122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #12718

Career Advancement through Academic Commercialization: Acknowledging and Reducing Barriers for Women Engineering Faculty

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Abstract

Although schools of engineering are increasingly considering patenting, licensing, and commercialization in faculty bids for tenure and promotion, women candidates participate in these activities at disproportionately lower rates than their male counterparts.[1–7] As research has shown that inventions by women are frequently designed to address important social problems, addressing the gap in engagement in academic commercialization activities has growing societal relevance.[2,8] This gender gap can largely be explained by the significant obstacles that women faculty in engineering face as they advance their careers and as they engage in academic commercialization.[9–11] Barriers such as gender discrimination, attitudinal and behavioral factors, work-life balance issues, and exclusion from networks impact the ability of women faculty to continue in the field, engage in academic commercialization, and ultimately advance their careers.[3,7,8,12–17]

This paper aims to synthesize relevant literature pertaining to impediments to academic commercialization and career advancement for women faculty in engineering and science. The purpose is to not only raise awareness of the likely origins of these issues, but to recommend ways that staff, faculty, departments, and universities can create a more equitable career trajectory for women faculty in engineering and science. Immediate and long term shifts in individual and institutional bias, policy, leadership, and training have the potential to make a significant difference in engineering innovation for social and environmental change.

Introduction

"Innovation is not gender-blind, but rather inherently gender-biased, because of an implicit, socially constructed assumption that women are less innovative than men as a function of traditional gender relations, that men-dominated industries/sectors are more innovative than women-dominated ones, all rooted in a social perception of technology that is more often associated to men than to women."[18]

In addition to teaching, research, and publishing, schools of science, technology, engineering, and math (STEM) are more frequently considering patenting, licensing, and commercialization activities in faculty bids for tenure and promotion.[2,6,19] This is particularly relevant to schools of engineering where a large proportion of research is geared toward real world application. Federal and state agencies, including the National Science Foundation (NSF) are promoting this shift in engineering and STEM through programming and funding initiatives. Additionally, this change can be seen in academic patenting rates which increased 700% between 1980 and 2000.[3,20]

In particular, the involvement of women faculty in the shift toward academic commercialization has the potential to positively impact the economy, applied research, and advance socially focused innovation. According to the Center for Women's Business Research, for the past 30 years, women owned companies have been growing at double the rate of all other companies. This translates to $3 trillion annually, a 39% increase in employment, and 23 million jobs.[21,22] These women led firms economically impact the individual, their families, communities, and the nation in a significant way. Additionally, 99% of all businesses (including women-owned) are small businesses which produce, "…13 times more patents per employee than large patenting firms."[21] Women faculty involved in academic commercialization have the potential to, and do contribute to these numbers through patenting, licensing, and spinning off inventions into companies. As professors, they also have the ability to teach others the skills and processes by which to do so as well.

The inclusion of women engineering faculty in academic commercialization better represents national and global gender ratios and adds to gender diversity. Traditionally, engineering is a white, male dominated field which would benefit from alternate perspectives and approaches to innovation and invention.[23] Without gender and other diversity in schools of engineering and STEM, innovation can become biased and the majority perspective can become dominant. By increasing diversity we not only move closer to the advancement of women in science, but also closer to a world where new technologies are useful and applicable to both men and women, and that they are socially beneficial.[18] In fact, several researchers have shown that women's inventions are frequently designed to address important social problems in areas such as health, poverty, and education, making the inclusion of women in academic commercialization both economically and socially beneficial.[2,8]

The Problem

Although it is apparent that the world would benefit from women engineering and STEM faculty involvement in academic commercialization, it is largely not occurring. As women move up the pipeline from engineering PhD, to professor, to involvement in academic commercialization, their numbers dwindle (as shown in table 1).

Table 1	
Activity	**% Women Involved**
Venture Founders	12%
Engineering Workforce	15%
Full Professor in Engineering	9%
Tenured and Tenure Track Engineering Faculty Combined	14%
Associate Professors of Engineering	16%
Assistant Professors of Engineering	23%
Doctorate in Engineering	23%

[16,17,24–29]

Since 2003 the percentage of women achieving doctoral degrees in engineering has increased 5%, but is still far below representative at 23% women earning engineering PhD's.[27] In one study of STEM PhD recipients, 1 in 6 reported working in a non-STEM field, post graduation. Compared to men, women STEM doctorates were more likely to leave the field, post graduation.[23] This results in fewer women in the engineering workforce and in the academy. Since the 1970's there has been an increase in women in the STEM workforce, but this growth has slowed somewhat since the 1990's. In 2011 women's employment in STEM was 27% (down from 34% in 1990) with women most underrepresented in engineering at 13% (this number rose to 15% by 2013).[16,27]

