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Breaking into the Lab: Engineering Progress for Women in Science and Technology

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ABSTRACT
Although the overall percentage of women receiving degrees in Science, Technology, Engineering, and Mathematics (STEM) fields has increased in the US during the last three decades, the data mask wide variance among fields. Responses of over 300 current women scientists who were National Science Foundation Professional Opportunities for Women in Research and Education (POWRE) awardees—both junior and senior—document that despite the increases, many of the same issues for women persist today, although the obstacles or expression of experiences may differ slightly. Balancing career and family, time management, isolation, lack of camaraderie, poor mentoring, issues experienced by dual career couples, as well as gaining credibility and respectability from colleagues and superiors in science remain problematic. Additionally, sexual harassment and gender discrimination still occur too frequently. Data from interviews of current scientists reveal what happens to successful women as they become senior and consider going into administration, and whether women are excluded from leading edge work in the commercialization of science and technology transfer. Since the focus of scientific research globally has shifted from basic to applied research and innovation, the dearth of women receiving patents suggests a new twenty-first-century face on the old story of women's exclusion from the leading edge of science.

Keywords: academic women scientists; POWRE; STEM; technology transfer; work-life balance; dual career couples

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INTRODUCTION

Despite large gains in both the numbers and percentages of women in most Science, Technology, Engineering, and Mathematics (STEM) fields over the last 30 years in the United States, gender inequities persist.[1] A few recent examples indicate that gender issues exist at all levels of STEM. A nationwide sample of 127 male and female science professors preferred a man over a woman when asked to choose between two undergraduates with the same qualifications to manage their lab (Moss-Racusin, Dovido, Briscoll, Graham & Handelsman, 2012). A study conducted at the University of Washington of a large introductory biology class revealed that male students chronically overestimate the knowledge of their male peers, while underestimating the knowledge of their female counterparts (Grunspan et al., 2016). When students of varying sex and ethnicity asked for mentorship via e-mail requests to 6,500 tenure track professors at top research universities, those sent by researchers presenting as white men were more likely to receive positive responses (Chugh, Milkman & Akinola, 2014). A study of 85,000 published scientific papers revealed that men and women perform different roles in labs producing scientific research. Women perform the experimental work involved in pipetting, centrifuging, and sequencing, while men analyze data, conceive the experiments, contribute resources, or write up the study (Macaluso, Lariviere, Sugimoto & Sugimoto, 2016). In short, gender inequality and disparity in science persist.

One possible reason for gender inequity in STEM may result from the fact that there have historically been less women obtaining STEM degrees compared to their male counterparts. In the United States, women currently earn more bachelor's and master's degrees than men (Table 1). In 2012, women earned 57.4% of the bachelor's degrees in all fields and 60.1% of all master's degrees. From the beginning of the year 2000 onwards, women also earned more of the bachelor's degrees in science and engineering (S&E), although they earned only 45.6% of the master's degrees in science and engineering in 2012. In 2012, women earned 61.8% of the PhDs in non-science and engineering fields, but only 41.1% of the PhDs in science and engineering received by US citizens and permanent residents (NSF, 2015).

The aggregated data mask the wide variance of women's participation among the different fields in STEM (Table 1). Major differences occur in the distribution of gender across the disciplines. Overall, at the bachelor's level, women earn the majority of the degrees in the non-science and non-engineering fields, such as the humanities, education, and fine arts, as well as in the science fields of psychology, the social sciences, and biological sciences. Men earn most of the degrees in the physical sciences, earth, atmospheric, and ocean sciences, mathematics and statistics, and especially in computer science and engineering (NSF, 2015).

Table 1: *Women as a percentage of degree recipients in 1996 and 2012 by major discipline and group*

	All Fields		All Science & Engineering		Psychology		Social Sciences		Biology		Physical Sciences		Geosciences		Math/ Statistics		Engineering		Computer Science	
	1996	2012	1996	2012	1996	2012	1996	2012	1996	2012	1996	2012	1996	2012	1996	2012	1996	2012	1996	2012
Percentage of bachelor's degrees received by women	55.2	57.4	47.1	50.5	73.0	76.7	50.8	54.7	50.2	59.3	37.0	40.6	33.3	39.1	??.?	43.1	17.9	19.2	???	18.2
Percentage of master's degrees received by women	55.9	60.1	39.3	45.6	71.9	79.1	50.2	55.9	49.0	57.5	33.2	35.9	29.3	42.7	??.?	40.6	17.1	22.9	??.?	27.8
Percentage of PhD degrees received by women	40.0	49.6	31.8	41.1	66.7	72.6	36.5	48.7	39.9	53.1	21.9	31.5	21.7	43.3	??.?	28.2	12.3	22.6	???	21.4

Sources:

Calculated by author from data in NSF 2015, *Women, minorities, and persons with disabilities* ; Table 5.1 for Bachelors, Table 6.2 for Masters, Table 7.2 for Ph.D. for 2012 data.

Calculated by author from data in NSF 2000, *Women, minorities, and persons with disabilities*; Table 2-6 for Bachelors, Table 4-3 for Masters, Table 4-11 for Ph.D. for 1996 data.

Unfortunately, the percentage of women earning bachelor's degrees in computer science and engineering has actually decreased from a decade earlier, in contrast to all other science and engineering fields, where the percentage of women bachelor's degree earners has increased. For computer science, this continues a downward trend since 1984, when women earned 37% of the degrees in the field (NSF, 1997).

