering students in Lebanon, finding that female engineers face significant hurdles in both professional and social settings and that family and friends often question their choices. Houjeir et al. (2019) report on women in STEM higher education in the United Arab Emirates. Women outnumber men in the three UAE universities studied, and constitute about half of the engineering students at one of them. But the researchers report that women in the UAE have little incentive to join the workforce after graduating and that family priorities and a culture of modesty requiring the separation of women and men makes their involvement in engineering work a challenge.

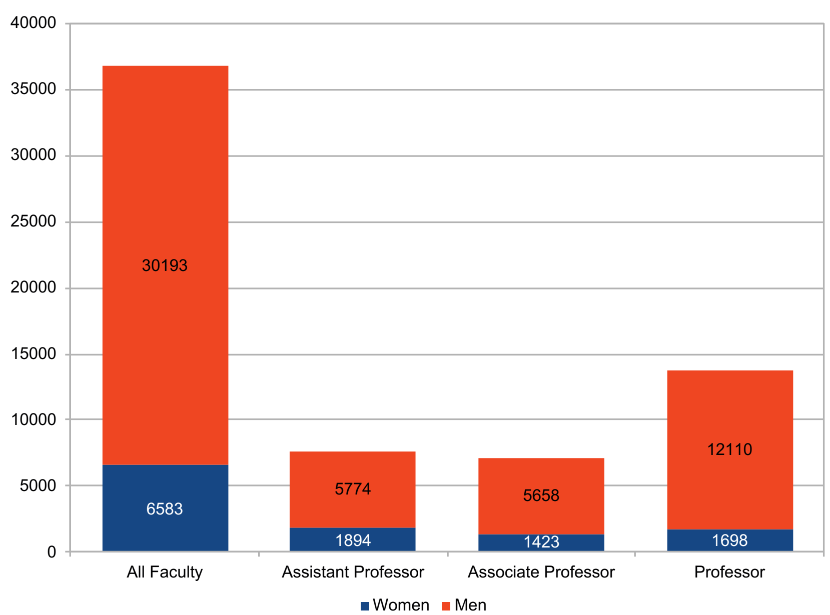
One other study on a predominantly Muslim country, this time not in the Middle East, is Edirisinghe and Cheok's (2019) study of female research engineers in Malaysia. Women make up almost half of engineering students in Malaysia, and outnumber men in other STEM disciplines. However, the researchers report that the women to whom they spoke tend to see work as a steppingstone to marriage and were more concerned with work/life balance than with advancing their careers.

Rincon, Korn, and Williams (2019) present findings on the state of the engineering workplace for women in India. Based on 693 survey responses (61% women, 39% men ages 25-43), Rincon et al. found that women in India faced the same well-documented gender bias challenges as women in Western countries, with similar effects on their careers. However, they note that there are distinctive features to the experience of bias among female engineers in India. Specifically, they found the experience of "tug-of-war" bias, in which gender bias leads to tensions among women, to be more common in India. Rincon, Korn, and Williams also describe women's ambivalent response to the Shops and Establishments Act, which was intended to protect women by prohibiting late-night work. Many said that they had experienced negative effects because of this law, but others talked about how it made work/life balance easier to achieve. They also found that while women faced gender biases, men faced biases related to where they were from and the language they spoke.

MEN AND MASCULINITIES

There was one relatively new emphasis in the literature on diversity in engineering we reviewed this year: research on men and masculinities in

Engineering Faculty by Rank and Gender



Source: Roy, Engineering by the Numbers, American Society for Engineering Education, 2019

engineering. Given the interest in men as allies in the effort to increase gender diversity in engineering, this is a promising research direction. In addition, understanding masculinity in engineering may further understanding of the obstacles women in engineering encounter, since many researchers have found the masculine culture of engineering to be the most significant barrier women engineers face.

We have already noted several studies that compare women's and men's experiences, as well as Sattari and Sandefur's (2019) study of male faculty's perceptions of gender bias in engineering. Other research comparing men and women in engineering in the university context included a paper by Pla-Julián and Díez (2019). They conducted a survey of four groups of students in Spain (men and women engineering majors, and men and women humanities/social science majors) to determine students' perceptions of societal-level gender equality and the importance of efforts to promote social equality. Compared with the other three groups, the men engineering students — inaccurately — perceived the most social equality between men and women, and they were the group that rated the importance of efforts to promote gender equality lowest. This is troubling indication of some of the difficulties faced by those working to advance women in engineering in Spain.