Compared to white men, women faculty are less likely to work at prestigious universities or research universities, and more likely to hold assistant-professor, associate professor, and non-tenure track positions.[14,30] In fact, in 2011 only 9% of full professors in engineering were women.[17] In regards to academic commercialization this is especially unfortunate because prestigious research universities are typically the most entrepreneurial and secure higher numbers of faculty patents.[2] In addition to the disproportionate number of women involved in higher levels of the academy, women faculty are also much less likely to be involved in entrepreneurship or academic commercialization, compared to men.[7,15,31,32] Women also publish and patent less than men. In one study of a sample of 4227 STEM faculty, 6% of women and 13% of men hold at least one patent.[31] Interestingly, men and women do not differ in the number of citations their publications and patents receive. So, although women publish and patent less, their work is at least as well received as the work their male counterparts.[15,31] Furthermore, women disproportionately sit on Scientific Advisory Boards (8.5% of members are women), found companies (12% of founders are women), or work as venture capitalists (10% are women) compared to men.[4,28,33–35]

The Approach

Concentrating on literature in the intersecting areas of women science faculty, women entrepreneurs, and academic commercialization, this paper synthesizes current research pertaining to career advancement through academic commercialization for women faculty in engineering and STEM. This paper argues that the major factors contributing to the disparity between men and women in this cross-section of engineering and academic commercialization are, first, based in gender discrimination. This includes discrimination through resources, organizational climate, and sexual harassment. Second, this base of discrimination may influence identified behavioral and attitudinal barriers such as women faculty's lower self-efficacy and confidence, lower productivity, and higher risk-aversion. Third, discrimination and attitudinal barriers come into play when considering the differences women experience navigating work-life balance such as marriage and parenting, and inclusion in critical networks. Finally, taking all of the listed factors into consideration, a picture emerges around why women faculty in engineering are not participating in academic commercialization education and training at the same rate as their male counterparts.

The purpose of this paper is to not only to lift up the likely origins of these issues, but also to make recommendations on strategies for affecting change. By raising awareness, educating stakeholders, implementing policy change, and making organizational changes, institutions can create a more equitable career trajectory for women faculty in engineering and ultimately make a difference in engineering innovation for social and environmental change.

Theory

The pervasive disparity in all levels of women's participation in engineering and STEM have been conceptualized in a variety of ways. Two widely used frameworks are the differences model and the deficit model. The differences model views men and women as fundamentally different in a way that affects their participation in the sciences. These differences are seen as either innate or socialized by gender or cultural norms and include goals, behaviors, and working styles. Conversely, the deficit model, "posits the existence of mechanisms of formal and informal exclusion of women scientists. Women as a group, according to this model, receive fewer chances and opportunities along their career paths, and for this reason they collectively have worse career outcomes. The emphasis is on structural obstacles, legal, political and social, that exist … in the social system of science."[13]

The following research is in line with the deficit model and sees the stated obstacles and resulting negative experiences as major contributors to the difference in women engineering faculty's advancement and participation in academic commercialization.

