

# **Women in Engineering: A Review of the 2004 Literature**

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**Abstract**—This paper gives an overview of the annual Society of Women Engineers' literature review of women in engineering. Each year the literature review examines research published on women in engineering in peer-reviewed articles, reports, magazines and conferences. The review presents a "need-to-know" summary for advocates of women in engineering and offers resources for women within the field. WEPAN/NAMEPA conference attendees will find the literature review a useful tool in writing grants and identifying potential campus speakers on various issues related to women and minorities in engineering.

## **Overview**

Starting in 2002, the New Mexico State University ADVANCE Program began assembling the annual literature review of research on women in engineering for the Society of Women Engineers' (SWE) Annual Yearbook. In 2002 we examined a total of 127 articles, reports, dissertations, books, and conference proceedings and included 100 items in the literature review (Frehill, Benton-Speyer & Hunt, 2003). In 2003 we included 92 items in the literature review (Frehill, Jeser-Cannavale & Benton-Speyer, 2004).

To date, a total of 292 sources published in 2004 and early 2005 were identified for this year's SWE literature review. Of those, 123 were journal articles that appeared across a wide array of disciplines. There were seven dissertations, 37 conference proceedings papers (or entire conference proceedings), seven reports, and 118 items from newspapers, magazines, electronic sources, and other media.

The process of assembling the literature review requires an enormous expenditure of effort. The ADVANCE Program staff search online databases several times throughout the year, ordering many references via inter-library loan. Many articles suffer from flaws like the use of convenience samples, low response rates or failure to report response rates at all. We usually describe key methodological features so readers will be aware of each study's strengths and weaknesses.

The review provides material to assess the extent of progress toward equity, highlights the contributions of women who excel in science, mathematics, and engineering (SME), and discusses the current barriers within SME academic departments and workplaces that continue to disadvantage women. We tend to prioritize research that has been subjected to peer-review, such

as journal articles and books from academic presses rather than magazine articles, which have not usually been subjected to similar review.

Oftentimes, numerous magazine articles report on one or two “big stories,” so we attempt to locate one comprehensive article from among the many to include in the list of references in the SWE literature review. We also highlight important conferences, reports, or other special events that might be of interest to women in engineering and to those who work with women in engineering programs. Content about the experiences and status of women of color in engineering is included in an effort to bridge the divide that often exists between gender equity and ethnic equity advocates.

The Journal of Women and Minorities in Science and Engineering (JWMSE) continues to be the predominant location of most of the research on gender and engineering. Without this peer-reviewed journal, many of the articles that appear therein would be spread across disciplines and, indeed, a specific focus on engineering may be construed as “too narrow” for the more important national journals in some fields. Therefore, if you are interested in the most current research on women and engineering, you should subscribe to this important journal.

A special issue of the journal of the National Association for Women’s Studies, the *NWSA Journal* was dedicated to women’s participation in science and engineering. We mention a couple of these articles in other sections of this literature review, but recommend that you carefully consider the others, all of which have been included in the references section. Pieces by Beoku-Betts, Bix, Bystydzienski, Hanson, Harris et al., Jackson, Kohlstedt, Niemeier & Gonzalez, Rosser and Valian are included in this important volume.

Of course, *SWE Magazine* is also an important source of reporting about the status of women in engineering. The organization has long been concerned with diversity, indicated by the many articles published this year that recognized the intersection of ethnic, racial, and gender issues for individuals pursuing careers in engineering. In a winter 2004 article, the National Action Council for Minorities in Engineering’s (NACME) 30<sup>th</sup> anniversary was covered. SWE also covered such events as National Hispanic Heritage Month, highlighting the necessity and benefits of diversifying the engineering profession (Reydman, 2004).

