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Supporting Career Choices for Women in the Sciences and Engineering

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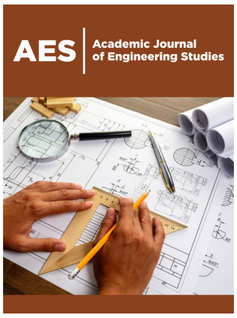

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Abstract

The purpose of this article is to review of current literature on women's career growth in the sciences and engineering fields. It became evident quickly that sufficient evidence exists documenting the gender disparities in the Sciences, Engineering, Technologies, and Mathematics (STEM). Essential at this time is the generation of remedies to encourage and promote women as they pursue careers in the hard sciences and engineering fields. The economies of Canada and the US urgently need competent scientists and engineers across domains of business, higher education, and for innovation in the creation of new technologies. The article explains how stereotype threats and biases remain prevalent barriers to both men and women in the sciences and engineering. The author proposes adoption of the growth mindset, the reinforcement of leader identify for engineers, and she recommends urgency on mentoring and coaching approaches to strengthen retention of women in the fulfillment of careers in science and engineering.

Keywords: Mentoring; Coaching; Mathematics

Introduction

As the third decade of the new millennium approaches, many significant science and technological changes continue to accelerate national economies. These economies demand creative, innovative professionals in the sciences and in numerous fields of engineering; yet the availability of competent professionals remains elusive for labor markets in Canada and the United States (US) [1]. Despite numerous programs and initiatives at state and national levels, the shortage of graduates, experienced scientists, and professional engineers remain a daunting challenge Grover [2] & Jensen [3]. The demand for educated professionals in the subject areas such as computer science, physics, and agricultural sciences is particularly discouraging Herrmann et al. [4]. Noteworthy is the list of desirable attributes that employers seek, (Table 1) Attributes Sought by Employers [5]. Review of the list indicates demand for professionals with competency in the soft skills, such as leading, teamwork, written and verbal communication, and creativity, to name a few. Starting in the late twentieth century, the US sought to address the need for such job candidates by successfully implementing federal and state level educational initiatives to strengthen science teaching of its students. These efforts embraced the diversity of American society and endeavored to follow the lead of the United Kingdom (UK) to "grow its own" supply of engineers [6]. The Canadian government response to this need appeared included accelerated immigration programs, inviting experienced technologists, university graduates, and qualified professionals to quickly enter the country Cohen [7,8].

Table 1: Attributes Sought by Employers (National Association of Colleges and Employers, 2019).

Attribute	% of Respondents
Leadership	80.10%
Ability to work in a team	78.90%
Communication skills (written)	70.20%
Problem-solving skills	70.20%
Communication skills (verbal)	68.90%
Strong work ethic	68.90%
Initiative	65.80%
Analytical/quantitative skills	62.70%
Flexibility/adaptability	60.90%
Technical skills	59.60%
Interpersonal skills (relates well to others)	58.40%
Computer skills	55.30%
Detail-oriented	52.80%
Organizational ability	48.40%
Friendly/outgoing personality	35.40%
Strategic planning skills	26.70%
Creativity	23.60%
Tactfulness	20.50%
Entrepreneurial skills/risk-taker	18.60%

Source: Job Outlook 2016, National Association of Colleges and Employers.

Gender disparities in sciences begins in elementary education and continues throughout the career of a woman. According to the Canadian census data from 2016, women were more likely than men to leave the sciences, technology, engineering and math, known as STEM studies, in their early years of university, while in the later years both sexes were equally likely to leave. Women were more likely to switch to the fields that require of the soft skills and thus study business, humanities, arts, social sciences, and education Wall [8]. Interestingly, there are some women that choose alternative programs like nursing, psychology, and pharmacy, where they continued to use their math skills. This paper reviews literature on the prevalence of gender disparities in STEM and makes three recommendations to address the urgency of improving career guidance for women studying and working in the hard sciences and fields of engineering.

In the United States, although over 50% of the degrees in biology, chemistry, and mathematics are earned by women, less than 20% of the graduates are in subject areas like computer science, physics, and engineering Cheryan [9]. Cheryan et al. [9] identified one of the key weaknesses of the STEM literature; that is, the aggregation of statistics under the STEM umbrella does not adequately reflect the variation in the culture of different subject areas. The authors identified three factors contributing to the gender imbalance: women felt a low sense of belonging due to the male culture in the subject area; women lacked prior experience in subjects like computer science, engineering, and physics; and thirdly, the gender gap is most problematics in computer science, engineering, and physics. A consequence of the third is that women miss out on high paying jobs and lack access to the new technology initiatives within existing corporations and university institutes. Unless the woman is an entrepreneur, opportunities are lost for her to access the creativity, innovation, and business potential of new technology.