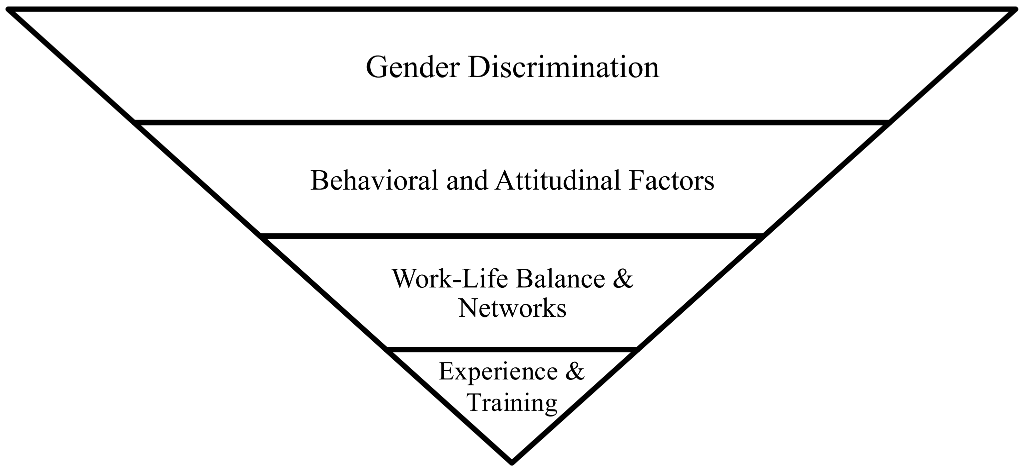
Method

The literature synthesized in this paper is primarily focused on women faculty in engineering and science. As commercialization and entrepreneurship are interdisciplinary fields, literature from a variety of disciplines such as business, science industry, and higher education was considered. Public search engines such as Google Scholar and Pub Med were used to search key words including "women", "engineering", "science", "faculty", "STEM", "gender", "commercialization", "entrepreneurship", "patenting", etc. References from relevant articles were also considered for inclusion.

Factors involved in the disparity

Barriers such as gender discrimination, attitudinal and behavioral factors, work-life balance issues, and exclusion from networks impact the ability of women faculty to continue in the field, engage in academic commercialization, and ultimately advance their careers.[3,7,8,12–17] These factors can be conceptualized hierarchically with the upper barriers influencing and affecting the lower barriers (as seen in figure 1). For example, the research will show that gender discrimination is at work in all of the other major factors that women face.

Figure 1: Factors involved in the disparity



Gender Discrimination

The major documented factors related to gender differences in the advancement of faculty include gender discrimination, such as resource discrimination, negative organizational climate, and sexual harassment. Gender discrimination is defined as treating a person unfairly based on their gender. One form of gender discrimination is gender discounting. This specifically occurs when women with the same qualifications and accomplishments as their male counterparts are treated differently, in a negative way, based solely on gender.[4] In one study, exploring the careers of high achieving men (N = 361) and women (N = 99) in science, 73% of the women interviewees reported experiencing gender discrimination.[13] These rates are expected to be similar in engineering in particular as women in male dominated workplaces experience more discrimination than those is female dominated situations.[36] In practice, gender discrimination can look like less pay, smaller lab space, less departmental influence, under-crediting women, and a hostile work environment.[18,37,38] For women, these experiences can mean, lower levels of productivity, more social isolation, slower advancement and less opportunity to hold high level positions.[13,38]

A study looking directly at gender discounting matched men and women faculty on variables including productivity levels, job locations, and credentials and found that women faculty obtain less attention and support from their institutions compared to their male counterparts.[39] Additionally, in a study by Murray, several women faculty interviewed about involvement in commercial science, “describe cases of clear and explicit exclusion from the biotechnology industry; they were not invited by investors to found firms and their colleagues explicitly excluded them from [scientific advisory boards].”[34]

RESOURCE DISCRIMINATION

Gender discrimination in engineering through the unequal allocation of resources has been well documented. In 2013, the Census Bureau put out a report showing that on average, women with a science or engineering degree, employed full-time in STEM, earned $75,100.[16] On average, men of the same status earned $91,000, a difference of almost $16,000. In 1999, MIT conducted a study on women faculty in their life science departments and found resource discrimination such as differences in salary, laboratory size, funding, award nominations, and startup packages.[37] In regards to academic commercialization, according to Murray,[40] faculty are often invited to engage in this type of activity by former students involved in entrepreneurship. There is some evidence to show that resource discrimination is happening around the number of graduate students assigned to men and women faculty as a consequence of lab space. One researcher found that women faculty in the sciences have an average of 2.2 postdoctoral students while men faculty have an average of 3.3.[41] In addition to potentially affecting women faculty's involvement academic commercialization this type of resource discrimination is negatively affecting advancement into tenured positions of power and influence.[38]

Organizational Climate

"Organizational climate is the individual's perceptions of the organization's policies, practices, and procedures."[38] Specifically, organizational climate is what is perceived and/or experienced by the employee. Whether this perception is accurate or not, it colors the way the individual sees the organization and their position at that organization. This is true of whole organizations, departments, work-groups, etc.[38] A study that looked at organizational climate for men and women STEM faculty at nine research institutions, found gender differences in the way that faculty perceive the climate of their department. In their survey responses, women faculty were significantly more likely to describe their departments as stressful and less likely to describe them as informal, exciting, helpful, creative, and inclusive.[42] Another study by Callister looked at over 300 science and engineering faculty and found that perceptions of the affective and instrumental facets of organizational climate differ by gender and affect job satisfaction.[43] The affective organizational climate refers to relationships between people within a department and instrumental organizational climate refers to access to resources, information, and promotion. Essentially, gender discrimination on an interpersonal level and on a more tangible, resource level can influence women faculty's perception of their department and their work satisfaction. "Thus, the literature on workplace climate suggests that those environments that are sexist or more hostile toward women create an undesirable work atmosphere that is tied to poorer work outcomes, whereas positive climates and effective leadership foster good work outcomes."[38]

