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Pipeline or personal preference: women in engineering

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Although the number of women in the engineering field has increased since the 1960s, those increases have largely stagnated over the last few years. This paper re-examines the pipeline for bringing women into engineering and, based on survey data, examines the attitudes, motivations, and interests of 969 male and female engineering students. Gender similarities and differences are identified, and their implications for recruitment and retention of women are considered.

Keywords: women in engineering; design; build; analyse

1. Introduction

The gender disparity in science and engineering programs has been of concern to educators and scholars worldwide (Kovaleva 1999, Nguyen 2000, Darke *et al.* 2002, Beraud 2003, Parikh *et al.* 2003, Schäfer 2006, Viefers *et al.* 2006). Unlike other historically male-dominated occupations that have seen gains in achieving gender equity, many science, math, and engineering fields have remained peculiarly unbalanced in terms of gender. Statistics show that in spite of talent, ability, and opportunity, women are choosing not to pursue programs in fields such as computer science and engineering (Darke *et al.* 2002, Building Engineering and Science Talent 2004b, Ford *et al.* 2004, Government Accountability Office 2004). Interestingly, women are entering biological and biomedical engineering programs in greater numbers. This trend might illuminate how and why women might be successfully recruited into and remain in engineering educational programs and careers.

Since the early 1990s, the "pipeline theory" has been the dominant conceptual framework used to explain the science, mathematics, and engineering gender disparity (Darke *et al.* 2002, Xie and Shauman 2003). According to this framework, the gender gap in science and engineering exists because few women take science and math prior to college and/or are lost at various leakage points in the pipeline from school to work. However, the evolutionary process, where students develop an interest in science and engineering, appears to be similar in male and female precollege students (Beraud 2003). Furthermore, while women in the past did not graduate from high school with the necessary math and science prerequisites to enter engineering (American

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Association of University Women 1992), women now take as many high school science classes, and their achievement levels are roughly the same level as men (Building Engineering and Science Talent 2000, 2004a, Congressional Commission on the Advancement of Women in Science & Engineering and Technology Development 2000, Long *et al.* 2001, Thom 2001, Clewell and Campbell 2002, Beraud 2003, American Association of University Women 2004, Committee on Equal Opportunities in Science and Engineering 2004, Freeman 2004, Government Accountability Office 2004, Jackson 2004).

Finally, at this time, the rate of leakage from the pipeline appears to be similar for male and female students. Indeed, female students are slightly more likely than male students to complete an engineering degree and less likely to switch to non-engineering programs. Thus, although women are less likely than men to enter science and engineering, women who enter science and engineering fields are likely to do well and graduate (Seymour and Hewitt 1997, Adelman 1998, Huang *et al.* 2000, National Science Board 2000). They are not lost in significant numbers due to leakage, as the pipeline theory would suggest.

Thus, the pipeline appears to have been repaired and filled, suggesting that the pipeline is a necessary, but not sufficient, requirement for improving the number of women enrolled in engineering (Xie and Shauman, 1997, 2003, Clewell and Campbell 2002, Committee on Equal Opportunities in Science and Engineering 2004, Correll 2004).

Further, a body of empirical literature suggests that, while women now acquire as many years of education as do men, they major in different subjects, choose different occupations, and accumulate less overall labour market experience (Badgett and Folbre 2003). Women have made great strides in fields such as law, veterinary medicine, biological sciences, and medicine. Yet, engineering remains a male-dominated field (Long *et al.* 2001, Darke *et al.* 2002, Ford *et al.* 2004, Building Engineering and Science Talent 2004, Government Accountability Office 2004, Tietjen 2004). The pipeline theory cannot account for these occupational choices.

If the pipeline theory fails to account for the pervasive gender imbalance in engineering (Seymour and Hewitt 1997), how do we explain why these fields remain less responsive to forces that have, otherwise, successfully affected gender equity in other professions? One place to look is the set of motivations and interests that lead women and men to choose different educational and career pathways. Seymour notes, for example, that in comparison to men, women are more likely to explain their choice of science, mathematics, and engineering majors in altruistic terms (Seymour and Hewitt 1997). Pinker (2002) and Pressley and McCormick (1995) also point to a large body of research that indicates that "on average, women are more interested in dealing with people and men with things." This difference explains, in part, the great surge of women into anthropology, sociology, psychology, law, and medicine. It may also help explain why fewer women express interest in engineering, math, and the hard sciences. Indeed, a 2003 study found that "young women value working with and for people," and "they don't perceive engineering as a profession that meets that need" (Eccles 2003). There may also be a perception that, for instance, biology is "a more feminine subject" than physics (Viefers *et al.* 2006) or, similarly, that engineering is not feminine (Godfroy-Genin and Pinault 2006).