At the level of the master's degree, women earned the majority of degrees in 2012, not only in non-science and non-engineering fields, but also in biological sciences, psychology, and the social sciences (Table 1). Women earned less than half of the master's degrees in earth, atmospheric, and ocean sciences, mathematics and statistics, physical sciences, computer science and engineering (NSF, 2015), although in all fields, with the exception of computer science, the percentage of women master's degree recipients has increased compared to a decade ago. The percentage of women at the master's level remains low in engineering (22.9%), while in computer science the percentage decreased to 27.8% over the decade, although not as markedly as the percentage decrease of those receiving bachelor's degrees (Rosser, 2017).

Women still earned less than half of the science and engineering PhD degrees in 2012 (Table 1) in all fields except psychology, biology, and a few social sciences, such as anthropology, linguistics, and sociology. Women earned 53.1% of the PhDs in biological sciences (Table 1). Although the percentage of women earning PhDs in 2012 in computer science (21.4%) and engineering (22.6%) remains relatively low, the percentage has increased since 1996 (Table 1) (NSF, 2000; 2015).

In short, in many of the social sciences and the life sciences, women have reached parity in the percentages of degrees received (Table 1). In other areas, such as the geosciences, as well as mathematics and the physical sciences, the percentages of women continue to increase, although they have not yet achieved parity. In contrast, in engineering and computer science the percentages of women have dropped during the past decade at the bachelor's level, and also at the master's level in computer science.

Aggregated data fail to adequately reveal women's withdrawal at every stage of the educational and career STEM pipeline. Similarly, academia reflects this decrease of women at each rung of the career ladder (Table 2); women decrease in percentage at the more prestigious and financially more rewarding levels of the profession. Women in US academic liberal arts colleges and in universities reported by the National Science Foundation (NSF) in 2015 make up 42.8% of assistant professors, 34.0% of associate professors, and 20.8% of full professors in science and engineering. These percentages represent increases at all ranks compared to a decade ago, although R1 Doctoral Universities (Highest Research Activity; formerly, Research I institutions) have fewer female professors, as well as women at the lower ranks of assistant and associate professors compared to less research intensive institutions (NSF, 2015).

Table 2: *Percentage of women doctoral scientists and engineers in academic institutions by field and rank in 1997 and 2013*

	All Science & Engineering		Psychology		Social Sciences		Biology/ Life Sciences		Physical Sciences		Engineering		Math & Statistics		Computer Science	
	1997	2013	1997	2013	1997	2013	1997	2013	1997	2013	1997	2013	1997	2013	1997	2013
Assistant Professor	36.9	42.8	61.0	68.5	39.6	49.5	36.7	46.0	26.1	32.1	13.7	22.8	24.1	38.5	-	21.0
Associate Professor	25.7	34.0	44.3	57.6	32.4	46.7	22.9	31.3	13.5	25.3	6.3	19.0	14.3	22.2	-	25.0
Full Professor	11.6	20.8	22.5	41.2	14.9	26.6	13.1	23.4	4.2	15.2	1.4	7.5	6.7	16.2	-	12.5
Total (includes Instructor/Lecturer)	25.1	33.5	43.1	58.3	28.3	40.5	27.8	37.6	13.3	23.9	6.5	15.5	14.2	26.6	-	16.5

Source: First column on left for each discipline calculated by author from Commission on Professionals in Science and Technology (CPST), 2000, Table 5-1.]

Source: Second column on right for each discipline calculated by author from data in NSF, 2015. *Women, minorities, and persons with disabilities* , Table 9-25. • 1997 data for Math and Statistics includes Computer Science]

Studies have drawn attention to the failure of the elite research institutions to hire women faculty in general, and women science and engineering faculty in particular, at rates comparable to the number of women receiving PhD degrees from the science and engineering departments of those institutions (Nelson, 2007; Rosser, Daniels & Wu, 2006). Many have sought to explain the small number of women in tenured positions relative to the percentage of qualified women with PhDs and the reasons for their relatively larger percentages in industry (Catalyst, Inc., 1999; Etzkowitz, Kemelgor, Neuschatz & Uzzi, 1994), small liberal arts colleges (Rosser, 2004; Schneider, 2000), or non-tenure track positions, such as research scientist or lecturer in research institutions (Arenson, 2005; Mason, Goulden & Frasch, 2009; Mason, Wolfinger & Goulden, 2013). Although some disciplines, such as physics and astronomy, appear to be hiring women into tenure track positions at R1 Doctoral Universities at approximately the same percentages at which they receive their PhDs (Ivie & Nies Ray, 2005), other disciplines, such as chemistry (Nelson, 2007), hired an exceptionally low percentage of women into tenure track positions relative to the percentage of female PhDs awarded by those same institutions. For example, at the top 50 PhD-granting institutions in chemistry, women accounted for 21% of assistant professors, 22% of associate professors, and only 10% of full professors (Marasco, 2006).