### **Top Stories about Women in Engineering**

This past year, several topics of interest to women in engineering have caught the media’s attention or are of particular note. Perhaps one of the most important stories concerned the release of a new report by the American Association for the Advancement of Science (AAAS) and NACME titled “Standing Our Ground: A Guidebook for STEM Educators in the Post-Michigan Era.” This is essential reading for administrators of targeted programs such as those for minorities in engineering (MIE) or women in engineering (WIE). In light of recent Supreme Court decisions, the report attempts to clarify the appropriate procedures and tactics that are legal for those administering programs aimed at recruiting and retaining these targeted populations.

In addition to a “Legal Primer,” the report offers advice to program administrators. First, the report stresses that administrators need to work at their institutions to create a campus mission

statement that embraces a commitment to diversity. Second, programs should be built around a specific, identified problem supported by data and related directly to the campus mission statement. Third, “race-neutral alternatives” and the possible deleterious effects that could occur to omitted populations as a result of criteria for providing benefits should be considered and appropriately documented. Fourth, the need for comprehensive data collection, internal and external networking, and continuous research, evaluation and analysis are emphasized as key components of any successful and compliant program. Lastly, the report underscores the need for adequate faculty recruitment and retention and emphasizes the importance of an allied relationship with leadership within the institution at every level. A free downloadable PDF version of the report is available at the AAAS website.

Many articles appeared in newspapers, magazines, and in the electronic media in 2004 concerning science- and engineering-based programs and summer camps designed to reach out to girls. One traveling camp called Exploring Interests in Technology and Engineering (EXCITE) sponsored by IBM provided more than 1,000 girls around the world last summer an opportunity to meet female scientists and participate in hands-on engineering projects. Another summer conference with a focus on increasing diversity within engineering for teachers, scientists, parents and students was the 28<sup>th</sup> Annual Summer Institute of SECME at the University of Houston with workshops, presentations, and hands-on activities. Other outreach efforts covered this year included ExxonMobil’s “Introduce a Girl to Engineering Day”, the University of Washington’s “Rural Girls in Science” program and the University of California’s Mathematics Engineering Science Achievement (MESA) program.

Several articles also appeared this year about Smith College’s Picker Engineering Program. Started in 1999, this is the first engineering program established at an all-women’s college and its first all-female class of engineers graduated in May 2004. The engineering program at Smith College is noted for its basis in the humanities and its rigorous, comprehensive requirements. According to Grasso (2004), the Founding Director of the Picker Engineering Program, engineering is defined as “the application of mathematics and science to serve humanity”.

Accomplishments of women engineering leaders were also popular magazine topics. In Fall 2004, *SWE Magazine* spotlighted two female engineering deans, Dr. Belle Wei of San Jose State University and Dr. Janie Fouke of Michigan State University, as part of a yearly series exploring the influence female leaders have on the engineering profession (Layne). *U.S. Black Engineer and Information Technology* featured a number of biographies of women leaders in engineering associations and their impact on the profession. These leaders included Susan Kemp (past president of the American Society of Mechanical Engineers), LeEarl Bryant (the first female president of the Institute of Electrical and Electronics Engineering), Teresa Helmlinger (the first woman president of the National Society of Professional Engineers), Dianne Dorland (president of the American Institute of Chemical Engineers), and Patricia Galloway (president of the American Society of Civil Engineers) (Phillips, 2004).

Two news stories were of particular importance in 2004: Susan Hockfield’s selection as President of MIT and Denise Denton’s advancement to chancellor of the University of California-Santa Cruz. At least a dozen stories appeared in the national electronic media, newspapers, and magazines about Hockfield, former Yale University provost, between October

2004 and January 2005. (See Symond's piece in *Business Week Online* for a particularly good summary of the story.) Additionally, at least 19 different articles appeared reporting on Denise Denton's appointment as chancellor to the University of California-Santa Cruz. An electrical engineer, Denton had been the University of Washington's engineering dean (and, she is openly gay) (Bartindale, 2004).