Instead of engineering, both Eccles (2003) and Spears *et al.* (2004) found that young women who are strong in math tend to seek careers in the biological sciences. Recent statistics show that, although women now earn more than half of the bachelor's degrees in the biological sciences, they earn just 21 % of all bachelors degrees in physics (American Association of University Women 2004) and just 20 % in engineering (Tietjen 2004).

This paper is particularly concerned with the question of whether gender differences exist in the interests and attitudes of engineering students. In the engineering and scientific community, there is emerging consensus that one way to address the under-representation of women is to interest women in engineering by developing a gender-balanced curriculum, or a curriculum that is equally appealing to men and women (American Association of University Women 2004, Building Engineering and Science Talent 2004, Committee on Equal Opportunities in Science and Engineering 2004, National Academy of Engineering 2002). To date, little research has been done to explore whether students agree with such tactics and, more importantly, if gender differences even exist in educational interests. With low enrolment of women in engineering and overall engineering enrolment stable or dropping, an understanding of student interests is a critical component of recruitment and retention (Gibbons 2006). Further, noting that significant review of engineering curricula is occurring (National Academy of Engineering 2004, 2005), a window of opportunity currently exists to integrate this information into the curricula.

2. Objectives

This study examines data collected from engineering students attending American universities using an online survey from the fall of 2005 through the spring of 2007. The survey was designed to help understand the backgrounds, interests, and attitudes of engineering students. It obtains information on the number of high school science, engineering, and math classes. In addition, it probes the students' motivations for studying engineering, their interests within engineering, and their comfort in various elements of engineering practice.

3. Methods

3.1. *Survey methodology*

3.1.1. *Survey data set size*

A total of 969 students from 21 US universities (Table 1) participated in this online survey. A rule of thumb for determining the size of a quantitative study is to make the sample as large as possible with a minimum of 100 respondents in a survey (Gall *et al.* 2003). According to the National Science Board, 60,639 engineering degrees were awarded in 2002 (National Science Board 2006), while a Duke University study estimated the number of engineering graduates in 2004 to be 222,335 (Wadwha 2006).

Table 1. Respondents by university.

Institution	Number of responses	(%)
Iowa State University	37	(3.8)
Louisiana State University	127	(13.1)
Mississippi State University	26	(2.7)
Ohio State University	25	(2.6)
South Dakota School of Mines & Technology	13	(1.3)
University of Arkansas	28	(2.9)
University of Georgia	37	(3.8)
University of Houston	49	(5.1)
University of Idaho	51	(5.3)
University of Maryland	74	(7.6)
University of Nebraska, Lincoln	26	(2.7)
University of Utah	70	(7.2)
Utah State University	361	(37.3)
York College of Pennsylvania	14	(1.4)
Other Universities (unidentified/<1 %)	25	(2.4)
Total number of participants	969	(100)

3.1.2. *Selection of the survey participants*

This survey used a convenience sample. Participation in the survey was voluntary. The students, a combination of graduate and undergraduate students, were categorized as enrolled in engineering disciplines. Specifically, they self-identified as majoring in an engineering program discipline listed by ABET, Inc. (2007).

3.1.3. *Survey design*

The survey was released in three major iterations (1/year), with minor corrections (e.g. spelling) made between the iterations. The first major iteration emphasized biology-based engineering disciplines, in part, to sample the higher percentages of women in these disciplines. The second and third iterations included a much broader array of engineering disciplines.

The survey had seven sections: four were applicable to all engineers, irrespective of major (and were included in all of the survey iterations), and three were, specifically, applicable to engineering disciplines (and were included in the second and third iterations). The latter group of questions contained a series of questions linked to three basic engineering activities: designing, building, and analysis. The questions within these three groups were directly related to specific engineering disciplines. To obtain valid and reliable data, the methods suggested by Dillman (2007) and Suskie (1996) were adopted. There were no right or wrong answers.

The survey incorporated a combination of question formats including pre-categorized information and 5-point Likert scale. Table 2 shows the question types and numbers of questions in each section. The time it took to complete the survey was approximately 15–20 min. The survey was published using SurveySuite software package created and hosted by the University of Virginia. The use of an online format allowed the students at all of the locations to access the same survey at their convenience.

3.2. *Data analysis*

Data from the survey were exported directly from SurveySuite into an Excel (version 11, Microsoft Corporation, 2003) spreadsheet. In Excel, all string data were converted into numerical data for analysis. In addition, the participants who were not enrolled in an engineering discipline did not identify themselves sufficiently to allow unique identification, or those who completed the survey improperly were removed from the data set. Students who did not fill in all three areas of

Table 2. Number and type of survey questions.