Although many studies have examined the failure of women to obtain STEM degrees, enter STEM careers, or progress and remain in them, fewer have explored successful women in STEM, especially in academia. A group representative of successful women scientists, particularly in US public higher education, are the NSF Professional Opportunities for Women in Research and Education (POWRE) awardees. Between 1997 and 2000, NSF gave competitive POWRE awards to facilitate the careers of individual women scientists. The POWRE awardees were surveyed at the initial time of the award and were asked: What are the most significant issues/challenges/opportunities facing women scientists today as they plan their careers? In 2012, the survey was re-administered to the same POWRE awardee individuals to examine the persisting and changing perspectives of these women scientists, who have been successful and stayed in academia during the last 12 to 15 years. After a brief summary of the results and methods used in prior research on the POWRE awardees, the remainder of this article examines the quantitative results, and particularly the qualitative responses to the re-administered survey, providing insights into how this same group of individuals perceives career issues 12 to 15 years later. Since POWRE awardees have remained in science and academia, the quantitative results and qualitative comments of the survey provide indicators of the conditions necessary for the success of women over the long term.

PRIOR RESEARCH

In the period 1997–2000, approximately 400 out of a total of almost 600 NSF POWRE awardees responded to e-mail questionnaires addressing the major issues and opportunities women scientists and engineers faced, as well as the impact of the laboratory climate on their careers in US universities (Rosser, 2001, 2004; Rosser & Lane, 2002a). The relatively large sample size and high response rates coupled with a lack of disciplinary bias suggested that these data might be generalizable to the broader population of women scientists and engineers. All of the POWRE awardees were successful female scientists. The overwhelming majority had achieved tenure track positions at universities, mostly at R1 Doctoral public institutions, but some at private or liberal arts colleges. All participants had received this major and highly competitive peer-reviewed grant from the prestigious National Science Foundation. Conducting follow-up interviews with a subsample of 40 questionnaire respondents deepened our understanding of the qualitative context of the problems faced by these women, as well as potential solutions. The results of this prior research were published in journal articles (Rosser, 2001; Rosser & Daniels, 2004; Rosser & Lane, 2002a; Rosser & Lane, 2002b; Rosser & Zieseniss, 2000) and two books (Rosser, 2004, 2012), and have been useful in identifying potential changes to remove barriers, particularly to institutions with NSF ADVANCE grants. Knowing and understanding the perceptions and experiences of these successful women faculty, as well as the context revealed through their qualitative comments, provided significant information that administrators and faculty used to develop strategies for institutional transformation and incorporated into both ADVANCE grants (the successor to POWRE) and other initiatives to attract, promote, and retain women faculty.

Some evidence suggests that the budget cuts and increasing reliance on technology that have impacted higher education, especially since the Great Recession beginning in 2008, have exacerbated gender issues (Chugh, Milkman & Akinola, 2014; Moss-Racusin, Dovido, Briscoll, Graham, & Handelsman, 2012), but little research has focused directly on the effects of these changes on successful female scientists who have remained in the professoriate. Having remained in academia and achieved seniority provides the female POWRE awardees with an interesting and unique perspective on this particular period. Examining the persisting and changing perspectives of these women scientists, who have been successful and stayed in academia since 1997–2000, constitutes the focus and contribution of this paper. Women in STEM who left academia or who never received a POWRE award did not participate in the resurvey of POWRE awardees conducted in 2011–2012.

METHODS

For the 2011–2012 resurvey, all of the POWRE awardees who responded to the survey more than a decade earlier and for whom a valid e-mail address could be found were invited to participate in the questionnaire, with the date particularized for each participant’s POWRE awardee cohort year—1997, 1998, 1999, or 2000. The sample included 329 individuals. The questionnaires were first sent out between October, 2011 and January, 2012, with the first cohort receiving the questionnaire in October, 2011 and the final follow-up e-mail sent to the last cohort in March, 2012. A total of 175 individuals—54% of those for whom valid e-mail addresses could be found—responded to the questionnaire in 2012. Specifically, 63% of the 1997 awardees, 53.2% of the 1998 awardees, 50.6% of the 1999 awardees, and 50% of the 2000 awardees responded. As was the case with the sample responding to the 1997-2012 e-mail questionnaire, all four cohorts appeared to be representative with regard to discipline of the population of awardees, and those who did not respond to the questionnaire did not appear to cluster in a particular discipline (Rosser, 2017).

Table 3: *Total responses to Question 1: What are the most significant issues/challenges/opportunities facing women scientists today as they plan their careers?*