Sexual Harassment

In 2003, a meta-analysis of the reported incidence rates of work related sexual harassment found that 58% of women in the academy had been sexually harassed at work. Additionally, the study showed that harassment at work tends to happen more frequently in workplaces where there are power disparities between lower and upper levels of the organization.[44] In engineering and STEM fields, where there is a clear disparity between women and men faculty, one could assume that the rates of sexual harassment experienced by women faculty match or exceed 58%. Another study surveyed tenure track women science faculty (including engineering and social science faculty) to better understand workplace experiences of sexual harassment and discrimination. The results of this study showed that the experience of harassment and gender discrimination is related to lower outcomes such as less job satisfaction. In workplaces without this type of climate women faculty reported more positive outcomes and higher job satisfaction.[38] Specifically, "these findings reinforce that sexual harassment and gender discrimination have a significant negative impact on women's overall attitudes toward their employment and extend this line of inquiry to the context of academic science."[38]

Behavioral and Attitudinal Factors

Behavioral and attitudinal factors exhibited by women faculty, such as lower productivity, lower self-efficacy, and higher risk-aversion, are likely influenced by the gender discrimination that can occur in the academy.[13,45,46]

PRODUCTIVITY

A commonl stereotype of women scientists is that they are less productive in the academy and publish in peer-reviewed journals at a slower rate than their male counterparts. According to one study, women are more likely to publish none or one paper, while men are twice as likely to publish 20 or more papers during the same time period.[49] Contemporary research on women engineering and science faculty's productivity has taken external factors into consideration including position within the organization, amount of grant funding, time spent teaching, resource distribution, workplace climate, and sexual harassment. These studies have found that when these factors controlled for, men and women faculty have similar rates of productivity. Basically, gender discrimination in its various forms are largely responsible for the disparity in productivity.[15,50–53] Unfortunately, in relation to commercialization, this disparity puts women at a disadvantage with venture capitalists who tend to select scientists of high stature, with high productivity, for investment and/or to sit on scientific advisory boards.[4]

Interestingly, there are also positive findings, which are seldom heard in reference to women engineering and science faculty. In addition to showing that external factors influence productivity, Colyvas et al.[50] found that women's inventions secured licenses to firms at the same rate as men's inventions. Additionally, two studies add support to the idea that articles written by women are cited more often than articles written by men. One study that looked at 25 biology faculty found that women are cited at a rate of 24.4 citations per article compared to men who receive an average of 14.4 citations per article published.[54] Although this research looked at a small sample, it supports another article on a large sample of biochemistry faculty, which found a similar difference in citation rates.[55]

ENTREPRENEURIAL SELF-EFFICACY

In general, women in science tend to underestimate their skills in relation/comparison to men with comparable qualifications. In a study of high achieving men and women scientists, more men considered their scientific ability to be above average and more women considered their ability to be average.[13] Similarly, self-efficacy in entrepreneurship, or confidence in one's entrepreneurship abilities, has been shown to influence whether or not an individual decides to pursue a business venture. According to Chen, Greene, and Crick,[47] women tend to stay away from entrepreneurial opportunities due to lack of confidence in their entrepreneurship skills.

Wilson et al. compared the entrepreneurial self-efficacy of teenagers to adults pursuing graduate business degrees.[22] The researchers found that self-efficacy does influence career intentions for both genders and that women show significantly lower levels of self-efficacy, both in high school and as adults in a business program. However, the researchers did see women's self-efficacy increase with targeted entrepreneurship education. Another study of graduate business students found that women with equal levels of formal entrepreneurship education did not differ from men in their entrepreneurial self-efficacy. Unfortunately, the same women were still less likely to aspire to be entrepreneurs.[48] These findings suggest that women with adequate training, "may feel as capable of performing entrepreneurial tasks as men (i.e., they have the same level of entrepreneurial self-efficacy), but still perceive the task environment as more difficult or less rewarding than do men."[48] In summary, these studies indicate that external factors, such as training and possibly gender discrimination, are influencing women faculty's entrepreneurial self-efficacy and intentions.