Section in survey	Survey question type	Responses types	Number of questions
Demographics	Fill in the blank and check appropriate box(es)	Fill in the blank and check appropriate box(es)	9
High school course work	Check appropriate box(es)	Check appropriate box(es)	3
Comfort with skills used in engineering	5-point Lickert scale	Strongly disagree (1) to strongly agree (5)	14
Motivation	5-point Lickert scale	Strongly disagree (1) to strongly agree (5)	9
Interest			
Design	5-point Lickert scale	Boring (1) to interesting (5)	9
Analyse	5-point Lickert scale	Boring (1) to interesting (5)	10
Build	5-point Lickert scale	Boring (1) to interesting (5)	10
Total number of questions			64

the design, build, and analyse section (DBA) were included in the other analyses but were not included in the DBA analysis. The Excel file was then imported into SPSS (version 14 for PC, SPSS Inc., 2005) for statistical analysis.

In this study, data were analysed using the Mann–Whitney U test and the chi-square test. The mean and standard error of the mean are reported, where appropriate. The level of statistical significance was set at 0.05 for the data analysis. The analyses were performed by Utah State University's Office of Methodological and Data Sciences.

4. Results and discussion

4.1. *Population demographics*

4.1.1. *Surveyed population*

The participating population was selected through voluntary response to an electronic survey distributed among 21 universities from across the USA. A total of 969 engineering students responded to the survey (Table 1). Participants ranged from freshmen to doctoral students. The majority of respondents were freshmen (29.8 %) and sophomores (25.5 %) (Figure 1). The participants included students in age bands ranging from 17 or younger to 50–54 years of age. Though a large percentage of the respondents were either 18 or 19 (37.0 %), students who were 20–23 years old comprised 38.1 % of the population (Figure 1). The age group of 18–23 is typical for college students. Students identified themselves as majoring in one of 14 majors (from a supplied list of 25 ABET listed engineering majors). Majors containing 1 % or more of the respondents are shown in Table 3.

4.1.2. *Gender*

Many fields in engineering and the physical sciences have not reached the critical mass where women and minorities make up at least 15 % of the field. Minorities of less than 15 % are often referred to as tokens or treated as representatives of their category rather than as an individual. There is also a tendency to exaggerate the extent of the differences between them and the dominant group. Thus, the personal characteristics of the individual tend to be distorted into the stereotype of their group. Furthermore, low numbers result in enhanced visibility, which tends to create performance pressures for the token (Kanter 1977, Salminen-Karlsson 2002, Godfroy-Genin and Pinault 2006). By this definition, the women in 7 of the 11 majors listed in Table 3, although in the minority, no longer qualify as tokens. In this study, 27.5 % of the respondents were female and 72.3 % were male.

4.1.3. *Home communities*

A variety of home community types and sizes are also found among the respondents. Though a large majority came from suburban (38.5 %) and rural (31.4 %) areas, small urban areas (population $<1,000,000$) and large urban areas (population $>1,000,000$) comprised 18.2 % and 10.9 % of the respondents' home communities, respectively (Figure 2).

In two of the five types of communities, a significant difference in the gender distribution of students was found. More men than women were recruited from rural environments, and more women than men were recruited from small urban areas (population $<1,000,000$). As student recruiting follows the general movement of the population from a rural to an urban setting