Category	1997 % of responses		2012 % of responses		1998 % of responses		2012 % of responses		1999 % of responses		2012 % of responses		2000 % of responses		2012 % of responses		Overall % 1997-2000		Overall % 2012	
1 Balancing work with family responsibilities (children, elderly relatives, etc.)	62.7	(42/67)	64.7	(22/34)	72.3	(86/119)	72.0	(36/50)	77.6	(76/98)	74.4	(32/43)	71.4	(75/105)	64.6	(31/48)	71.7	(279/389)	69.1	(121/175)
2 Time management/balancing committee responsibilities with research and teaching	22.4	(15/67)	17.6	(6/34)	10.1	(12/119)	12.0	(6/50)	13.3	(13/98)	11.6	(5/43)	13.3	(14/105)	18.8	(9/48)	13.9	(54/389)	14.8	(26/175)
3 Low number of women, isolation, and lack of camaraderie/mentoring	23.9	(16/67)	23.5	(8/34)	18.5	(22/119)	8.0	(4/50)	18.4	(18/98)	7.0	(3/43)	30.5	(33/105)	25.0	(12/48)	22.9	(89/389)	15.4	(27/175)
4 Gaining credibility/respectability from peers and administrators	22.4	(15/67)	11.8	(4/34)	17.6	(21/119)	20.0	(10/50)	19.4	(19/98)	16.3	(7/43)	21.9	(23/105)	6.3	(3/48)	20.0	(78/389)	13.7	(24/175)
5 "Two-career" problem (balance with spouse's career)	23.9	(16/67)	32.4	(11/34)	10.9	(13/119)	10.0	(5/50)	20.4	(20/98)	18.6	(8/43)	20.0	(21/105)	25.0	(12/48)	20.6	(80/389)	20.6	(36/175)
6 Lack of funding/inability to get funding	7.5	(5/67)	14.7	(5/34)	4.2	(5/119)	26.0	(13/50)	10.2	(10/98)	18.6	(8/43)	8.6	(9/105)	25.0	(12/48)	7.4	(29/389)	21.7	(38/175)
7 Job restrictions (location, salaries, etc.)	9.0	(6/67)	—	—	9.2	(11/119)	2.0	(1/50)	7.1	(7/98)	2.3	(1/43)	5.7	(6/105)	6.3	(3/48)	7.7	(30/389)	2.9	(5/175)
8 Networking	6.0	(4/67)	2.9	(1/34)	<1.0	(1/119)	12.0	(6/50)	—	—	—	—	4.8	(5/105)	2.1	(1/48)	2.6	(10/389)	4.6	(8/175)
9 Affirmative action backlash/discrimination	6.0	(4/67)	14.7	(5/34)	15.1	(18/119)	8.0	(4/50)	14.3	(14/98)	9.3	(4/43)	12.4	(13/105	20.8	(10/48)	12.6	(49/389)	13.7	(24/175)
10 Positive: active recruitment of women/more opportunities	6.0	(4/67)	—	—	10.1	(12/119)	10.0	(5/50)	9.2	(9/98)	4.6	(2/43)	14.3	(15/105)	12.5	(6/48)	10.3	(40/389)	7.4	(13/175)
11 Establishing independence	3.0	(2/67)	—	—	—	—	4.0	(2/50)	6.0	(6/98)	4.6	(2/43)	2.9	(3/105)	—	—	2.8	(11/389)	2.3	(4/175)
12 Negative social images	3.0	(2/67)	11.8	(14/34)	3.4	(4/119)	10.0	(5/50)	2.0	(2/98)	—	—	<1.0	(1/105)	4.2	(2/48)	2.3	(9/389)	12.0	(21/175)
13 Trouble gaining access to nonacademic positions	1.5	(1/67)	—	—	1.7	(2/119)	2.0	(1/50)	1.0	(1/98)	2.3	(1/43)	1.9	(2/105)	2.1	(1/48)	1.5	(6/389)	1.7	(3/175)
14 Sexual harassment	1.5	(1/67)	—	—	<1.0	(1/119)	—	—	2.0	(2/98)	—	—	1.9	(2/105)	—	—	1.5	(6/389)	—	—
15 No answer	—	—	—	—	<1.0	(1/119)	—	—	1.0	(1/98)	—	—	1.9	(2/105)	—	—	1.0	(4/389)	—	—
16 Cutthroat competition	—	—	2.9	(1/34)	—	—	—	—	1.0	(1/98)	2.3	(1/43)	1.9	(2/105)	—	—	0.8	(31/389)	1.1	(2/175)

Table 3 lists the 16 categories into which the data for the 1997–2000 responses to Question 1 (i.e. What are the most significant issues/challenges/opportunities facing women scientists today as they plan their careers?) were originally divided. These same categories were used in order to compare the 2011–2012 data with the earlier data for each cohort. The original categories emerged from the coding of the textual replies. One of the original coresearchers (Rosser & Zieseniss, 2000) developed the categories and categorized each response, while the other coresearcher independently categorized the responses using the 16 divisions. Table 3 summarizes the results as pairs of columns. The first column of each pair presents data from the original cohort (e.g., 1997), whereas the second column (e.g., 2012) represents the percentage (and number in parentheses) of women from that particular cohort giving the same response in 2011–2012. Although most respondents replied with more than one answer, in some years at least one awardee did not answer the question. Although each individual could give more than one response to a question, they could not respond to more than one survey, considering that each individual belonged to a particular cohort year. Responses were not anonymous, enabling a comparison between the responses that a particular individual gave in 2012 and her initial response to the survey conducted in the late twentieth century.

QUANTITATIVE RESPONSES

Differences in responses across awardee cohort years and across directorates clearly emerge when response frequencies are examined. Similar to the initial surveys, an overwhelming number of respondents (69.1%) across all four cohort years found "balancing work with family responsibilities" to be the most significant challenge facing female scientists and engineers in 2012, as can be observed in Table 3. Although the other four of the top five responses from the initial survey continued to be frequent responses in 2012, the frequency of some responses—such as the "low numbers of women, isolation, and lack of camaraderie/mentoring"—decreased in 2012 to 15.4%. Most likely a reflection of the very difficult fiscal constraints, "lack of funding/inability to get funding" became the second most frequent response (21.7%) in 2012 for all cohort years except 1997.

Chart 1 focuses on the number of aggregated responses to Question 1 from 1997–2000 compared to 2012. The arrows indicate whether a particular response has moved up or down in ranking. As Chart 1 demonstrates, in addition to "lack of funding/inability to get funding"—which moved up from position nine (7%) in 1997–2000 when the data from all original cohorts is aggregated to position two (22%) in 2012—"negative social images" increased to 12% in 2012, moving up in frequency by three positions. No other response moved up or down by more than three positions, if at all.