Risk Aversion

It is safe to say that research shows that women appear to be more risk averse, especially when it comes to finances. Charness and Gneezy pulled together 15 separate investment game experiments, including experiments done with graduate business students.[45] Overall, and specifically in the case of the business students, it was shown that men engage in more risk taking than women. Another study assessing the differences in risk taking between men and women recruited at the Pittsburgh Experimental Economics Laboratory, matched the participants by ability. These volunteers were entered into a non-competitive tournament and had the choice of entering into a competitive tournament. It was found that although there was no difference in performance, the men were significantly more competitive than the women, entering into the competitive tournament at a much higher rate. The researchers attribute this difference to men being overconfident and to feeling more positive about competition.[56] Murray & Graham relate these findings to their interviews with life science faculty at a prestigious university, intended to assess commercial activity.[34] The researchers see risk aversion as a potentially important factor in the decision to engage in entrepreneurial endeavors.

In addition to describing the gender differences in risk taking activity, other researchers have tried to provide an explanation for this behavior. Two studies looking at financial risk-taking found that women in general and women in finance weigh the potential for loss more than their male counterparts.[57,58] Stephan & ElGanainy hypothesize that this explanation could be playing a part in women faculty's decision to engage (or not) in commercialization.[4] Furthermore, Rosa & Dawson interviewed female founders of spinout companies from 20 universities in the UK to assess differences in behavior.[28] The findings explained, "Just when the financial and status rewards of years of academic research are about to be realized, it can be a major decision to dilute this competitive specialization with commercialization… the fact that women have to struggle harder to establish a career and move up the promotion ladder makes this even more important for female academics." As mentioned previously in relation entrepreneurial self-efficacy, in a world where women are already seen as less suited for entrepreneurship and commercialization, what is calculated as risk-aversion may in reality be a more accurate assessment of women's chances for success when facing gender discrimination on many levels.[18]

Work-Life balance

Faculty in engineering and STEM often progress directly from undergraduate, to graduate, to postdoctoral work. This career progression typically aligns so that women begin their faculty or tenure-track work when they are most likely to be starting a family.[14,53,59] As Sonnert & Holton stated, "…[women scientists] are faced with the dilemma of synchronizing the often-conflicting demands of three clocks: the biological clock, the career clock (as in timetables for tenure) and a spouse's career clock" (p.70).[13] For women science faculty, these competing life events have the potential to influence career choices related to both advancement in the academy and involvement in academic commercialization.[14] Marriage and parenting pose additional barriers for women and also contribute to disparity in advancement and commercialization.

In a study by Rosser, women scientists and engineers were asked to describe the most significant issues and challenges women scientists face as they plan their careers.[11] Balancing work with family was the number one response in Rosser's survey distributed to 400 women in research and education. Fox's study on women and men faculty in doctoral-granting departments in computer science, engineering, and science fields in nine research universities found evidence to support work-life balance as an important issue for women faculty.[42] Compared to men, women reported that family and work interfere with each other more, most frequently with family interfering with work. Fox hypothesized that this finding could stem from the higher family and household expectations typically placed on women.

Although women with PhDs in STEM are more likely to start their careers in the academy, men are more likely to secure prestigious positions at research institutions. These positions are most likely to lead to exposure and involvement in academic commercialization.[35] Several researchers have shown that being married and having children puts women, more than men, at a disadvantage when securing a position or advancing in the academy.[13,14,53] One barrier related to marriage is that women faculty in science are often married to other faculty or full-time workers. This appears to affect women faculty's career choices and upward mobility. Sonnert & Holton's study compared the careers of high achieving faculty and found that women with children were likely to choose a postdoctoral fellowship to be with a spouse. Conversely, men were not likely to choose a postdoctoral fellowship to be with a spouse.[13]

Whittington investigated the likelihood that women scientists who are mothers will be involved in academic commercialization.[53] Through data pulled from a survey of doctorate recipients conducted by the National Science Foundation, the researcher found that mothers in the academy are less likely to patent due to family factors (most likely childrearing and household chores). In addition, mothers in the academy show more of a disparity in their patenting activity than their publishing activity. One explanation for this is that mothers selectively allocate their time to preserve essential career activities such as publishing and engage less in non-essential activities such as mentoring, patenting, and committees.[49,60] Beyond time demands, another factor that comes into play is gender discrimination related to motherhood. Mothers tend to be seen as less competent, committed, and available, and receive fewer resources than childless women and men in general.[15,53,61,62] These perceptions may affect upward mobility and mean that colleagues are less likely to approach mothers with opportunities to engage in academic commercialization.[53]

