Preface

Ronald J. Burke and Mary C. Mattis

Advances in science, technology, engineering and mathematics (STEM) have been key factors in contributing to past and future economic performance and success of both developed and developing countries. This success has then been translated into higher living standards and improved quality of life for their citizens. Such advances were the products of educated and skilled STEM workforces.

However, these countries are facing a likely skill shortage of workers knowledgeable and skilled in STEM. The STEM workforce, comprised mainly of white males, is aging, with many on the verge of retirement. Immigrants from developing countries such as China, India, Russia and Singapore made up a significant percentage of the STEM workforce in North America and Europe in the past, but as their home countries become increasingly developed, fewer choose to leave. In addition, women, minorities and the disabled, though talented, have historically been underrepresented in STEM education and occupations. It has been shown that these groups face unique challenges at all stages of the STEM pipeline. They are less likely to choose careers in STEM, more likely to drop out of STEM educational programs and STEM occupations, and less likely to advance in STEM careers, in both academic and business settings. These outcomes reflect the failure to create the conditions in which talented women and minorities can fully and fairly participate in STEM should they choose to do so. This may have negative effects on the quality of STEM education and contribution in the short term, with potential adverse effects on economic performance and quality of life in the long term.

It is necessary to encourage more women and minorities to participate in STEM in order to meet the needs for skilled employees. Fortunately, research and writing over the past 20 years has provided considerable understanding of the issues women and minorities face in contemplating and preparing for STEM careers. In addition, some initiatives have proven to be successful in supporting women and minorities in the pursuit of these STEM options and reducing obstacles to success.

The reasons for the underrepresentation of women and minorities in STEM are complex and exist at several levels (individual, family, the

educational system, the workplace, and in society at large); action strategies and solutions must also address each of these levels.

This collection provides an overview and integration of what is currently known about the status of women and minorities in STEM. It includes contributions from researchers with an ongoing interest in women and minorities in STEM, contributions from researchers interested in women and minorities in management and the professions more generally, and contributions from both academics and STEM program administrators. Our hope is that readers will be motivated to take individual action to address the challenges identified in the chapters that follow.

OVERVIEW OF THE CONTENTS

This volume is divided into five parts. Part I, *Women and Minorities in STEM: The Big Picture*, includes two chapters that provide an overview of the importance of including women and minorities in the STEM workforce, the challenges that lie ahead, and action strategies that have proven to be effective.

Ronald Burke sets the stage for the chapters that follow. His review considers the importance of STEM for continued economic success, why a skilled STEM workforce is critical, the looming shortage of STEM workers, the underrepresentation of women and minorities in STEM and why this represents a waste of educated and skilled talent, the benefits of including more women and minorities in STEM, barriers women and minorities face in the STEM journey, and action strategies that address these barriers. While these issues are not new, there is an urgent need to address them today.

Donna Dean and Anne Fleckenstein, following a review of statistical evidence indicating that women drop out of the STEM pipeline at higher rates and at earlier stages than men, and make slower career progress, examine barriers to women's full participation in science. These obstacles, while perhaps more subtle today, are not new. Young girls and women choose not to pursue careers in STEM, often the result of a lack of self-confidence. Girls and women receive less encouragement, lack female role models, face discrimination in the workplace, endure the male culture of science, and express concerns about successfully integrating work and family. Fortunately, some solutions have proven to be successful. The authors review initiatives, mostly in academic settings, targeting recruitment and hiring decisions, supporting the visibility of women scientists in the larger community, and system change permitting more workplace flexibility around maternity and the tenure clock. In addition, they summarize efforts

at various levels of the educational system to recruit more girls and women to STEM careers. The important role of professional societies is also addressed. They end on a hopeful note, concluding that although girls and women face obstacles, they can still succeed in STEM if they have a love of science itself.

Part II, *Experiences of Women and Minorities in STEM*, includes five chapters that consider women in engineering programs in the UK, women's experiences in IT, the experiences of African Americans in PhD STEM programs, women's experiences in the Israeli high-tech sector and career experiences and progress of Asian-American scientists in the USA.