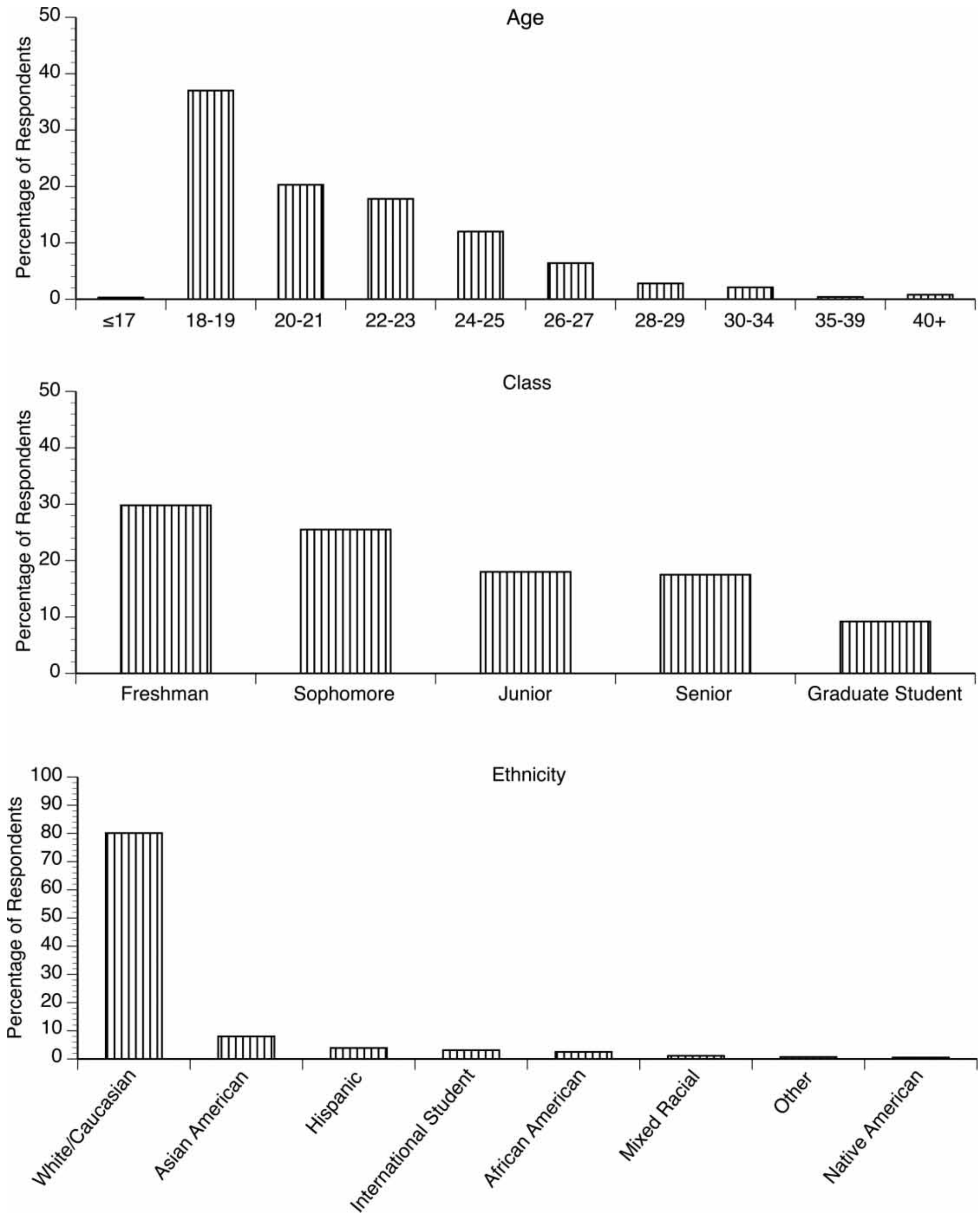

Figure 1. The ages, class standing, and ethnicities of respondents: most respondents were in their first or second year of engineering and are under 21. Most respondents were white or Asian/Pacific islander, as is typical of engineering students.

(United Nations Population Division 2005), these differences in distribution are likely to impact the percentage of women in engineering over the longer term.

4.2. *Academic preparation*

Although not the only indicator, academic background is an indicator of persistence in engineering at the college level (Zhang *et al.* 2004, Burtner 2005, French *et al.* 2005). Quite unsurprisingly, male

Table 3. Respondents by major.

Major	Gender breakdown within majors (%) Women	Men	# Responses (%)
Aerospace engineering	22.2	77.8	18 (1.9)
Agricultural engineering	12.3	87.7	57 (5.9)
Biological engineering	44.7	55.3	323 (33.3)
Biomedical engineering	39.0	61.0	59 (6.1)
Chemical/biochemical engineering	55.6	44.4	36 (3.7)
Civil engineering	14.6	85.4	104 (10.7)
Computer engineering	12.0	88.0	25 (2.6)
Electrical engineering	7.2	92.8	167 (17.2)
Environmental engineering	31.8	68.2	22 (2.3)
Industrial/manufacturing engineering	25.0	75.0	24 (2.5)
Mechanical engineering	18.1	81.9	127 (13.1)
Other engineering majors (<1 %)	57.1	42.9	7 (0.7)
Total for all majors	27.5	72.3	969 (100)

