Literature Overview

Introduction

Women have achieved parity with men more than ever before in education and in their places of work. However, after decades of research involving the retention and recruitment of women in the fields of science, technology, engineering and mathematics, the progress made is still comparatively insignificant. The struggle for equality is an ongoing process that continues to make advances, but we must keep at this process and continue to serve the needs of women in order to make a significant difference.

The following literature overview provides some insights and key findings in the available literature relating to working women in science and engineering. The idea, first conceptualized by Sir Isaac Newton, that we all stand on the shoulders of giants is important for understanding how we advance in our society, particularly with discoveries in the sciences. The "myth of scientist as a superman" reveals that there has been consistently strong institutional support for these scientists; "they were allowed to study at the top institutions, to continue working there, and to benefit from their associations with other scientists" (Hornig, 1997, p. xiii). Ideas such as Descartes' declaration that mind and body must be kept separate for the development of scientific theory compounded this myth, implying that women were incapable of thinking scientifically. In addition, Francis Bacon asserted that science is the vehicle for man to control nature. These are some of the root premises many researchers have identified as "alienating women from science" (Ambrose, Dunkle, Lazarus, Nair, and Harkus, 1997, p. 7).

A careful review of history shows us the many ways women have been discriminated against and often overlooked simply because of their gender. Such examples include: Aristotle's (384-322 BC) belief that women were unintelligent; the fiery death of Hypotia (370-415 A.D.), a master scientist and inventor of scientific tools, who was considered a pagan; and the stripping away of the craft of midwifery from women and giving it to more scholarly trained men, thereby transforming it into the new fields of obstetrics and gynecology. Jane Colden Farquher (1724-1766) was responsible for discovering a new genus, the gardenia, and was a prolific botanist until her marriage, when she stopped scientific pursuit all together. More recently we can look to how Marie Curie's (1867-1934) success, instead of opening doors for women, "was used to set an impossible standard: no woman scientist was considered worthy unless she promised to be another Marie Curie. Of course, no similar standard applied to men" (Ambrose et al., 1997, p.19). Even today, most efforts for change are limited to women adapting to the "chilly climate" of the sciences (Ambrose et al., p. 31). One could conclude that in order for women to continue advancing in STEM fields, institutional and cultural change must occur so that truly equitable opportunities are available to all.

This literature overview stems from a **citation analysis** and a **Delphi Study**. The citation analysis was conducted to identify *what* scholars have written about barriers to women in STEM fields and to identify *which* are most frequently cited by others. This process enabled us to uncover the most influential work in this area of research and was essential to identifying our research themes. The Delphi Study was conducted to provide structure for our working conference which was intended to foster intergenerational, interdisciplinary dialogue and to develop a set of potential research questions to guide future work on workplace factors associated with women's success in STEM fields.

A larger database of 1,036 items (86 books or book chapters, 123 conference papers, 13 reports and 814 journal articles) was reviewed in order to narrow our focus to particular goals. We reviewed articles that were: 1) published from 1970 to the present, 2) were peer reviewed and 3) addressed factors that influence the recruitment, retention and promotion of women in STEM fields. As a result 285 were designated as "key articles". The key articles were further reviewed and then cut back to 87 (see attached list) and then to 46 based on our criteria which included 1) number of times cited, 2) important authors in the field represented, 3) authors from different generations represented and 4) knowledge base of our Principal Investigator. After careful evaluation of the identified 46 articles and the Delphi study, we arrived at 4 major themes which were most prominent in the content of the literature. The 4 themes are:

- Educational Pathways for Women in STEM careers
- Job and Organizational Factors
- Work-Life Balance
- Work-related Discrimination

Educational Pathways for Women in STEM Careers

Over the years the face of education for women has drastically changed. Women have made great strides which have led to improvement in their status; however; the fight for equal educational opportunities is far from over. Unintentional biases, outdated institutional policies and lack of networking and mentoring opportunities still contribute to the serious underrepresentation of women in STEM fields. Studies have found that women are unfairly treated and face barriers regarding retention and promotion, even in fields in which they have reached relative parity.

Higher education is considered the "true gatekeeper to technical careers" (Davis, Ginorio, Hollenshead, Lazarus, Rayman, and Associates, 1996, p.xii). Since higher education sets the standards for entrance into the STEM fields as well as providing the training ground for future teachers, it makes sense to focus on the restructuring of higher education's role in advancing women in STEM fields (Davis et al, 1996). As the most important contributors to the socialization of gender roles parents, teachers, counselors and peers (Ambrose et al, 1997) have the opportunity to alter perceptions and create institutional change.