Although the US is Canada's most important trade partner, as a member of the Commonwealth, Canadian leaders tend to look to Europe for inspiration. In the European Union (EU), the report is dismal on changes in the gender divide after a ten-year period from 2006 to 2016 Yatskiv [10]. Improvements were visible only in the number of women politicians and government managers; in the important domains of higher education, research and development male domination remained. Nevertheless, the EU established The European Institute of Gender Equality and made available substantial free resources to encourage employers to address gender disparities. In business, higher education, and for research and development, and with the exception of the United Kingdom, Europe offers little inspiration on changes to the gender disparity.

Literature Review

Sources for this paper included a variety of books, surveys, studies, and peer-reviewed journal articles. Twelve surveys conducted by government or their agencies provided accurate data on the presence of women in the sciences and engineering fields, as well as the demographic profiles present in Canada and the US. Eight books published between 1988 and 2016, provided source material on career development, adult learning, on women leaving the sciences, on the MBA, and on coaching and mentoring. Most intriguing were the twenty-two research reports and peer-reviewed journal articles that revealed the abundance of research on gender disparities, stereotype threats motivation and instructional strategies related to women in the sciences. Finally, the literature from social psychology was a fascinating expedition for this author Shapiro & Williams [11].

The Growth Mindset

An individual's self-concept emerges early in Western countries due to the pre-school socialization that begins as early as two years of age. Male and female children quickly pick up the cues from adults and other children and readily form their perceptions based on this life experience. Immediately, the child begins to build a repertoire of impressions, organizing and interpreting the cues from those around him or her. By the time a Canadian child enters the school system, particularly in the urban areas, he or she has acclimatized to the nature of social interaction with adults and other children. Gender-related attitudes emerge as a consequence of the exposure to sights and sounds that are gender activated. For example, if the child has a bright older brother who excels in math and physics, this becomes a topic heard at the family table, at meals, in the car, and everywhere the child goes, the family conversations send messages about a male who succeeds in math and physics.

As the younger child grows, he or she is proud of the older brother; and wants to copy him. If the younger child is a boy, he senses the similarities, and it's easy to copy his older brother. If the child is a girl, differences surface in words and actions; the brother's performance is gender-activated if someone states or alludes to the normality that boys are better at math. This stereotype becomes part of the girl child's collected data and begins to distort her self-concept. Through sight, sound, touch, and emotions, the young girl perceives then then aligns her brother's performance in accordance with family beliefs and values. If gender was not activated, the girl had an enriched, implicit self-concept and assumes copying her older brother is a nature act Stout et al. [12]. If the girl child has no basis for attributing success in math and physics to her gender, then she proceeds with free choice, and clearly this is an ideal situation. Without gender-related threats, the example illustrates the benefits of a growth mindset within the family Dueck [13].

The growth mindset implies the child's potential aligns with the family's values and beliefs about generative growth and development of their children. Their beliefs about their child's potential seems boundless, a continuous one of learning and improving. The growth mindset suggested that learning continues to expand as the child moves through life; and that assessments of a child's potential can change. A fixed mindset is a contrast to growth, with a focus on an individual's potential as limited to what is known at one point in time, like the results of an IQ test. After taking the IQ test in school, teachers and parents believed their child's intellectual capacity was given and unchangeable, and a good example of a fixed mindset. The significant technological advances in the second half of the twentieth century helped to change this erroneous view of IQ. As different areas of medicine and psychology converged, new knowledge emerged about how the brain and nervous systems worked and evidence became abundant that the brain is plastic; individual cells, the neurons, changed as synaptic connections took place between them. It did matter whether one is three, thirty, or eighty-three, the neuroplasticity of the brain ensured that, as long as the heart pumped, the human brain learned and unlearned. The implications of neuroplasticity were enormous for educators, as new interpretations of the fluidity of the brain established different ways of assessing and interpreting learning disabilities and learning at all ages. At the beginning of the new millennium, it seemed that the fixed mindset was a thing of the past; that parents and teachers would accept more generous views of the human potential of their children.