In another comparative survey, this time of engineering students at three universities in Canada, Denis and Heap (2019) identified several differences between men and women: Women were significantly more likely to have had an A average in the previous year (40% vs. 26%), and significantly more women held leadership roles in engineering or technical societies (30% vs. 10%); but men were more likely to participate in engineering competitions and to find that participation encouraging. However, overall the authors noted many similarities between men and women in terms of their perceptions of support for students, having an influential role model or advisor, and family backgrounds. This survey was one part of a larger mixed-methods study with data collected between 2004 and 2008.

Another new research direction for students of gender in engineering is exemplified by Danielsson et al.'s (2019) research examining the experiences of four "working class" men mechanical engineering students in Sweden. This study utilized ethnographic observations, interviews, and video diaries to better understand the socially and discursively constructed identity work done by the participants navigating their engineering program. The authors found that while a norm of "technicist" masculinity easily aligned with participants' identity trajectories, the norm of "laddish" masculinity created a "troubled" identity trajectory for one participant. The study also revealed that project work was difficult to incorporate into some of the students' identity trajectories. By identifying different types of masculinities, and linking them to social class, this article demonstrates the need to study men, not just women, in order to advance understandings of gender in engineering, which has been a prominent gap in gender research in engineering (Beddoes, 2019c).

Research on men and masculinities in engineering was encouraged, this year, by the publication of a special issue of *Engineering Studies* on men and masculinities in engineering edited by Kacey Beddoes (2019c). Several of the articles reviewed here (Danielsson et al.; Pla-Julián and Díez; Ettinger et al.) were included in that special issue. In another article from that same collection, Secules (2019) reflects on his own ethnographic observations of masculinity, competition, and competition-as-masculinity in engineering education through historical lenses. He problematizes often unseen and taken-for-granted aspects of masculine engineering education culture and summarizes historical literature to frame the findings. He notes how engineering has been "constructed" as identity-less — "Engineering is quintessentially colorblind and class-blind and gender-blind — it just happens to be occupied consistently by middle-class straight White able-bodied men." (199)

Within this frame, the relative absence of women seems unremarkable, and the emergence of women and minority group members in engineering represents the appearance of a mysterious "other" who constitute a problem of integration. Secules also stresses the role played by competition in constituting engineering as male. He notes how competition is an important part of engineering

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education but has been found to be uncomfortable for female and minority students, who are drawn to more collaborative and cooperative learning environments. Readers may wish to consider Secules' article in combination with Amy Sue Bix's (2019) history of concrete canoe competitions and the growth of competition culture in engineering programs, which also appeared in *Engineering Studies*, and touches briefly on gender issues as well. It is to be hoped that research on masculinity in engineering will continue in future years, enabling a deeper understanding of the ways in which engineering culture is gendered.

WHAT WORKS?

As in previous years, many of the studies we reviewed focus on evaluating interventions designed to help increase the numbers of women in engineering and/or to support their progress within the profession. In summarizing this portion of the research literature, we would like to emphasize two important themes. First, several studies we reviewed this year raise the question of whether interventions designed to support women in engineering can have unintended consequences or even backfire in some ways. These studies need to be read critically, but do sound an important note of caution to which future research should attend. Second, we noted again this year an ongoing debate within the literature exploring how to encourage gender diversity in engineering between approaches that focus on equipping women to cope better with the conditions they encounter and approaches that call for structural changes to engineering itself. The emphasis on the role of psychological and attitudinal variables in explaining the underrepresentation of women in engineering is clearly linked to the former approach. But, if diversifying engineering requires changing engineering itself, then future research, and actions, will need to focus more on structural factors such as engineering's masculine culture, discriminatory practices, or the experience of harassment and bias.