Many articles in 2004 reported Donna Nelson's research. According to Hamilton (2004), Nelson studied women and minority professors in 14 science and engineering fields at the country's 50 most elite departments. Providing an important base of comprehensive data on the subject, she found that considerable barriers exist for women and minority faculty, including few mentoring opportunities, problematic hiring patterns, obstacles in the tenure process, and a clustering of women and minority faculty at the lowest ranks in their departments at these elite institutions.

## **History of Engineering**

New histories of engineering education are shedding further light on the challenges for those interested in transforming the institution of engineering. Two such articles provide insight into how engineering education was affected by gender in historical perspective. Frehill (2004) documents the early history of engineering as a profession in the United States. Using historical sources like the *Engineering News*, proceedings from conferences of the Society for the Promotion of Engineering Education (now the American Society for Engineering Education: ASEE) and career guidance books, she documents how masculinity was embedded within the discipline as it moved increasingly towards a profession with strong academic requirements. Bix (2004) discusses the history of women's participation in engineering education. Women who sought engineering education struggled within hostile environments and often experienced difficulties in finding employment in the pre-Title IX era. Bix also notes women engineers' resistance to efforts to marginalize their work in the field.

## **Diversity in the Professoriate**

With a new National Science Foundation Report (Rapoport, Bentley & Wise, 2004), a new book on faculty diversity (Moody, 2004a), journal articles (Jackson, 2004; Mantani, 2004; Valian, 2004) and various magazine articles (Gordon & Keyfitz, 2004; Layne, 2004; Moody, 2004b) questions, answers and solutions to the underrepresentation of women and minorities at the pinnacle of the U.S. science and engineering enterprise was the focus of much attention. In many cases, as in the past, this literature featured pieces that did an excellent job on one dimension of diversity while treating other dimensions of diversity only superficially. Unlike in previous years, however, the number of counterexamples (i.e., literature that dealt with ethnicity and gender simultaneously) seems to be increasing. Riskin et al. (2004) provide an important document (available online) for those interested in increasing diversity in the engineering professoriate compiled as a result of a conference on the topic.

However, the question remains: Why are there so few people of color among the professoriate? According to a 2003 book by Cole & Barber, the principal issue in diversifying the professoriate in science (and, by extension, engineering) depends upon academia's ability to

deal with what economists call “supply side” issues rather than “demand side” issues. “Supply side” refers to the notion that characteristics of underrepresented minority groups account for their low participation rates, while those who advocate “demand side” forces as responsible for low participation cite institutional racism and other actions by employers as the cause of disparity. Cole & Barber argue that low average educational attainment among African Americans and Latinos/as is the principal reason that these groups are not highly represented among the professoriate. Their study examines the fields chosen by high-achieving African American and Latino/a college students. They indicate that without early mentoring, including research experiences as undergraduates, high-achieving underrepresented minority students will continue to choose economically lucrative areas like medicine and law rather than the comparatively lower economic rewards of academia.

Maton & Hrabowski (2004) report on a “strengths-based” approach to increasing the number of African American PhDs in science and engineering that has been quite successful at the University of Maryland, Baltimore County (also a “second round” recipient of an ADVANCE: Institutional Transformation grant). Their approach has incorporated many elements cited as essential by the supply-siders Cole & Barber, such as early identification of students with an interest in academia and interventions to improve the human capital of the African American student participants with important bridges between secondary and post-secondary school.

Smyth & McArdle (2004) used data from 23 colleges included in the 1989 dataset “College and Beyond” to examine persistence in science for the 5,074 students who had declared an intention to major in science. The authors found support for the notion that at selective institutions, prior academic preparation explained the high persistence rates of Asians (highest) and whites and the comparatively lower persistence rates among American Indians, Hispanics, and African Americans. Prior academic preparation also explained the gap between men’s and women’s persistence rates. The authors’ analysis did not support the notion that more selective colleges had higher persistence rates than less selective colleges.