Networks

Gender discrimination, behavioral and attitudinal factors, and work-life balance all have a negative influence on women science faculty's inclusion in key networks. According to Fox, women faculty are not included in discussions, social networks, scientific communities, or scientific culture.[42] Sonnert & Holton's study found this to be true in that women reported difficulty collaborating with men as equal or senior partners.[13] Women in the sciences actually experienced a higher level of collaboration as a junior partner than as an equal or senior partner. Exclusion from networks can also be seen in the rates of women who have the opportunity to disclose and in the rates of women involved in scientific advisory boards. Murray & Graham interviewed life science faculty to understand their involvement in commercial activity and found that women experience less exposure, more exclusion, and fewer opportunities to engage in academic commercialization than men.[34] Stephan & ElGanainy reviewed literature on faculty in the biomedical sciences and found that there were only 4 women out of the 70 scientific advisory board members included in their sample.[4]

Inclusion in networks is critical to the advancement of engineering and STEM faculty and assists with identifying funding, understanding organizational policies, meeting mentors, and even fostering commercial activity.[63] Stuart & Ding looked at detailed career histories of 6,000 academics to understand when scientists become entrepreneurs.[35] They determined that academic commercialization began and spread across a network of top scientists. This is supported by their additional findings that faculty are more likely to become involved in entrepreneurship when they work with or for other scientists who had already been involved in commercialization, with high social standing. Since women are less likely to fall into an elite category and less frequently invited to participate in collegial collaborations, they have fewer opportunities to increase their awareness, learn about processes, and be involved in commercialization activities.[28,34,64] In summary, women were excluded from the first opportunities in academic commercialization, which put them at a disadvantage in terms of networking and developing skills in selling science. This meant that women were not seen as entrepreneurial and that commercialization came to be seen as a masculine activity. These barriers left women with more gender discrimination, less contact, less experience, and with less confidence about their skills in academic commercialization.[34]

Experience and Training

Women engineering and science faculty have less experience and training in academic commercialization largely due to barriers such as gender discrimination, behavioral and attitudinal factors, work-life balance issues, and exclusion from networks.[1–7] In summary, resource discrimination such as differences in salary, laboratory size, funding, award nominations, and startup packages limits advancement and the flexibility to engage in academic commercialization.[38,65] Negative workplace climates and sexual harassment create an undesirable work atmosphere, lower job satisfaction and poorer work outcomes that may hinder women faculty's ability to advance and experience academic commercialization.[38,43] Attitudinal and behavioral factors such as lower entrepreneurial-self efficacy, lower productivity, and higher risk aversion often lead to lower participation in entrepreneurial endeavors, less time to dedicate to activities that are not essential for tenure, and more impediments to consider when deciding to engage in commercialization activities.[13,18,28,48,51,66] Women also have to deal with additional work-life balance issues and are excluded from networks, both of which significantly hinder their exposure to and practice in academic commercialization and entrepreneurship.[4,11,13,14,34,35,53,64]

Strategies to address problem areas

The impediments towards academic commercialization and career advancement for women faculty in engineering and science clearly include gender discrimination, attitudinal and behavioral factors, work-life balance, and exclusion from networks. The purpose of this paper is to not only raise awareness of the likely origins of these issues, but to make recommendations on how staff, faculty, departments, and universities can create a more equitable career trajectory for women faculty in engineering. Strategies to address the barriers that women faculty experience, first, begin with awareness and education. Second, recommendations for policy change and organizational change are made to encourage cultural and practical shifts in the academy.

Awareness and Education

This literature review, in itself, reflects the need for more awareness and education around the barriers facing women in the academy. Much of the literature is focused on individual factors as explanations for the disparity in the rates of women in higher ranks and engaged in academic commercialization. Although this research is a positive first step, institutions, departments, leaders, and faculty must take a critical look at their entire system. Before they can critically assess their institutional environments, they must develop awareness and become educated about all of the factors involved.

In a study on the gender inequality facing women professionals in science Cech & Blair-Loy examined impediments to advancement.[67] The researchers found that not all women who had successfully advanced to senior positions had an understanding of the gender discrimination and structural inequities at work in their organizations. Although 60% did have this awareness, more than 25% of those interviewed cited women's lack of individual motivation as the primary reason for disparity. If not all women who are experiencing these factors have an understanding of their underlying causes, one can assume that the predominant population of men in the academy have even less awareness. To address education and awareness, Sandler, a Senior Scholar at the Women's Research and Education Institute, urges stakeholders to recognize that change is not only the responsibility of women, faculty, or administrators, but it is the responsibility of all.[68] It is also important to recognize and cultivate the notion that change is ongoing and that there is no quick fix for this pervasive issue.