Chart 1: *Number of aggregated responses to Question 1 from 1997-2000 compared to 2012*

Aggregated Original Survey Responses

Balancing work with family responsibilities (children, elderly relatives, etc.)	279 (72%)
Low number of women, isolation and lack of camaraderie/mentoring	89 (23%)
Gaining credibility/respectability from peers and administrators	78 (20%)
"Two-career" problem (balance with spouse's career)	70 (21%)
Time management/balancing committee responsibilities with research and teaching	54 (14%)
Affirmative action backlash/discrimination	49 (13%)
Positive: active recruitment of women/more opportunities	40 (10%)
Job restrictions (location, salaries, etc.)	30 (8%)
Lack of funding/inability to get funding	29 (7%)
Establishing independence	11 (3%)
Networking	10 (3%)
Negative social images	9 (2%)
Trouble gaining access to nonacademic positions	6 (2%)
Sexual harassment	6 (2%)
Cutthroat competition	3 (1%)

Aggregated 2012 Survey Responses

Balancing work with family responsibilities (children, elderly relatives, etc.)	121 (69%)
Lack of funding/inability to get funding	38 (22%)
"Two-career" problem (balance with spouse's career)	36 (21%)
Low number of women, isolation, and lack of camaraderie/mentoring	27 (15%
Time management/balancing committee responsibilities with research and teaching	26 (15%
Gaining credibility/respectability from peers and administrators	24 (14%)
Affirmative action backlash/discrimination	23 (14%)
Negative social images	21 (12%)
Positive: active recruitment of women/more opportunities	13 (7%)
Networking	8 (5%)
Job restrictions (location, salaries, etc.)	5 (3%)
Establishing independence	4 (2%)
Trouble gaining access to nonacademic positions	3 (2%)
Cutthroat competition	2 (1%)
Sexual harassment	0 (0%)

Table 4: *Responses to Question 1[a] according to directorate across all four cohorts*

	SBE		MPS		ENG		EHR[b]		CISE		BIO		GEO	
Category	1997–2000 % of responses	2012 % of responses	1997–2000 % of responses	2012 % of responses	1997–2000 % of responses	2012 % of responses	1997–2000 % of responses	2012 % of responses	1997–2000 % of responses	2012 % of responses	1997–2000 % of responses	2012 % of responses	1997–2000 % of responses	2012 % of responses
1 Balancing work with family responsibilities (children, elderly relatives, etc.)	60.3 (38/63)	66.7 (16/24)	77.4 (65/84)	60.0 (24/40)	65.2 (45/69)	86.7 (26/30)	91.7 (11/12)	66.7 (4/6)	60.0 (21/35)	68.8 (11/16)	82.4 (70/85)	74.4 (32/43)	73.7 (28/38)	75.0 (12/16)
2 Time management/balancing committee responsibilities with research and teaching	15.7 (10/63)	20.8 (5/24)	13.1 (11/84)	15.0 (6/40)	11.6 (8/69)	11.6 (3/30)	— —	33.3 (2/6)	17.1 (6/35)	12.5 (2/16)	12.9 (11/85)	14.0 (6/43)	21.1 (8/38)	— —
3 Low number of women, isolation, and lack of camaraderie/mentoring	23.8 (15/63)	16.7 (4/24)	11.9 (10/84)	15.0 (6/40)	21.7 (15/69)	16.7 (5/30)	33.3 (4/12)	33.3 (2/6)	31.4 (11/35)	12.5 (2/16)	20.0 (17/85)	11.6 (5/43)	39.5 (15/38)	6.2 (1/16)
4 Gaining credibility/respectability from peers and administrators	17.5 (11/63)	20.8 (5/24)	20.2 (17/84)	7.5 (3/40)	24.6 (17/69)	20.0 (6/30)	25.0 (3/12)	— —	31.4 (11/35)	— —	16.5 (14/85)	18.6 (8/43)	13.2 (5/38)	18.8 (3/16)
5 "Two-career" problem (balance with spouse's career)	14.3 (9/63)	8.3 (2/24)	28.6 (24/84)	30.0 (12/40)	13.0 (9/69)	11.6 (3/30)	16.7 (2/12)	16.7 (1/6)	22.9 (8/35)	18.8 (3/16)	11.8 (10/85)	20.9 (9/43)	21.1 (8/38)	37.6 (6/16)
6 Lack of funding/inability to get funding	4.8 (3/63)	20.8 (5/24)	7.1 (6/84)	12.5 (5/40)	8.7 (6/69)	26.7 (8/30)	— —	33.3 (2/6)	5.7 (2/35)	12.5 (2/16)	8.2 (7/85)	30.2 (13/43)	10.5 (4/38)	25.0 (4/16)
7 Job restrictions (location, salaries, etc.)	3.3 (2/63)	4.2 (1/24)	7.1 (6/84)	— —	5.8 (4/69)	— —	8.3 (1/12)	— —	5.7 (2/35)	— —	11.8 (10/85)	4.6 (2/43)	10.5 (4/38)	6.2 (1/16)
8 Networking	1.6 (1/63)	8.3 (2/24)	1.2 1/84)	2.5 (1/40)	— —	3.3 (1/30)	8.3 (1/12)	— —	5.7 (2/35)	6.2 (1/16)	2.4 (2/85)	9.3 (4/43)	5.3 (2/38)	— —
9 Affirmative action backlash/discrimination	7.9 (5/63)	12.5 (3/24)	6.0 (5/84)	12.5 (5/40)	15.9 (11/69)	6.6 (2/30)	8.3 (1/12)	16.7 (1/6)	20.0 (7/35)	18.8 (3/16)	11.8 (10/85)	14.0 (6/43)	23.7 (9/38)	18.8 (3/16)
10 Positive: active recruitment of women/more opportunities	7.9 (5/63)	8.3 (2/24)	15.5 (13/84)	10.0 (4/40)	13.0 (9/69)	3.3 (1/30)	8.3 (1/12)	16.7 (1/6)	8.6 (3/35)	6.2 (1/16)	3.5 (3/85)	7.0 (3/43)	15.8 (6/38)	— —
11 Establishing independence	3.3 (2/63)	4.2 (1/24)	4.8 (4/84)	2.5 (1/40)	1.4 (1/69)	3.3 (1/30)	— —	— —	2.9 (1/35)	— —	3.5 (3/85)	2.3 (1/43)	— —	— —
12 Negative social images	1.6 (1/63)	4.2 (1/24)	2.4 (2/84)	5.0 (2/40)	2.9 (2/69)	11.6 (3/30)	— —	— —	5.7 (2/35)	12.5 (2/16)	2.4 (2/85)	7.0 (3/43)	— —	6.2 (1/16)
13 Trouble gaining access to nonacademic positions	1.6 (1/63)	— —	2.4 (2/84)	— —	— —	3.3 (1/30)	— —	33.3 (2/6)	5.7 (2/35)	— —	1.2 (1/85)	2.3 (1/43)	— —	— —
14 Sexual harassment	3.3 (2/63)	— —	1.2 1/84)	— —	— —	— —	— —	— (0/6)	5.7 (2/35)	— —	— —	— —	2.6 (1/38)	— —
15 No answer	4.8 (3/63)	— —	— —	— —	1.4 (1/69)	— —	— —	— —	— —	— —	— —	— —	— —	— —
16 Cutthroat competition	— —	— —	— —	— —	— —	— —	— —	16.7 (1/6)	2.9 (1/35)	— —	1.2 (1/85)	2.3 (1/43)	2.6 (1/38)	— —