UNINTENDED CONSEQUENCES

One important area of interest we observed in the literature this year were the outcomes of diversity and bias interventions, including negative, or unintended, outcomes. Martin and Phillips (2019) present findings from a series of six different experiments that compared the effects of "gender-aware" versus "gender-blind" interventions. By "gender-aware," they mean emphasizing differences between men and women, and women's unique attributes/qualities. By "gender-blind," they mean emphasizing similarities between men and women. It is important to note that their participants were drawn from general populations and were not necessarily in STEM fields themselves. Martin and Phillips' conceptualization of "gender awareness" as emphasizing women's unique attributes/qualities is rather limited and essentialist, so this research should be treated with caution. Nevertheless, the upshot across the six studies was that, among men, gender-blindness related to and led to less gender stereotyping about women's STEM competencies. However, the authors discuss many caveats, nuances, and cautions for interpreting and drawing implications from these findings. For instance, they recognize gender-blind approaches carry their own problems.

Pietri et al. (2019) looked at the effects of video interventions for diversity in STEM (VIDS) in a series of three studies that included participants from the general U.S. population as well as women scientists. On the one hand, the interventions increased bias literacy and lowered gender bias among both men and women, which was a desirable outcome. On the other hand, however, the interventions decreased women's sense of belonging in the sciences and increased negative affect and social identity threat for women from the general population and women scientists, which was an undesirable outcome. Negative sense of belonging was mitigated by the inclusion of a woman scientist as a role model, but stereotype threat was not. The authors conclude that, "Interventions (such as VIDS) that increase bias literacy therefore unintentionally may act as an external cue that increases women's social identity threat. Although such interventions can help address one problem (bias), they also may increase another (social identity threat), further exasperating gender disparities in STEM" (p. 529).

In a survey study from the U.K., McCarthy et al. (2019) analyzed data from 700 employees (22% women) at three civil engineering companies to determine if there was a relationship between perceptions of overall fairness in the company and attitudes toward equality initiatives. They found that there was indeed significant correlation between the two, suggesting that responses to and outcomes of equality initiatives for underrepresented groups may depend, at least in part, on how fair the organization is perceived to be overall. The authors conclude that without first addressing overall perceptions of fairness, equality initiatives may be "short-sighted and dangerous." We would add that this conclusion raises interesting and difficult questions about potential tensions or incompatibilities in that approach, however, given that fairness is not an objective concept and dominant groups typically get to define what is fair (Beddoes & Schimpf, 2018). For example, parental leave is often seen as unfair by men in STEM academic departments (Beddoes et al., 2013); yet, that is a common gender equality initiative.

Some of these studies are experimental, and such studies must be read with a critical eye to see if the intervention bears similarities to the types of interventions taking place in engineering programs and workplaces. For example, Lewis, Sekaquaptewa, and Meadows (2019) conducted experimental research with 143 STEM majors at a large Midwestern university to examine the effects of exposure to a counter-stereotypic video on gender gaps in verbal participation in mixed-gender teams. They found that students exposed to the counter-stereotypic presentation had groups that showed relatively equal gender participation, while those who saw the stereotypic presentation had groups in which men dominated. This is suggestive evidence, but one must ask whether the brief exposure involved would have a similar effect in real workplaces, where traditional gender roles remain in place and where male team members may also have seniority and greater power.

CHANGE THE WOMEN OR CHANGE ENGINEERING?

Many interventions designed to promote gender diversity in engineering focus on women themselves. They seek to do things such as bolster women's feeling that they "belong" in engineering, to encourage women to be more confident about their skills and abilities, and to provide them with resources to compensate for advantages their male colleagues may have had. A report on collaborative work done by DiscoverE and the Concord Evaluation Group, *Despite the Odds: Young Women Who Persist in Engineering* (2019), illustrates well this type of intervention. The report seeks to identify the primary reason girls choose to pursue engineering and the factors that affect whether or not they persist. Their review of the literature points to a series of characteristics of women themselves: demonstrating an interest in and positive attitudes about engineering, seeing value in the profession, demonstrating engineering self-efficacy, embracing a STEM identity, and feeling a sense of belonging, and identifies examples of interventions that might help young women interested in or already involved in engineering to develop them. They also identify resources outside the workplace (support networks, social capital) that can help women succeed in the profession. For the most part, the review says little about engineering itself or about how it might become more welcoming to women.

Diekman, Clark, and Belanger (2019) adopt a similar approach in their effort to identify common ground in the wide-ranging literature on women in STEM. Their review notes that there are multiple, competing explanations for women's underrepresentation; what they see as common among the various theories is an emphasis on the incongruity between women and STEM and on the incongruity between STEM and student values. Based on this, they recommend interventions that challenge stereotypes, align STEM activities with students' values, and cultivate growth mindsets related to STEM ability. With the partial exception of the second strategy, these intervention tactics focus on adapting women to engineering, rather than on the reverse.