A child's early life experiences rarely are confines to the family; and other venues implant the stereotypes about career choices in the sciences and engineering. Computer games consume an abundance of children's time since they became available in the 1990s, yet the gender imbalance is already present in high school College Board [14]. The content of computer games may contribute to the gender imbalance because the games are overwhelmingly male oriented with few substantive roles portrayed by women. American statistics reveal a startling contrast with only18% of women choosing undergraduate degrees in computer science, even though women made up 44% of the undergraduate degrees in mathematics [15]. The post-secondary programs for computer science attract huge numbers of men, making the gender disparity more difficult to track; and also, companies tend to hire more men for information technology jobs, regardless of their qualifications.

According to the [16], the gender mix is complicated by the addition of international students who attend American universities to complete graduate and doctoral studies. For college entrance exams, high school girls are as likely as boys to take the tests; however, their involvement in subsequent career stages declines from the undergraduate to doctoral levels. The only way to increase female numbers between high school and post-secondary is more aggressive recruitment programs plus the addition of interventions such as mentoring and coaching throughout all education levels. Differences across subject areas are relevant to understanding the gender imbalance; and more attention to data differences between the hard sciences will benefit research on women's career choices in sciences and engineering fields.

In 2012, the U.S. Department of Education established a Teacher Incentive Fund (TIF), to improve teaching of STEM content in kindergarten to high school. This included a career ladder for science teachers and access to a range of instructional materials intended to more fully engage the diversity of students. The objective is inclusiveness in science education with students and teacher learning in a way that stimulates and sustains interest in science. The outcome of this federally funded program is inclusiveness; such programs are essential to recognize and include the diversity of American society by intentionally placing value on learning science and acknowledging the important roles of teachers in promoting

STEM careers. Through the TIF, teachers and school administrators received support and reinforcement to pursue teaching the sciences with more rigor and they received rewards for making extra efforts to teach and communicate the value of science to their community Millanoski & Miller [17].

When a new student enters a university program, they look to the faculty for confirmation of their career choices; and remain mindful that the evaluative process goes both ways. While faculty evaluate students on achievement of the course competencies, they also communicate their values and beliefs in the way they interact with the student. In the earlier example of the older brother who does math and physics, the younger sister engages in an assessment of the beliefs and values of the family that surrounds her. At university, students assess their faculty constantly, observing their behavior, speech, and attitudes in the classroom, on the campus, and in the community. If the student perceives that a faculty member has a negative image about the role of women in his subject or discipline, this assumption discourages the women student from succeeding in the subject. In this context, a fixed mindset is an unwillingness to change one's view of a group; that is, a stereotype is present. Fuesting et al. [18] suggest that faculty's influence not only relates to the student's ability to acquire new competencies in the subject but also whether the student wants to be successful in the faculty's field of study. The authors suggest that the faculty adopt a growth mindset that helps women in the faculty's subject to pursue their career goals.

Leader Identity for Engineers

Engineering education and the MBA

Only recently has management and leadership education become part of the curriculum in engineering education (MacIntyre, 2014). For engineers, acquisition of the Master's In Business Administration (MBA) from a reputable business school was the most desirable addition to an undergraduate degree in engineering. By the late twentieth century, criticism of the MBA required significant improvements; course content stressed analytical skills in finance and accounting. As a result, graduates were unprepared to address the multi-faceted organizational issues that were more evident as a consequence of global business Mintzberg [19] & Shoemaker [20]. American business schools led the way with the re-design of the MBA curriculum, which became multi-disciplinary, integrating human resource management and change management. More emphasis stressed adult learning principles, and critical thinking; instructional strategies included teaching methods of inquiry, use of individual and shared reflective practice, and dialogue education Vella [21].

Criticism of the MBA curriculum emphasized its lack of course attention to creativity and innovation; and as a result of the criticism competency based, modular programs became the priority in most management education and business administration degrees. Even continuing education programs articulated learning outcomes and skills development, copying the lead of MBA degrees (Datar, Garvin, Cullen, 2010). Management educators also began to make distinctions between managing and leading, as national economies moved away from the stability of the second half of the twentieth century into rapid response to customers and clients. Thus, leading became synonymous with change, while managing related to factors with some sense of predictability.

Engineering leadership education

To address improvements in engineering education necessitated the addition of learning to lead with respect to new technology, including leadership in relevant public policy debates, such as infrastructure projects Farr, Brazil [22] & Fishbein [23]. Since 1995, the undergraduate engineering degree at Pennsylvania State University offered a minor in leadership development through courses in organizational leadership, communication, and marketing. Avolio (2005) defined the full range of leadership styles with emphasis on the movement of the leader from the passive style of little interaction with followers to the relationship styles of transformational leadership. This tool became a valuable one for teaching leadership; its graphic form helps students to understand that leadership is an unending process that is situational and experiential. Avolio's model reinforces the role of the leader in assessing the situation or context, the importance of the developmental role of the leader, and the role of the 'follower' that began to emerge in the new millennium.