The National Science Foundation released an action plan for 2008 to address concerns in the U.S. STEM education system which warned: "danger exists that Americans may not know enough about science, technology or mathematics to contribute significantly to, or fully benefit from, the knowledge-based economy that is already taking shape around us" (National Science Foundation [NSF], 2007). It further stated that 30% of college freshman have to take remedial science and math courses before they are able to take on college-level courses (NSF, 2007). It would seem that not only are women slipping through the cracks, but that many students entering college are not prepared to enter the track to scientific careers. The NSF plan is an important call for leadership at all levels of government in order to start seeing real change in STEM education (NSF, 2007). The necessary institutional change requires leadership dedicated to making the U.S. STEM education system as diverse and inclusive as possible.

According to Baum, women students currently lack important networking opportunities and effective support systems (1990); in turn there is also a great need for mentoring of women and minorities at the executive level in industry (Pfleeger and Mertz, 1995). Studies indicate that for girls and women, a loss of confidence in scientific and/or mathematical ability is not directly related to actual skills (Ambrose et al, 1997). One such study shows that "a comparison of undergraduate GPA's for bachelor's recipients, women averaged 3.17 in engineering and computer science to men's 2.96, and women's science and math GPA averaged 3.18 to men's 2.98" (Ambrose et al, 1997, p. 27). Surprisingly, females who choose to study engineering and science in college end up having much higher dropout rates than their excellent SAT scores would predict (Baum, 1990). These are perfect examples for why educators should "maintain aspirations of women already committed to science, mathematics and engineering and keep the door open for others to rediscover science in college" (Davis, et al, 1996, p. xiii). Between 1966 and 2001, the number of women earning science and engineering degrees has increased: 41% of science and engineering graduates and 37% of doctoral degree recipients are women (Byko, 2005). Yet, women hold only 1 out of 6 bachelor's degrees in engineering and only 25% in computer and information sciences (Fountain, 2000).

One critique of higher education is the number of universities and colleges that do not enroll enough women in science programs to create a "critical mass" (Baum, 1990). Prior to Title IX of the 1972 Education Amendments, women were not given equal access to higher education. In fact, some educational institutions had enrollment caps; many medical and law schools had a quota for women of 5 to 10 percent of enrollment (Ambrose et al, 1997). These discriminating practices, according to Lilli Hornig, "[are] useful to remember [sic] while such polices no longer exist because they are illegal, many of the faculty members and administrators who instituted them are still in place. Remnants of restrictive practices and attitudes persist in some graduate science departments" (Hornig, 1997).

Key questions to consider include: How does students' understanding of specific careers and of career opportunities change during the college years? At what point during college do students lose interest in science? Is the STEM field itself a turn-off or does college provide new opportunities students had not previously considered (Sax, 1994)?

Job and Organizational Factors

Women continue to encounter numerous hurdles in their efforts to find the right STEM career path. A majority of the articles reviewed raise concerns regarding the availability of opportunities and prospects for women in their respective careers. Today's working women still report significant barriers to career advancement and often feel excluded from informal networks in their workplaces. Organizations are still charged with bias regarding family responsibilities and work. Compared to men, women still feel like they have to prove themselves again and again in order to prove their worth. In spite of women's talent and ability to deliver, many organizations make little or no effort to make the work environment more favorable to them.

According to *The Equity Equation: Fostering the Advancement of Women in the Sciences, Mathematics, and Engineering,* "in spite of somewhat reduced academic and research opportunities, scientific and technical occupations still present greater opportunities and rewards for women than more traditional fields" (Davis, Ginorio, Hollenshead, Lazarus, Rayman, & Associates, 1996, p. xi). Still women in STEM fields must contend in practice with Merton's theory on the sociology of science in which "the urgency of original discovery creates both great intellectual pressure and a work environment that encourages competition rather than cooperation" (Rayman and Brett, 1993, p.10). Yet new scientific breakthroughs such as the recent "discovery of a gene for Huntington's disease was credited to a collaborative effort that prevailed over a more competitive approach" (Rayman and Brett, 1993, p. 12).

In the article "Women in manufacturing: engendering change", J.V. Owen (1993) points out a need for women to choose better jobs and opportunities, making a conscious effort to counteract stereotypes which are the biggest barrier for women. For instance, in the court case Equal Employment Opportunity Commission versus Sears, it was ruled that there is no issue of discrimination when women are simply not interested in high paying positions (Williams, 1989). Obviously there is a need to break down the institutional stereotypes that still exist about women's desires and needs in the workplace and beyond. In order to attract and retain highly skilled professionals, there has to be an understanding of how men and women perceive their own professional and domestic roles (Beasley, Lomo and Seubert, 2001).