— = 0% or 0

[a] Question 1: What are the most significant issues/challenges/opportunities facing women scientists today as they plan their careers? SBE, Social Behavioral, and Economic Sciences; MPS, Mathematical and Physical Sciences; ENG, Engineering; EHR, Education and Human Resources; CISE, Computer and Information Science and Engineering; BIO, Biological Sciences; GEO, Geosciences.

[b] Because of the low numbers of awardees, the EHR directorate should be carefully interpreted here. Many of the women representing this directorate have other disciplinary training and could be classified in other directorates. We have chosen not to interpret the EHR responses as a result.

Table 4 shows the responses to Question 1 when the data from all four cohort years are combined and the responses are categorized by the NSF directorate of the awardee. This categorization assumes that the NSF directorate granting the POWRE award serves as an indicator of the discipline or field of the awardee. The 2012 responses were distributed among the NSF directorates, proportionate to the number of awardees (see Table 4). (For further detail about the proportion of grants awarded by each directorate for each of the cohorts, see Rosser, 2017, p. 24, Table 2.1.) Since directorates group similar disciplines together, the distribution among directorates eliminates the possibility that respondents from one discipline dominated the survey responses. The limited data available from the e-mail responses revealed no other respondent or non-respondent bias.

Perhaps the most striking finding is the overall similarity among the directorates. "Balancing work with family responsibilities" stands out overwhelmingly as the major issue experienced and described by women from all directorates, just as it did some 15 years ago. The top six responses were fairly consistent across all directorates, with few exceptions. "Lack of funding" received a much higher response in 2012 from all directorates than it had in 1997–2000, probably reflecting the very tight current funding situation.

To more clearly examine general themes, all responses to Question 1 were grouped into four categories (A, B, C, and D) as shown in Table 5. The means of the percentage of responses for each of the four 1997–2000 cohorts was compared with the 2012 mean percentage response for that cohort. Finally, the overall aggregate mean percentage of earlier responses for all four cohorts per category is compared with the aggregate 2012 percentage response.

Adding restrictions because of spousal situations (Responses 5 and 7) to "balancing work with family responsibilities" (Response 1) suggests that Category A—pressures women face in balancing career and family—continues to represent the most significant barrier a decade or more after the initial survey, identified by female scientists and engineers regardless of their awardee cohort year (Table 5).

The second grouping, Category B (Responses 3, 4, 8, 10 and 12)—resulting from the low numbers of female scientists and engineers, and consequent stereotypes surrounding expectations about their performance—appears to have slightly decreased in frequency in 2012 compared to the original survey cohorts, with the exception of the 1998 cohort.

In contrast to Category B, Category C (Responses 2, 6, and 16) has increased in frequency in 2012. Category C includes issues faced by both male and female scientists and engineers. "Time management/balancing committee responsibilities with research and teaching" continues to be a problem for women because female faculty members are often asked to serve on more committees and to advise more students in order to meet gender diversity policies (Burroughs Wellcome Fund & Howard Hughes Medical Institute, 2004). The increased frequency of responses falling into Category C seems to result from a higher "lack of funding/inability to get funding" response in 2012 compared to the earlier data (Table 5).