Demand-side forces were the also focus of two articles that appeared in a special issue of the *American Economic Review*. Following up on their 2000 book, Myers & Turner (2004) argue that persistent discrimination (e.g., tokenism, chilly climate, etc.) on the part of academic institutions plays a major role in the continued marginalization of minorities within the academy. Their economic models indicate that merely addressing the supply-side factors argued to be significant by Cole & Barber will actually do little to alter the relative numbers of minority faculty compared to non-minority faculty. Smith’s (2004) report on a campus diversity project, also available online, focuses on the role that institutions can play (demand-side) in attracting a diverse professoriate.

In the same volume of the *American Economic Review*, three panelists, Slaughter, Ehrenberg, & Hanushek (2004), do a nice job of framing and synthesizing the demand-side and supply-side perspectives. This article emphasizes the need to look at both sets of factors to understand how to increase minority participation in the sciences and engineering. An important shortcoming of many sources mentioned in this section so far is the classic problem of overlooking gender when dealing with racial/ethnic issues. That is, none of these authors devotes

significant attention to how gender affects the participation of underrepresented minorities in science and engineering nor the unique problems that are encountered by women of color in the academy. While Moody (2004a and 2004b) tackles this persistent problem head-on, many authors still pose ethnic and gender equity as players in a zero-sum game.

### **Research on K-12 Preparation for Engineering**

In addition to the research discussed in the previous sections, we want to highlight a few articles that deal with topics related to gendered effects of students' preparation for engineering. Gender stereotypes are ingrained into children at a very young age, which are then posited to affect girls' performance and participation in math and science. Heyman & Legare asked 60 kindergarten and 1<sup>st</sup> graders and 60 4<sup>th</sup> and 5<sup>th</sup> graders questions to determine the extent to which they stereotyped activities by gender. They found that regardless of sex and age, children indicated that girls were better at spelling and reading and had more pro-social tendencies while boys were more aggressive (physical and relational). Significantly, children did not stereotype math or a host of other activities as gendered.

The availability of advanced placement (AP) courses has long been an issue for schools located in poor and minority communities. Klopfenstein (2004) documents the persistent gap between whites and minorities in participation in AP courses. Klopfenstein's model explained some of the variance in the participation, but at least 50 percent of the gap between whites and minorities still existed, attributable to factors other than human capital. The effects of low income status on the decision to enroll in an AP course were also examined.

Research on math anxiety continues to show interesting results. Haynes, Mullins & Stein (2004) surveyed a stratified random sample, by discipline, of undergraduate students enrolled in mathematics or statistics classes at Tennessee Technological University. Achieving a 96 percent response rate, they found that males' and females' levels of math anxiety were not significantly different. However, via multiple linear regression analysis, they found that the components of math anxiety differed for males and females. For males, math anxiety was a manifestation of general test anxiety, which was also negatively related to ACT scores. For females, on the other hand, math anxiety was positively related to both test anxiety and ACT scores and negatively related to perceptions of high school math teachers' attitudes teaching methods and perceptions of one's own mathematics ability.

Ma & Xu (2004) performed structural equation modeling on data from the nationally-representative Longitudinal Study of American Youth to sort out the causal ordering of math anxiety and math achievement. Low math achievement was related to subsequently higher levels of math anxiety but prior high math anxiety did not necessarily lead to lower math achievement. As with Haynes, Mullins & Stein, Ma & Xu found no significant effects of gender on this causal ordering.

Over the past several years there has been much interest in determining the merits of single-sex education, especially for girls. The consensus is that in some situations same-sex education may be beneficial to girls, but it may not be ideal for all students. Some evidence suggests that girls and minority males benefit from same-sex classrooms, therefore, the single-sex option

should be available but not required across all educational levels (see Frehill, Jeser-Cannavale & Benton-Speyer, 2004 for a review). Robinson & Gillibrand (2004) examined the merits of single-sex schooling for girls in a Church of England urban secondary school. The impact of the single-sex context differed by the level of the science class. In lower level science classes, there were no effects associated with the single-sex model. Robinson & Gillibrand found that in the higher level science classes girls and boys benefited from the single-sex context. They found that boys in these higher level classes tended to need the girls to perform a variety of “services” such as help with practica. When the boys were not present, the girls were better able to focus their attention on the science rather than accommodating the boys’ needs or adjusting for the boys’ lower skills. At the same time, boys were forced to learn the skills that they had relied upon girls to provide.