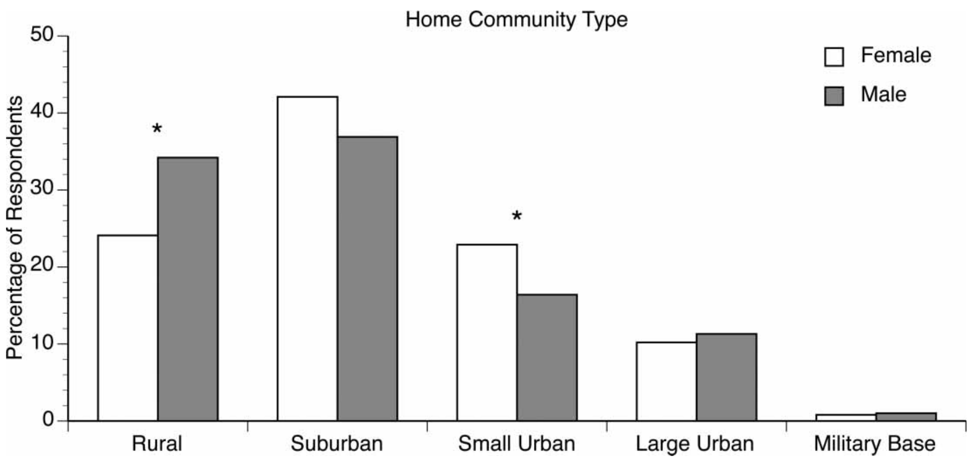

Figure 2. Community type of the respondents: most respondents were from suburban and rural areas. Significant gender differences (indicated with an asterisk) in home community size were found for rural (more likely for men) and small urban (more likely for women) communities.

and female engineering students had obtained considerable high school preparation in mathematics and science. Of the respondents, 83.2 % reported having completed high school coursework in pre-algebra, 84.3 % having taken algebra, 86.1 % having taken advanced algebra, 94.4 % having taken geometry, 86.9 % having taken trigonometry, and 68.7 % having taken calculus. The gender breakdown of the students in the courses is shown in Figure 3. It is interesting to note that in five of the six mathematics courses, significant differences were identified. In all five cases, more women had taken the course than men.

Of the respondents, 73.5 % reported having taken physical science in high school, 89.1 % reported having taken biology, 88.1 % reported having taken chemistry, 77.4 % reported having taken physics, and 31.3 % reported having taken computer science (Figure 3). In the sciences, significant differences were identified in chemistry and biology, both with more women than men having taken the courses.

One important factor to note is the high percentage of students in our sample who had taken biology and chemistry in high school. This finding suggests that these classes may be the most effective classes to use for recruiting. Since these courses are also part of the pipeline for biology,