This approach seems to build on attitudes we read about in several of this year's studies of female engineers. We have already summarized Ettinger, Conroy, and Barr's (2019) study of late-career and retired female engineers, which found that they adopted and advocated an individualistic approach to dealing with the challenges of being a woman in engineering. Myers, Gallaher, and McCarragher (2019) also describe women in STEM who see gender diversity through an individualistic lens in their study of 45 undergraduates at a large Midwestern university. They call the approach they encountered "STEMinism," in which women recognize gender differences and inequalities, but don't problematize gender power dynamics; from this perspective the solution to the problem involves individual women helping themselves. Nash and Moore (2019) discovered a similar set of attitudes among the 25 aspiring female STEMM leaders from five countries whom they interviewed. They found that these women recognized sexism and gender bias in their organizational context, but at the same time described science and engineering as gender neutral. They made considerable use of the "lean in" vocabulary to explain organizational success; the lean-in approach has been found by Chrobot-Mason, Hoobler, and Burno (2019) to be effective at times, but also to present dangers, since others may not be accepting of women who lean in ('he's aggressive, she's pushy...').

Not everyone agrees that engineering or STEM more broadly are meritocratic and gender neutral, or that an individualistic approach to change will be effective. Virginia Valian (2019), for example, writes of the need to collectively find ways to combat harassment and abuse in the workplace. Greider et al. (2019), writing in *Science*, summarize a policy forum held at Cold Spring Harbor in late 2018 (Valian was a participant in this forum as well) that recommended a series of efforts to end harassment and improve outcomes for women, most of which involved changing organizations, not just individuals: institutional sanctions for those who are found guilty of sexual harassment; transparency in start-up packages, salaries, and internal grant funding, etc.

Programs such as NSF ADVANCE also reflect a more structural approach to achieving gender diversity since Institutional Transformation grants, by definition, focus on changing departments and institutions. Of course, a more structural approach does not guarantee complete success, as two reviews of ADVANCE published this year make clear. Rosser et al. (2019) summarize the effects of NSF ADVANCE, as well as the Athena SWAN program in the U.K., finding that while progress has been made in both countries, attributing those successes to these programs is difficult, particularly in the case of Athena SWAN. They also note that sustainability has proved to be a challenge.

Zippel and Ferree (2019) also review the ADVANCE program in a provocative article in *Gender, Work and Organization*. They argue that while ADVANCE has had some success, it has been limited by the contradictory voices to which it had to attend. They identify tensions among the interest in gender equality that animated the program in the first place, the managerial interests that had to be satisfied to get universities to buy in, and the norms of scientific knowledge production that were imposed by the program's location in NSF. These conflicting influences have tended to focus the program on measurable results that are consistent with university priorities (e.g., research productivity) and to place an emphasis on publishable results, which is often difficult for single-site projects or for studies that involve conclusions that make people uncomfortable. None of this means that programs like ADVANCE are bad ideas or failures; but these reviews do indicate that even large-scale programs that focus on institutions need to be reviewed critically.

We conclude by noting a thought-provoking approach described in a small-scale study (Petray et al. 2019) of an Australian program intended to engage girls in STEM. The program involved drone-flying camps at two locations in Northern Australia. The camps were designed to provide girls with an opportunity to try flying and coding mini drones and to engage with peers and role models. What is innovative about this program is its approach to recruitment. While it attracted girls with STEM interests, it made a conscious effort to attract girls who did not already have a strong STEM identity or record of academic success in science or math. About half of the participants listed the arts and humanities as their favorite subject area. The authors praise this approach, arguing that it challenges the "pipeline" metaphor they believe limits the recruitment of women into engineering by focusing on only one source of potential recruits. In their view, the secondary school curriculum creates a structural barrier against girls entering STEM by prioritizing the early possession of "hard" knowledge in STEM (which can be acquired later) over "soft" skills such as creativity, innovation, and artistic ability. Not only would more women be attracted to STEM disciplines if those disciplines were more attuned to the value of these skills, and more welcoming of people who had them, but STEM disciplines would be enriched by the resulting changes: an increased emphasis on teamwork, creativity, and communication. This small intervention demonstrates what "changing engineering" might involve, and why it could benefit both women and the profession itself.

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