Supportive Interventions

Herman et al. [4] identified the benefits of an online intervention between university faculty and students in STEM. It was a simple action for American universities to address the high dropout rates of students who left STEM majors for studies in other undergraduate degrees. This dropout rate is not unusual given the rigor of science and engineering courses in the first two years of university. Interventions help to retain students in a field of study; this is particularly cogent for women in STEM, who lack a sense of belonging to the group and thus feel isolated and rejected. Stereotype threats have negative effect and are situational; the remedy requires an immediacy, such as self-affirmation to buffer the woman from the negativity Miyake et al. [24]. Role models reduce stereotype threats by confirming that female representation is a norm in the group Marx et al. [25].

As noted earlier in the paper these attributions may be self-created or a legitimate stereotype threats due to a male culture Cheryan et al. [9]. Herman et al. [4] reported on the Mentoring and coaching are two learning techniques that are indispensable for developing a succession of leaders in the fast-paced world of today's global business and education. In a mentoring relationship, an experience individual shares his or her experience of an open system with an individual who is newly entering the system. The mentor has the wisdom that is valuable for the mentee to learn; by acquiring this information, the mentee may be easily maneuver his or her entry to the system. Coaching is also a learning process; it involves a coach posing powerful, open ended questions to help the client or coachee focus on behavioral change. The relationship relies upon dialogue and conversation, although the coach requires an astute listening ability in order to steer the client in the appropriate direction. Coaching is goal oriented and philosophically is intended to generate energy within the client to change his or behavior, as a means for leading others into changing. The following paragraphs briefly introduce the mentoring and coaching relationships as a means to retain students and employees of science and engineering. In the Teacher Incentive Fund Millanoski & Miller [17], mentoring relationships supported the development of science teachers. One lead or master teacher mentored fifteen regular teachers and one mentor teacher mentored eight regular teachers in the context off.

Mentoring

A mentor is a role model who shares stories and experiences in order to educate the mentee about the field of practice. The mentor supports individual development while also providing a psychosocial function, such as giving counselling or giving career advice Kram [26]. It is very unlike coaching in this respect, as coaching shifts the talking from the coach to the client, who attempts to uncover ways of changing his or her behavior to achieve a goal. Mentors share their knowledge, experience, and attitudes, and may bring a refreshing view to mentee who is stuck on a problem or issue. Mentoring is the recognition of the constant shifting of content and context. Content relates to mastering skills or a functional discipline, while context relates to the movement of situational factors. As professionals move up the organizational hierarchy, they realize it is impossible to master content and they learn to rely on others for knowledge as their context changes. By establishing mentoring relationships an orgnaiztaion makes a deliberate attempt to share tacit knowledge; that is the working knowledge of the organization that is not explicitly learned from books, manuals, and the company Intranet. Only dialogue and sharing of stories about one's experiences in the company will reveal the organizational culture, where the values and beliefs are embedded.

Coaching

Coaching is a process for managers and leaders to enable followers to develop his or her potential in a desired field of practice. In an organizational context, the purpose of coaching is to help individuals lead change management projects Cox [27] & Grant [28]. Coaching is an interdisciplinary endeavour combining the principles of adult learning, organizational development, and coaching psychology; and many forms of coaching emerged since the 1990s: executive, managerial, business and life coaching Joo [29] & [30-35]. Coaches contribute to the creation of a pipeline of successors to populate one's company, laboratory, or institute with individuals who will further the legacy of its founders. Coaches provide a means for learning how to give and receive feedback, thus engaging followers in the performance management and human resource management systems of a company. Coaching looks easy; however, it requires a unique blend of competencies in emotional intelligence and cross-cultural awareness. Coaching requires good listening skills and engages the client in a conversational mode. The coach provokes the client in a positive, generative way intended to inspire self-efficacy [36].

Conclusion

This brief paper focused on the gender disparities in the education and employment of individuals who wish to pursue careers in the hard sciences and in the fields of engineering [37,38]. Initially the author intended to focus on careers within STEM and quickly discovered some of the limitations within the literature. In an effort to address the urgency of changing the process for aiding students and employees, the author recommended three approaches for immediate application within business, higher education, and areas of research and development of new technologies. These included adoption of a growth mindset for empowering children, university students, researchers and innovators in the hard sciences and most fields of engineering. The second and third recommendation were application of mentoring and coaching relationships to facilitate retention of existing students and employees in the pursuit of career goals [39-44].

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