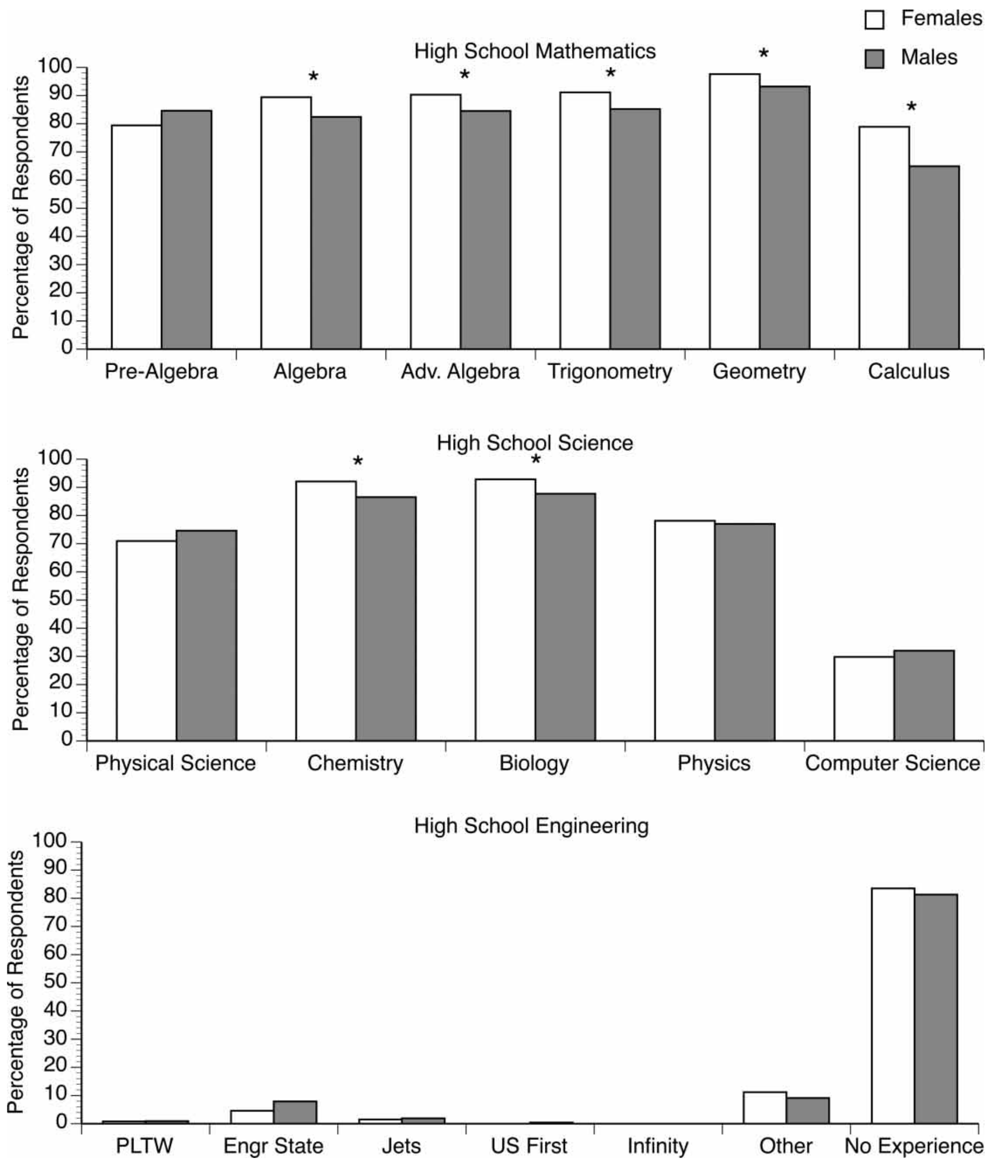

Figure 3. Mathematics, science, and engineering taken in high school by gender: with the exception of calculus, men took slightly more mathematics than women overall. Statistically significant differences between men and women are indicated with an asterisk.

veterinary science, and medicine, engineering may be able to tap into them for recruiting additional women into the field.

Over the last 10–15 years, a number of pre-engineering programs have been initiated for inclusion in the high schools. In the USA, these include Project Lead the Way (initiated in 1997), US First (initiated in 1992), and Infinity (initiated in 1999). The oldest national program considered was JETS (1950). Engineering State is a regional summer program hosted in some states. Although there were no significant differences between the men and women, this is likely due to the low number of students in the sample who had taken part in these programs. Given the growth of the pre-engineering programs, however, the numbers of participants is likely to increase (Figure 3).

Because entrance into engineering programs at most universities generally requires a rigorous high school curriculum, it is unsurprising that engineering students of both genders had taken an average of 4.9 ± 0.1 of the six mathematics courses and 3.6 of the four science courses (women $= 3.6 \pm 0.1$, men $= 3.6 \pm 0.0$). This finding indicates that the female respondents in this study were as prepared as the male respondents to pursue careers in engineering. This result is consistent with data from the National Center for Education Statistics indicating that 10 % of male and 11 % of female high school graduates in the USA completed a "rigorous" curriculum in 2005 (Shettle *et al.* 2007).

Engineering is, typically, chosen as a major prior to entering the university. Eighty-eight percent of the female and 93 % of the male respondents had chosen to enter engineering (either in general or with a specific engineering discipline in mind) prior to entering the university. Thus, to be successful, recruiting efforts need to be directed at high school and junior high school students as opposed to recruiting transfers from other majors.

Interestingly, 52.8 % of the women and only 46.2 % of the men had family members who were engineers and suggests that the belief that engineering is a viable profession for women is dominated by information transmitted from the family. This indicates that current informational outreach efforts in middle and high schools have had limited success. This hypothesis is further supported by the fact that almost twice as many women (12.3 %) as men (6.6 %) changed majors to enter engineering.

4.3. *Student comfort levels in engineering activities*

As previously noted, gender differences in engineering enrollment do not appear to be linked to enrollment in high school mathematics and science courses. It appears that the pipeline theory is no longer adequate to explain the differences in enrollment between men and women in engineering. Instead, the differences are likely to result from other factors, such as comfort at the tasks performed by engineers.

Successful completion of a course does not require comfort with the skills taught in that course. Engineering students may initially be choosing and later remaining in their majors because of their comfort with a particular subject, rather than their ability to perform in that subject. To examine this possibility, the survey included a series of questions where students were presented with a statement of the form "I am comfortable ..." in an activity performed by engineers and asked to indicate their level of agreement with the statement. The possible responses were drawn from a Likert scale ranging from strongly disagree (1) to strongly agree (5).

The results of these questions are shown in Figure 4. The wording of the comfort statements is shown in Table 4. Women were more comfortable than the men in three of the eight engineering activities: laboratory work, performing experiments, and writing. All three of these activities are performed as part of required high school curricula. Four of the remaining five categories where men are more comfortable are dominated by working with or designing equipment, such as tools, machines, and computers. While it should be a goal of an engineering curriculum to create graduates who are comfortable in all of these areas, priority should be given to areas where there are large differences.

Women are more comfortable writing than men, while men are more comfortable with design and computers. However, these activities are existing components of the ABET accreditation criteria and are largely being addressed. Working with tools and machines are more problematic. The male/female differences are large, and they are not, specifically, addressed by ABET criteria. The authors suggest two approaches to address this issue.