Table 5 *Categorization of Question 1*[a] *across cohort year*

Category		Response numbers[b]	Means of responses								Overall	
			1997	2012	1998	2012	1999	2012	2000	2012	1997–2000	2012
A	Pressures women face in balancing career and family	1, 5, 7	31.9%	32.4%	30.8%	28.0%	35.0%	31.8%	32.4%	32.0%	32.5%	31.0%
B[c]	Problems faced by women because of their low numbers and gender stereotypes held by others	3, 4, 8, 10, 12	12.3%	10.0%	10.1%	12.4%	9.8%	5.5%	14.5%	10.0%	11.7%	9.5%
C	Issues faced by both male and female scientists and engineers in the current environment of tight resources, which may pose particular difficulties for women	2, 6, 16	10.0%	11.7%	4.8%	12.7%	8.2%	10.8%	7.9%	14.6%	7.7%	12.4%
D	More overt discrimination and harassment	9, 11, 13, 14	3.0%	3.9%	4.4%	3.5%	5.8%	8.0%	4.8%	5.7%	4.5%	5.3%

[a] Question 1: What are the most significant issues/challenges/opportunities facing women scientists today as they plan their careers?

[b] Given the responses from all four years, after receiving faculty comments at various presentations of this research and after working with the data, we exchanged two questions from both Categories B and D to better reflect the response groupings. Specifically, Responses 10 and 12 (considered in Category D in Rosser & Zieseniss, 2000) were moved to Category B. Similarly, Responses 11 and 13 (included in Category B in Rosser & Zieseniss, 2000) were placed into Category D.

[c] The alphabetic designations for Categories B and C have been exchanged, compared with earlier articles (Rosser & Zieseniss, 2000), to present descending response percentages.

Category D (Responses 9, 11, 13, and 14) identifies barriers of overt harassment and discrimination faced by female scientists and engineers. The controversy about the failure of elite institutions such as the University of California at Berkeley to adequately discipline and remove known sexual harassers because of their disciplinary prominence (Clery, 2015) reveals continuing issues of harassment and discrimination.

QUALITATIVE RESPONSES

Example quotations from the respondents in 2012 drawn from all four initial cohorts provide the qualitative context for the categories. The quotations not only exemplify and distinguish the different categories from each other, but are also representative of the responses provided by most POWRE awardees. The respondents from 2012 express their experiences of continuing barriers, as well as the perceived changes, or new faces of the issues at stake.

Category A: Pressures Women Face in Balancing Career and Family

> There continue to be many issues around negotiating marriage/relationship/family and career (and those issues seem more pronounced for women than for men).[2] The shrinking base of tenure-track positions contributes vastly to the problem by limiting the options one has for making job responsibilities work with relationships. A surprising number of my younger female colleagues (compared to my younger male colleagues) are not married or are living apart from marriage partners and significant others because finding two jobs together wasn't feasible. Two of my younger female colleagues who are married and employed by the university live in different cities from their husbands. There are few options for a "trailing spouse," and men seem less amenable than women to play the trailing partner role, with the result that happily combining work and family is more problematic for women with academic careers. (2012 respondent from the Social, Behavioral and Economic Sciences Directorate in the 1997 cohort)

> Family issues still seem to rest disproportionately on women. Meaning the women do all the research and teaching and service that the men do and THEN all the care giving, particularly noticeable for faculty with elderly parents. I have not seen any progress on this issue/challenge yet. (2012 respondent from the Geosciences Directorate in the 1998 cohort)

> The usual: balancing work and family needs. I think the economic slowdown has been particularly hard on female scientists as they still tend to partner up with other scientists, so they suffer from the two-body problem more than men. (2012 respondent from the Mathematical and Physical Sciences Directorate in the 2000 cohort)

> Family responsibilities are assumed by women, and until the expectations change so that men [also] see families as their responsibility, things won't improve for women. And academic responsibilities do interfere with family life. The travel schedule is punishing. Academic life was invented by men,

> especially in CS [Computer Science], where there are conferences year round, and you are expected to appear at them to build a reputation. (2012 respondent from the Computer and Information Sciences and Engineering Directorate in the 2000 cohort)

Category B: Problems Faced by Women Because of Their Low Numbers and Gender Stereotypes

> The major challenge I see is that the cutting edge science and engineering remain out of reach of the vast majority if not all women. While [the] presence of women in science and engineering has become more or less accepted, I think that most often less significant scientific tasks are delegated to women. Men remain in the driving seat, especially in cutting edge science and areas that have been traditionally considered "to belong" to them. (2012 respondent from the Engineering Directorate in the 1998 cohort)

> There is a presumption that women are not interested in having a career in physics and therefore, women are overlooked in recruitment and promotion. (2012 respondent from the Mathematical and Physical Sciences Directorate in the 1997 cohort)

> The extra work a woman needs to put in to convince colleagues (men and women alike) that she is as good as an equivalently good man. Even when asking things from a secretary, a female professor needs to put some extra effort [in] to get the same response as a male professor. The same is true for speaking up in a meeting, managing not to be interrupted, supporting an idea, etc. Everything seems to require just a tad of extra effort (a differential we would say using math language). Cumulatively over a career, these "tads" make up for a large extra effort. (2012 respondent from the Engineering Directorate in the 1999 cohort)

Category C: Issues Faced by Scientists and Engineers in the Current Tight Financial Climate that Pose Particular Difficulties for Women