Sandler councils that leaders at all levels of the institution should work to make women's issues institutional issues.[68] This work can be done by educating students, staff, faculty, and even trustees about both the institution's commitment to this issue and the ways it can be addressed. Educational strategies can include discussion forums, speaker-events, and targeted trainings for students, staff, and faculty. In particular, several authors recommend education, starting with department heads. Massachusetts Institute of Technology's committee on women faculty recommends informing department heads that there needs to be a targeted effort to recruit women faculty.[37] Fox draws on NSF ADVANCE initiatives, which focus on the representation and advancement of women faculty in science, to suggest designing workshops for departmental chairs with the goals of raising awareness around climate, identifying issues, and creating action plans.[42]

Policy Change

After educating about impediments to women faculty's advancement and participation in academic commercialization, institutions can show their support by making policy changes linked to gender discrimination and work and life balance. In relation to gender discrimination, policy changes can effect resource distribution, workplace climate, sexual harassment, and ultimately faculty advancement. Instituting policies that determine the dissemination of resources has the potential to increase job satisfaction for women faculty. Open and well-communicated policies that regulate the distribution of startup funds, office and lab space, and patterns of release time should help in holding departments to equitable standards.[69]

To affect institutional and departmental climate, Sandler first advocates instituting a bias-free (with an emphasis on non-sexist) language policy.[68] Training for faculty and staff is recommended to ensure that all have the same basic understanding of definitions and how to use bias free language. As an example, the University of New Hampshire has developed such a policy and an accompanying website on bias free language.[70] Another policy to influence department climate should be focused on equitable distribution of teaching, committee work, student advising, and other services not considered in tenure and promotion. According to Rosser, to compensate for low numbers of women in engineering and science departments, junior women faculty are often asked to engage in higher numbers of these activities compared to their male counterparts.[11] STEM departments should set clear guidelines around how these activities are assigned and implemented to ensure adequate time for all faculty to engage in research and academic commercialization.

Sexual harassment is a very serious issue in institutions around the country. One step that can be taken towards eliminating sexual harassment and gender bias is to establish and enforce policies toward these ends. "Senior administrators play critical roles in terms of allocation of human, financial, physical, and time rewards for those who enforce such policies. For example, giving the outstanding research award from the university and/or providing a research sabbatical are not appropriate for a documented harasser as mechanisms to get him out of a problem situation. Upon rare occasions, where the senior administrator is the harasser, the institution must be particularly responsible to ensure that action is taken…" (p.65).[11]

Balancing work and family is never easy and as women tend to be responsible for a large portion of household and family care, responsive policies have the potential to make a significant impact on career trajectories. Several researchers recommend creating consistent and substantial policies around leave for birth, adoption, or family illness.[37] Fox suggests considering ADVANCE "life transition" awards, which are grants given to faculty to use for research assistance, release time, or other needs during significant life events such as caring for elderly family members.[42] One similar benefit implemented by universities such as Georgia Institute of Technology is active service-modified duties. This option allows spouses, partners, or parents spending a significant amount of time involved in childcare to request up to a semester of modified duties near the time of adoption or birth.[71] Institutions should also consider policies that stop the tenure clock during these types of life transitions so that women faculty do not lose critical time on work that impacts advancement and consideration for tenure.[11] Other suggestions around work family conflict include instituting on site child care and creating policies to facilitate dual-career hiring programs.[42] There are some universities that have created policies that encourage partner hires to attract and retain couples. These policies can include items such as paying a portion of one partner's salary for a specified period of time.[72]

Leadership

Research by Whittington & Smith-Doerr found that women faculty are more likely to engage in academic commercialization, "in flatter, more flexible, network based organizational structures…" (p.194).[7] As leadership tends to set organizational and departmental norms, guidelines, and values, the role of the department chair becomes quite significant for women faculty. Offermann & Malamut found that women faculty's productivity and job satisfaction are all effected by chair leadership.[73] The department chair can play an important role in communicating clear expectations for the fair treatment of faculty, encouraging collegiality and ensuring equity in resource distribution and departmental assignments.[38] One strategy which would assist department chairs in all of these endeavors is to support efforts to change department culture and climate through grant initiatives, similar to NSF ADVANCE.[74]