First, the need to retain women in engineering suggests that examples used in engineering science coursework should be diverse. For instance, automotive terminology should not dominate

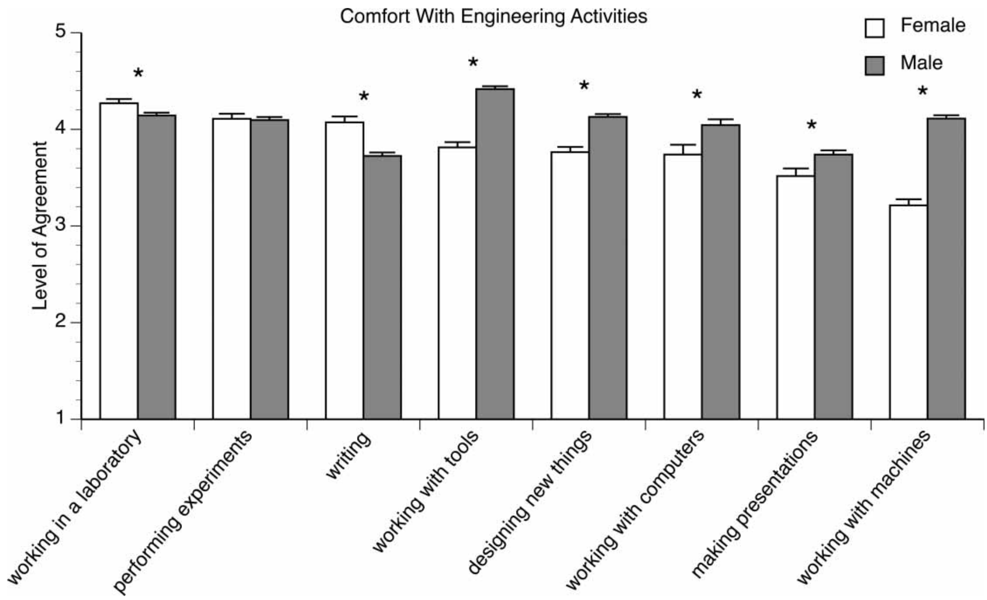

Figure 4. Student comfort in engineering activities. Students were asked to indicate their level of agreement with a statement of the form "I am comfortable. . . .". Statistically significant differences between men and women are indicated with an asterisk and error bars indicate the standard errors.

Table 4. The wording of the statements used in the comfort section of the survey.

I am comfortable learning new laboratory skills and working in a laboratory
I am comfortable performing experiments and analysing the resulting data
I am comfortable writing
I am comfortable working with tools and using them to build and/or fix things
I am comfortable designing new things
I am comfortable learning new computer skills and solving problems using a computer
I am comfortable making presentations in front of a class
I am comfortable working with machines and/or building/fixing them

dynamics discussions. Rather, equivalent examples from biomedical or other social consciousness topics can be used to balance the examples. Alternately, non-threatening laboratory equipment can be used. Lego Mindstorms® (and similar products such as Fischertechnics®) can effectively become part of a controls laboratory, demonstrating the same principles at a lower cost and a higher student comfort level (Schreuders *et al.* 2003).

Second, engineers are expected to be competent in the use of tools and machines. Therefore, these skills need to be developed in laboratories. In developing these skills, the instructors must recognize that significant differences exist between male and female students' comfort (and, likely, skill) levels and develop materials, accordingly. Another benefit of developing materials to improve machine and tool skills is that male and female students of all skill levels will benefit.

4.4. *The engineering interests matrix*

A critical question is whether gender differences in interests are linked to the practice of engineering or to the application areas in which they are practiced. To examine this question, a matrix of 30 questions was asked of the engineering students. These 30 questions were divided into three fundamental engineering activities (designing, building, and analysing) with 10 questions

Table 5. The items used in the DBA sections of the survey.