Abigail Powell and her colleagues explore how women experience engineering in higher education in the UK. While increases in the numbers of women in engineering education remain small, these increased numbers in education have not been translated into increases in female engineering professionals. The authors provide a deep analysis of the engineering culture in both employing organizations and higher education. Based on interviews and focus groups with women engineering students, they illustrate experiences ranging from 'good' to 'bad' to 'ugly'. Women engineering students were positive about their courses, lecturers and programs of study. They were critical of the teaching and learning methods, however. And they experienced negative attitudes from male peers and teachers that made commitment to engineering difficult. They conclude with suggestions for change that build on the 'good', and address the 'bad' and the 'ugly'.

Debra Major and her colleagues examine the extent to which common myths or beliefs about women and men in the IT workforce are true or not. Women are underrepresented at all stages of the IT pipeline. Gender myths can have powerful effects in organizations subordinating women and minorities in IT. Some myths include: women are too emotional and irrational to be good leaders; IT work is best done in isolation; and IT work is unsuitable for women because it is boring and solitary. They report findings from a longitudinal study of gender and workplace climate in 11 IT organizations in the USA. Some myths were supported (e.g. the IT work environment is fairer for men, women have a harder time developing work relationships) and some were not (e.g. women were effective leaders). If perception is reality, women in IT have made some progress, but there is still a long road ahead.

Daryl Chubin focuses specifically on the experiences of African Americans in STEM. He reports the results of focus group discussions with 40 black graduate students in STEM supported as Packard Scholars. The Packard Program supports a significant number of African-American students pursuing PhDs in STEM. What did these students voice? They felt pressure to reach out to other minority students. It was also difficult being

a trailblazer. They faced difficulties associated with racial and gender bias. Chubin also distills strategies and practices that helped these students. New PhDs underestimated their skills. Successful students felt accountable to fulfill the 'performance contract' between themselves and their faculty supervisors. In addition, some university departments were outstanding at supporting minorities. The Packard Scholars Program emerged as an important and unique opportunity to diversify the STEM workforce, and warrants replicating.

Ronit Kark considers women in the high-technology sector in Israel, a country that has made dramatic strides in this sector (patents, start-ups) in the past 20 years. The findings of her study of women in STEM in Israel seem strikingly similar to those carried out in North America and Europe. Women are underrepresented in STEM here as well. She discusses four barriers to women in STEM in Israel: the educational system; mandatory military service; family and motherhood; and the use of the Hebrew language. The Israeli government, aware of the need more fully to utilize women in STEM, is undertaking projects targeting the educational system, military service and the family. It is too soon to assess whether these efforts will bear fruit.

Tina Chen and James Farr report the results of an empirical study of the glass ceiling for Asian Americans in STEM. Asian Americans are overrepresented in STEM fields and are often seen as a 'model minority'. Would a 'model minority' face a glass ceiling? They considered both gender and racial aspects by comparing men with women and Asian Americans with African Americans. They used four waves of data collected by the National Science Foundation on scientists and engineers. White males fared better than all other groups, with larger differences found in the managerial sample. There was evidence for a glass ceiling effect for Asian Americans over a seven-year period for respondents at all stages of their careers. So much for the benefits of being a 'model minority'!

Part III, Building Interest and Commitment to STEM, includes three chapters. These address the role of stereotype threat in reducing young women's interest in STEM, factors that influence young women's interest and commitment to STEM education, and ideas for increasing women's enrollment in university engineering programs.

Jennifer Steele and her colleagues focus specifically on the barriers that gender stereotypes can impose on women in STEM. Girls at an early age begin to differentially associate male and female with particular academic content. The research evidence suggests that having awareness of self-relevant stereotypes, termed stereotype threat, might reduce performance and lessen interest in stereotyped areas for some women. Stereotype threat occurs when members of a negatively stereotyped group (e.g. women in

STEM) face the prospect of confirming the stereotype of their group. Unfortunately several context factors appear to reduce women's performance in STEM. Steele and her colleagues review possible interventions to reduce the negative effects of stereotype threat, including changing educational environments so that girls and women feel less concern they will be viewed stereotypically, self-affirmation, and changing one's susceptibility and responses to stereotype threat.

Susan Metz, building on data showing that engineering-ready women choose engineering at lower rates than other professions, tackles the question of attracting more women to engineering. The good news is that women are prepared to study the subject. But how can we interest and engage women and minority students in engineering? She focuses on two aspects of engagement in her chapter – *emotional* – a positive reaction to the academic setting, and seeing engineering as both fun and intellectually rewarding, and *vocational* – seeing engineering as meeting their aspirations and leading to valued long-term rewards. This involves challenging common stereotypes of engineering, improving the portrayal of engineering in the media, and broadening the descriptions of engineering to open up more career possibilities. The reality is that engineers can be found in most professions.