Career development has been documented as being more rewarding for women in biology than in physical sciences, engineering and math (Sonnert and Holten, 1996). Women are less likely to enter math and physical science occupations because they have less confidence and place less subjective value on these fields (Eccles, 1994). Only 10% of physics faculty are women, and women in the field of physics are paid less than men (Ivie and Ray, 2005). Solutions to combat pay inequity include greater representation of women in unions and comparable worth policies (Bodger, 1985). Obviously there is under-representation of women in many science fields. Additionally, there is a shortage of minority women. Between 1976 and 2003, a nearly thirty-year time span, just 35 African-American women and 57 Hispanic women in the U.S. earned Ph.D.'s in physics (Ivie and Ray, 2005).

In 2001, 26% of employed doctorate holders were women as compared to 37% of all doctoral degree recipients (Byko, 2005). In 2007, women earned 48% of all doctorates; however, "their gains in the ranks of the faculty have not kept pace with their growing presence in the pool of trained academic talent" (Wylie et al, 2007, p. 3). Women receive less extramural recognition; women with doctorates are invited less frequently than men to participate in conferences, lectures, editorial boards and panels (Kashket, Robbins, Leive and Huang, 1974). An academic career is a profession with very high overload and high psychological pressure. In many institutions mentors are recommended for junior faculty but are not considered to be necessary once someone reaches senior status (Bailyn, 2003). Perhaps lack of available mentors is one reason for this situation. For instance, consider that as of 1980 only 35 of the 1361 members of the National Academy of Sciences were women, and only 5 of the 345 scientists who had received Nobel prizes were women (Cole, 1981).

The industrial sciences saw an increase of women working by fourfold from 1979-1989 (Culotta, Kahn, Koppel and Gibbons, 1993). The IT profession has not seen such a surge of women professionals. While 26.9% of computer system analysts are women and 28.5% of computer programmers are women, they comprise less than 30% of IT professionals (Fountain, 2000).

Key questions to consider include: Participation of women in different fields has improved from the 1970's to 2000, but what are the similarities and differences across the generations in terms of opportunities and challenges? Why are there still very few women in leadership positions? Why are companies still less likely to hire a woman than a man with identical qualifications, and why are they less likely to ascribe credit to a woman than to a man for identical accomplishments?

Work-Life Balance

Balancing work with family can be regarded as the biggest challenge women continue to encounter. Women wrestle with how to prioritize these two equally important aspects of their lives.

They struggle with the stereotype that equates having a family with lack of commitment to career and job and further implies that women who give their careers high priority make bad mothers (Ambrose et al, 1997). A significant "structural issue is the notion that science is unlike other professions in that it involves a special calling and the expectation that scientists will be wedded to their work…. and culminates in a career model that takes little account of having a life outside of work. At each stage of scientific training women are thus expected to conform to a traditionally male mode of behavior" (Rayman and Brett, 1993, p. 12-13).

Motherhood presents a set of expectations; there is a need to balance work and family life, which Evetts says requires developing a particular resolution and identity (1994). In the attempt to achieve balance of work and life, many women accept part-time work, while others prefer flexible scheduling as a condition of full-time employment (Beasley, Lomo and Seubert, 2001). Often, balancing work and family results in women taking breaks from their employment track which leads to fewer opportunities for occupational advancement (Rosenfeld, 1978).

Interestingly, the perception that married women with children do not publish as much as their single female colleagues is not true (Zuckerman and Cole, 1987). Yet, the most significant differences in pre-doctoral productivity was found to involve the effects of having young children, which decreased the odds of having a mentor, which in turn decreased productivity (Long, 1990).

Key questions to consider include: Can there really be a "balance" between work and family? In order to be a successful scientist, must one be "wedded" to science and relegate family life to a secondary status?

Work-related Discrimination

In addition to gender discrimination many women have to combat sexual harassment and racial discrimination in order to survive in educational institutions and workplaces. Sexual harassment is a serious concern for women in the sciences. In a 1993 survey of women in technical and scientific fields, 46% of respondents reported that they had been sexually harassed (Boiarsky, Earnest, Grove, Northrop & Phillips, 1993).

Many women scientists report having to work harder and to be more successful than men in order to overcome discrimination and succeed in their careers; professors report training their female students to think in these terms as well (Etzkowitz and Kemelgor, 1994).

Bar-Haim and Wikes conducted a quantitative analysis which documents "that the perspectives of men and women, among potential science aspirants, differ enough to skew the types of men and women recruited to science in different directions and that these differences have implications for distribution of cognitive types one would expect to find entering each field by sex" (1988). This research indicates that discrimination not only takes place at the workplace, but often begins at the educational level, where women and girls might get "weeded out" of the sciences. But "…regardless of what size the supply of scientists should be, the proportion of women at every level of scientific and technological education and work should be equitable" (Davis, et al, 1996, p. xi).

Key questions to consider include: Voices of women who have been discriminated against have certainly been heard, and actions have been taken; however, is there still "unconscious discrimination" against women in all STEM fields? Did "affirmative action" change anything? Do models exist within the academy and corporate sectors which prevent discrimination and create a culture of fairness and inclusion?

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