> Funding sources are drying up; very discouraging. For academic scientists, move to adjunct teaching, online teaching will decrease the number of positions available, especially tenure track positions. Sexism is still a problem, coupled with the assumption that all women are "motherly" and want to take on lots and lots of "helpful" projects. (2012 respondent from the Biological Sciences Directorate in the 1999 cohort)

> Rising expectations for tenure-track faculty combined with year to year uncertainty in funding availability exacerbates the lack of flexibility in career trajectory for women who wish to start a family or who need to provide care for elderly family members. (2012 respondent from the Engineering Directorate in the 1999 cohort)

Category D: More Overt Discrimination and/or Harassment

> Other challenges include unconscious bias (which also affects funding rates), often accompanied by a distrust/dislike of successful women that have an opinion. (2012 respondent from the Mathematical and Physical Sciences Directorate in the 1997 cohort)
>
> Sexism. (2012 respondent from the Social, Behavioral and Economic Sciences Directorate in the 1998 cohort)
>
> The good old boy system is still alive and well and serves as a barrier to advancement and funding. (2012 respondent from the Mathematical and Physical Sciences Directorate in the 2000 cohort)

IMPACT

Analyses of the 2012 responses by the 1997–2000 POWRE awardee cohorts suggest that, overall, the same issues remain 12 to 15 years later. Despite programs such as the NSF's POWRE and ADVANCE, as well as considerable media attention to work-life balance, the issues that women face in balancing career and family, including dual career issues, continue to be identified as the overwhelming problem facing women scientists and engineers, including those in the Social, Behavioral, and Economic Sciences, as well as in Education and Human Resources Directorates. Issues faced by women because of their low numbers and gender stereotypes held by others have decreased slightly in frequency of response, perhaps due to increasing numbers and percentages of female scientists (Table 2), despite a diminishing pipeline of undergraduate women in computer science and engineering (Table 1). The frequency of more overt discrimination and harassment mentioned in the responses remained relatively consistent, although the relatively low percentages should be measured against the tolerance goals that institutions and departments must adhere to. Sexual harassment and its impact on derailing careers, or causing women to leave STEM entirely, have recently become more openly discussed and documented (Clery, 2015; Jahren, 2016; Shipman, 2015). Issues faced by scientists and engineers in the current tight financial climate, posing particular difficulties for women, show increased responses in 2012. The 2012 data document that the increased percentages come primarily from responses focused on a lack of funding.

What is the impact of these problematic issues remaining and increasing for women scientists over a period of at least 15 years? Perhaps more women from STEM disciplines have left academia for the technology workforce, or are involved in technology transfer, translation, or the commercialization of science? Data, indicators, and studies reveal that women are less well-represented and may experience more discrimination in these cutting-edge areas than they do in the overall STEM workforce, including academic science. The relatively low numbers and percentages of women engineers and decreasing numbers of women receiving degrees in computer science partially explain the scarcity of women in technology. Although 42% of all STEM degrees were attained by women, and 27% of the STEM workforce is made up of women, only 3% of Silicon Valley tech startups have at least one female founder (Sposato, 2015). Investors who heard pitches by entrepreneurs preferred pitches by a man (68%) over identical pitches delivered by a woman (32%; Brooks, Huang, Kearney & Murray, 2014). Performance reviews in a study of technology jobs reported in *Fortune* found negative personality criticism in 85% of the reviews of high-performing women, but only in 2% of the reviews of high-performing men (Snyder, 2014). It takes women three times longer to raise seed money (nine months for $1 to 5 million) than their male counterparts (three months for $1 to 5 million; Sposato, 2015).

In the United States, focus and funding have gradually shifted from basic research to applied research. Patents stand as a proxy or indicator of technology transfer, translation, and the commercialization of basic science research. Although the numbers and percentages of women holding patents is increasing slowly, women register patents at significantly lower rates than their male counterparts in all disciplines, sectors, and countries. 7.5% of US patent holders are women, as well as 5.5% of commercialized patent holders (Hunt, Garant, Herman & Munroe, 2013). Wide variances exist among the disciplines with regard to the percentage of women who register patents, with most women registering patents in pharmaceutical and medical fields and least in mechanical and electrical fields. Although the numbers and percentages of women patent holders are drastically lower than the numbers and percentages of women in STEM, the disciplinary variances are not surprising, since the numbers and percentages of women in engineering remain low, while those in the biological sciences have reached parity.

Many of the same persistent issues for female academic scientists demonstrated in this e-mail survey—such as work-family balance, gender stereotypes, gender prejudice in mentoring and networks, and geographic constraints—also appear to be factors contributing to the dearth of women patent holders and technology workers. A scarcity of women may result in underperformance due to a lack of gender diversity—the First Round Capital Startup Report, for example, documented that teams with women perform better than their all-male counterparts for the venture capital firms by over 60% (Evans, 2016).

The loss of women in STEM means a loss of lucrative and influential jobs for women in precisely those sectors of predicted economic growth and competitive potential for the future. A dearth of women results in fewer women being eligible for leadership positions in the industry, corporate boards, and academic institutions. Most importantly, the absence of women means the loss of potential creativity, ideas, efficiency, and products that emerge from increased diversity in the science and technology workforce.

ENDNOTES

[1] Please note that portions of this article have been previously published in Rosser, S. V. (2017). *Academic women in STEM faculty: Views beyond a decade after POWRE*. New York: Palgrave Macmillan. Reproduced with permission of Palgrave Macmillan.

[2] Please note that all parentheses within the quotations are part of the original written responses of the respondents as appeared in their e-mails

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