### **Programming for Women and Underrepresented Minorities in Universities**

Knight & Cunningham (2004) address programmatic issues for administrators and directors of WIE/WISE programs. As part of the Women’s Experience in College Engineering (WECE) project, telephone interviews and follow up surveys were administered to 26 WIE program directors across the country whose programs had existed for 3 or more years. The authors found that a strong base of support, flexibility, overcoming barriers to reaching undergraduate women, and a willingness to be adaptable and broad-based were typical features of successful outreach programs.

Another useful resource for MIE and WIE directors is an article by Jeffers, Safferman & Safferman (2004), who provide details about over 55 K-12 outreach programs run by colleges and universities throughout the country. The authors believe one way to improve children’s skills in math and science is to integrate these outreach programs into existing core curriculum.

An evaluation of a retention program called the Biology Undergraduate Scholars Program at the University of California, Davis was conducted by Barlow (2004). Three hundred ninety seven underrepresented minorities students who agreed to participate in the program were compared to the 877 underrepresented minority students who opted not to participate between 1988 and 1994. The program was successful in increasing the retention of underrepresented minorities in biology and increasing these students’ success in basic math and science classes, with program participants more likely to graduate than non-participants.

Several papers were presented at the ASEE conference that dealt with gender or ethnic equity in engineering. Two papers focused on programs for women and underrepresented minorities in engineering at Arizona State University (ASU). Anderson-Rowland & Johnson (2004) explained the Collaborative Interdisciplinary Research Community, which focuses on increasing the number of women and minorities seeking engineering graduate degrees. Anderson-Rowland, Vanis, Banks, Mater, Zerby & Chain (2004) explained the Maricopa Engineering Transition Scholars project, which is a collaboration with ASU’s School of Engineering and Maricopa Community College to improve the transition from the community college to ASU. A third paper by Pawley (2004) describes how feminist principles and theories can be used to design a more inclusive engineering curriculum and classroom.

Harris et al. (2004) report on a pilot study of the reasons that the University of Oklahoma is an “outlier” when it comes to gender. One half of the students are female—not unusual in industrial engineering—and 4 of the 10 professors in the program are female. The authors point out some interesting and potentially fruitful areas to which researchers interested in institutional transformation to bring about gender equity might want to attend. First, the authors identified a helpful administrative assistant and faculty who worked with open doors as a particularly welcoming climate for the students. Second, hands-on classroom activities are alluded to as an important curriculum feature that kept students engaged and interested in the field. An issue that the authors did not pursue, but which needs to be given more attention concerns an almost incidental comment in the manuscript about the denigration of industrial engineering. This is a significant issue: according to the sociological literature about occupations (for example, see work by Reskin and Roos 1990), as occupations transition from male to female majorities, it is common for the occupational prestige and rewards to be downgraded, leading to an increasing flight of men from the occupation. The extent to which engineering subfields with significant percentages of women (especially industrial engineering) experience downgrading needs to be further explored. How do students react to these forces? Are men more likely to leave the field? Does such denigration lead to increased solidarity among students within the major being denigrated? How do racial/ethnic compositions affect these same areas?

## Conclusion

We have used this article to provide a smattering of the literature that was published in the past year about women in engineering. Given the space limitations, we were unable to provide full details about all of the literature that has appeared in the past year and encourage you to make use of our references to obtain articles that are of interest to you. The full literature review will be available later this year. We encourage you to join SWE soon in order to receive the Annual Yearbook edition of *SWE Magazine*, in which the literature review will appear.

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This research was supported by a grant from the National Science Foundation ADVANCE: Institutional Transformation Program, NSF #0123690. The views expressed are those of the authors and do not reflect those of the National Science Foundation.