As inclusion in networks is a significant barrier for women in engineering and STEM, department chairs can take steps to facilitate interactions and knowledge sharing among faculty. One approach is to place junior women faculty in projects and networks which are highly collaborative.[75] Productivity, inclusion, and cooperation can be created through constructive interactions, or opportunities for essential knowledge sharing around work, expertise, funding, etc. Department chairs have the ability to formally and informally create these interactions in departmental meetings, working groups, and trainings for faculty.[42,76]

In addition to facilitating women's inclusion in networks, department chairs can serve as mentors for faculty and/or build mentoring structures. In many instances mentor relationships develop naturally, but in a male dominated department this this may not be the case for women faculty. Where these relationships do develop, "mentors can make otherwise unspoken norms and expectations clear, identify departmental procedures and politics, and assist in the practical aspects of teaching, research, and service activities often required of faculty."[38] Beyond standard faculty responsibilities, mentors can also facilitate academic commercialization. Mentors have the potential to not only encourage women faculty to consider commercialization activities, but also to connect them with resources and networks engaged in commercializaton.[34]

Since department chairs and mentors can play an important role in organizational change, selectivity becomes essential. When possible, the university should seek women for these positions. Regardless of gender, these individuals should have awareness and a stated interest in creating a positive department climate. To create accountability, the university can create mechanisms to solicit input from faculty about the department and it's leadership.[38] One outcome of MIT's study on the status of their women faculty in STEM is the recommendation to create a standing committee to hold departments and their leadership accountable for improving gender equity. This committee is responsible for raising awareness and educating around the need for equity, creating channels of communication between women faculty and department heads, and creating a yearly progress report on the status of women faculty.[77]

Training

Although much of the literature has shown that women faculty's lack of exposure to and training in academic commercialization results from a large number of other barriers, there are ways in which training can assist with this issue. Wilson et al. found that for graduate business students, targeted entrepreneurship education made a difference in women's self efficacy.[22] In Rosser's article on the gender gap in patenting, she makes astute recommendations around student training that should be implemented by current faculty with their own students and that could be incorporated in the training of faculty themselves.[2] These recommendations emphasize the equal training and treatment of men and women. They include making the stages of commercialization transparent, providing access to appropriate mentoring and networks, encouraging students to engage in a balance of low and high risk ideas and experiments, emphasizing the social and environmental usefulness of commercialization, and providing courses and online training in all aspects of entrepreneurship.

Conclusion

The advancement of women faculty in engineering and science and their involvement in academic commercialization needs to be addressed by institutions and by society at-large. These women have the potential to impact applied research, socially focused innovation, and the economy through patenting, licensing, and spinning off inventions into companies. It is imperative that stakeholders inform themselves, raise the awareness of others, and engage in educational activities to lift up the barriers facing women in the academy. Gender discrimination such as resource discrimination, negative organizational climate, and sexual harassment set the tone and affect women faculty's experience in the academy and their ability to engage in academic commercialization. Behavioral and attitudinal factors including entrepreneurial self-efficacy, productivity, and risk aversion are clearly linked to gender discrimination and are often, incorrectly, discussed as inherent to women scientists. In addition to these significant impediments, women are required to navigate complicated work-life balance issues and professional networks that discriminate against them, again, based on their gender. All of these barriers stack up so that women do not advance in the academy in the same ways as their male counterparts and therefore have less exposure to and less engagement in academic commercialization.

Fortunately, some researchers have begun to make recommendations about ways in which institutions, departments, leaders, and stakeholders can address these barriers. Beyond the first step of education and awareness, departments can begin to institute policies to effect gender discrimination, work and life balance challenges, and equitable advancement. In addition, department leadership plays an important role in cultivating department climate, facilitating inclusion in networks, and building systems that create accountability and change. Finally, engaging in training around the barriers that women faculty face, inclusion and diversity, and academic commercialization for staff, female and male faculty, and students, will begin to chip away at inequity.

Unfortunately, these recommendations are not enough. There is a dearth of research around best practices for advancing women faculty in engineering and science and engaging them in academic commercialization. Now that researchers have begun to identify and understand barriers, research much be expanded to strategies that target change. Additionally, much of what does exist in the literature addresses various pieces of the puzzle, but does not discuss change in a comprehensive, sustainable manner. In order to truly address this issue we must tackle everything from overt and subtle bias, to lack of training, and everything in-between. As Fox stated, "The opportunity, then, is that just as social-organizational environments are structured, so they can continue to be restructured—to support enhanced and gender-equitable participation of faculty in science and engineering. This involves ongoing examination and attention to the ways in which the organization and climates of departments and the distribution of human and material resources can support equity toward full and significant participation and status in science and engineering." (p.1009)[42]

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