Helen Madill and her colleagues review what is known about developing career commitment to STEM-related fields. Girls and women (and some men) have problems identifying a career focus prior to university, being a success in their first jobs following graduation, and advancing in their careers. They report findings from three studies to better understand women's career decision making in STEM. They found specific initiatives (science career workshops, paid research assistant jobs) increased STEM interest and commitment. In addition, other people (family/friends) influenced people's STEM choices, as did hands-on work experiences. The authors identify seven myths (e.g. recruitment is the real issue; once I get a degree everything will fall into line) and consider research evidence addressing each, debunking all as wrong or incomplete. They conclude with practical suggestions to develop career commitment to STEM – a process than can be unpredictable, with a wide variety of possible options. The pipeline in STEM is not a linear progression but instead has multiple entry points and options.

Part IV, Enriching the Educational Experience, in two chapters, suggests ways for making the university educational experience more relevant to women and minorities. These include efforts to make the pedagogy and content more meaningful, ways to make the transition from high school to university smoother, and how mentoring via the Internet can provide information, advice and support to women and minorities.

Ilene Busch-Vishniac and Jeffrey Jarosz focus on the STEM courses in the undergraduate experience of science and engineering students. They come at this from the perspective of how students are taught (pedagogy) and what is taught (curriculum). Progress is being made on both fronts. More attempts are being made to link learning and pedagogy, there is less of a 'boot camp' atmosphere intending to 'weed out' students, more use of writing and experience and less use of memorizing, more student feedback, greater efforts to generate more student involvement; and more use is being made of team projects and efforts to create a more supportive learning environment. There has been less effort to address course content, however. Interesting efforts here have involved creating links between various courses, more use of applications, more emphasis on social relevance, including diversity and multiculturalism in the curriculum, reducing prerequisites and streamlining the curriculum. The authors offer specific suggestions on how topics can be linked with applications. They believe strongly and argue convincingly that the educational experience would be significantly richer if contributions of women and minority STEM contributors were more widely represented in the engineering curriculum as well.

Bevlee Watford describes three different types of student programs within the College of Engineering at Virginia Tech. These initiatives aim to help women and underrepresented minority populations make the transition from high school to college so they can become successful students. These programs target three areas of student development: academic, professional and personal. She discusses these three programs in some detail: pre-college bridge or transition programs, mentoring programs and residential communities, providing enough detail (e.g. advertising, operations, forms, bibliographies) so that other institutions interested in one or more of them can undertake initial planning and implementation strategies.

In the last part, Part V, Improving the Professional Experience, efforts to support women and minorities in academia and the engineering profession are outlined.

Xiangfen Liang and Diana Bilimoria considered the representation and experiences of women faculty in STEM. There are relatively few of these, reflecting the small numbers of women STEM graduates. Women faculty are less likely to achieve career advancement; they feel isolated, lacking in role models and mentors; they have to work harder to earn reputation and credibility. In sum, women faculty face a 'chilly climate'. The authors present data from focus groups of women at their university supportive of the existence of a 'chilly climate', driven in part by the attitudes of male colleagues and administrators. The findings are remarkably consistent with the experiences of women faculty in STEM at other US universities. The authors conclude their chapter with a description of their university's

efforts supported by an NSF Advance award, to transform the STEM cultures of various departments. Initiatives were undertaken at university, department/school and individual faculty member levels. As this effort is relatively young, it was too soon for the authors to determine its effects.

Finally, Mary Mattis, using the metaphor of a pipeline, explores conditions upstream and downstream that impact the attraction/recruitment, retention and advancement of women in the engineering workforce, drawing on findings from national datasets, surveys and focus groups with girls and young women, benchmark studies, and the efforts of engineering firms and corporations to increase the gender diversity of their technical workforce. The discrete environments upstream (factors impacting attraction and recruitment of girls and young women to academic engineering programs) and downstream (the culture and work environment of engineering companies/firms that impact recruitment, retention and advancement of women engineers) are discussed, along with possible feedback loops from each end of the pipeline to the other that impact women's representation in the engineering workforce. Best practices that address negative conditions upstream and downstream are explored, along with recommendations to influencers of young women's career aspirations and to corporate decision makers.