Rank	Design item		Build item		Analyse item	
	Female	Male	Female	Male	Female	Male
1	Energy–efficient house	Energy–efficient house	An artificial arm for the handicapped	Robot to explore mars	Function of an artificial pancreas for diabetics	Manufacturing processes for building racecar engines
2	Process for purifying cancer drugs	mp3 player	Robot to explore mars	Re-entry system to allow the recovery of spacecraft	Biosensor to detect anthrax spread by a terrorist	Movement of a skyscraper during an earthquake
3	X-ray analysis system for a hospital	X-ray analysis system for a hospital	Re-entry system to allow the recovery of spacecraft	An artificial arm for the handicapped	Movement of a skyscraper during an earthquake	Transmission distance of a cell phone signal
4	Portable water quality laboratory	Satellite to gather data on the effects of drought on forests	Robot to pick peaches	Robot to pick peaches	Manufacturing processes for building racecar engines	Biosensor to detect anthrax spread by a terrorist
5	mp3 player	Design the mechanical components of a computer hard drive	Computer system to control a robot to explore the ocean bottom	Computer system to control a robot to explore the ocean bottom	Air flow across the wing of a jet plane	Air flow across the wing of a jet plane
6	Satellite to gather data on the effects of drought on forests	Computer game development system	Bridge across the Chesapeake Bay	Computer board to gather data from a low light camera	Efficiency of a food processing plant	Flow of data through a computer network
7	Distillation column to refine gasoline from oil	Process for purifying cancer drugs	Bioreactor to produce penicillin	Bridge across the Chesapeake Bay	Transmission distance of a cell phone signal	Function of an artificial pancreas for diabetics
8	Facility to raise trout	Distillation column to refine gasoline from oil	Reactor to make acrylic	Computer model of a local river	Movement of heat through a liquid in a pipe	Movement of heat through a liquid in a pipe
9	Computer game development system	Portable water quality laboratory	Computer model of a local river	Bioreactor to produce penicillin	Waste breakdown in a landfill	Efficiency of a food processing plant
10	Design the mechanical components of a computer hard drive	Facility to raise trout	Computer board to gather data from a low light camera	Reactor to make acrylic	Flow of data through a computer network	Waste breakdown in a landfill

The upper and lower shaded regions indicate regions of some interest and general lack of interest, respectively. (See 4.4.2 for details).

in each group. The items were chosen from 10 sub-disciplines, including aerospace engineering, agricultural engineering, biomedical engineering, biotechnology, chemical engineering, civil engineering, computer science/engineering, environmental engineering, mechanical engineering. All of the questions were of the format "I would find an opportunity to *activity* an *item*," where the items are drawn from the list shown in Table 5. In responding to these questions, students indicated their level of interest using a Likert scale ranging from 1 (boring) to 5 (interesting).

In discussing the results of the DBA questions, the authors have avoided drawing conclusions with regard to interest in the different engineering disciplines. Each engineering discipline is sufficiently broad that the list does not provide an accurate evaluation of student interest. Instead, the disciplines were used to ensure that the items list was varied and to minimize the bias in the analyses.

4.4.1. *Fundamental engineering activities*

When the 30 questions were analysed based on the fundamental engineering activities of building, designing, and analysing, statistically significant gender differences were identified for each activity (Figure 5). In all cases, the male students were more interested in the activity than the female students, with the gender difference the greatest in the build activities and the smallest in the analyse activities.

4.4.2. *Engineering interests by item*

The engineering interests by item are shown in Figure 6. Examining Figure 6, several things are apparent. First, of the 30 items considered in the DBA analysis, 17 showed statistically significant differences linked to gender.

In Table 5, the individual items have been sorted based on their ranking within the items listed for each category. These items have been divided into three groups, interest level ≥ 3.75 (some interest), $3.00 \geq$ interest level < 3.75 (neutral), and interest level < 3.00 (general lack of interest). Fifteen items received a mean interest score of 3.75 or greater by women, men, or both genders. The items are the shaded items at the top of the table. As a group, these items follow the expected pattern, with women expressing interest in biological/biomedical items and socially conscious

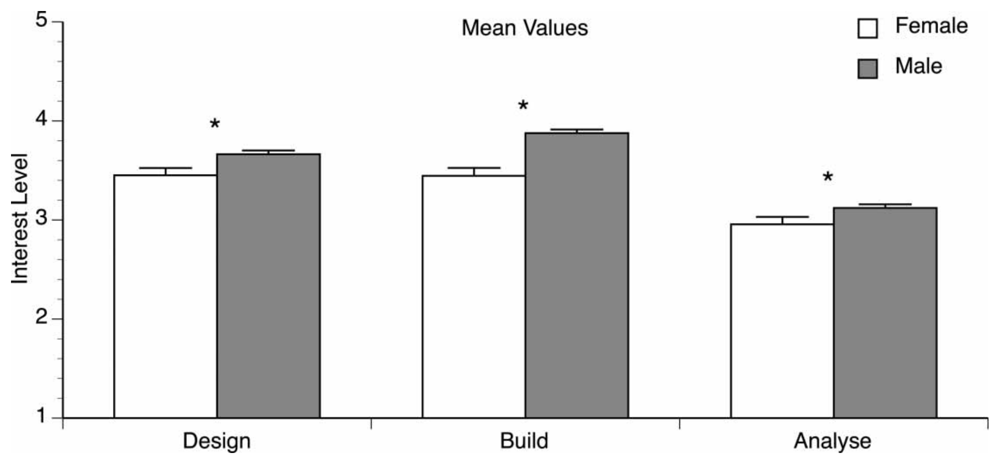

Figure 5. DBA means by gender: the mean is the average score for all questions. Statistically significant differences between men and women are indicated with an asterisk and error bars indicate the standard errors.

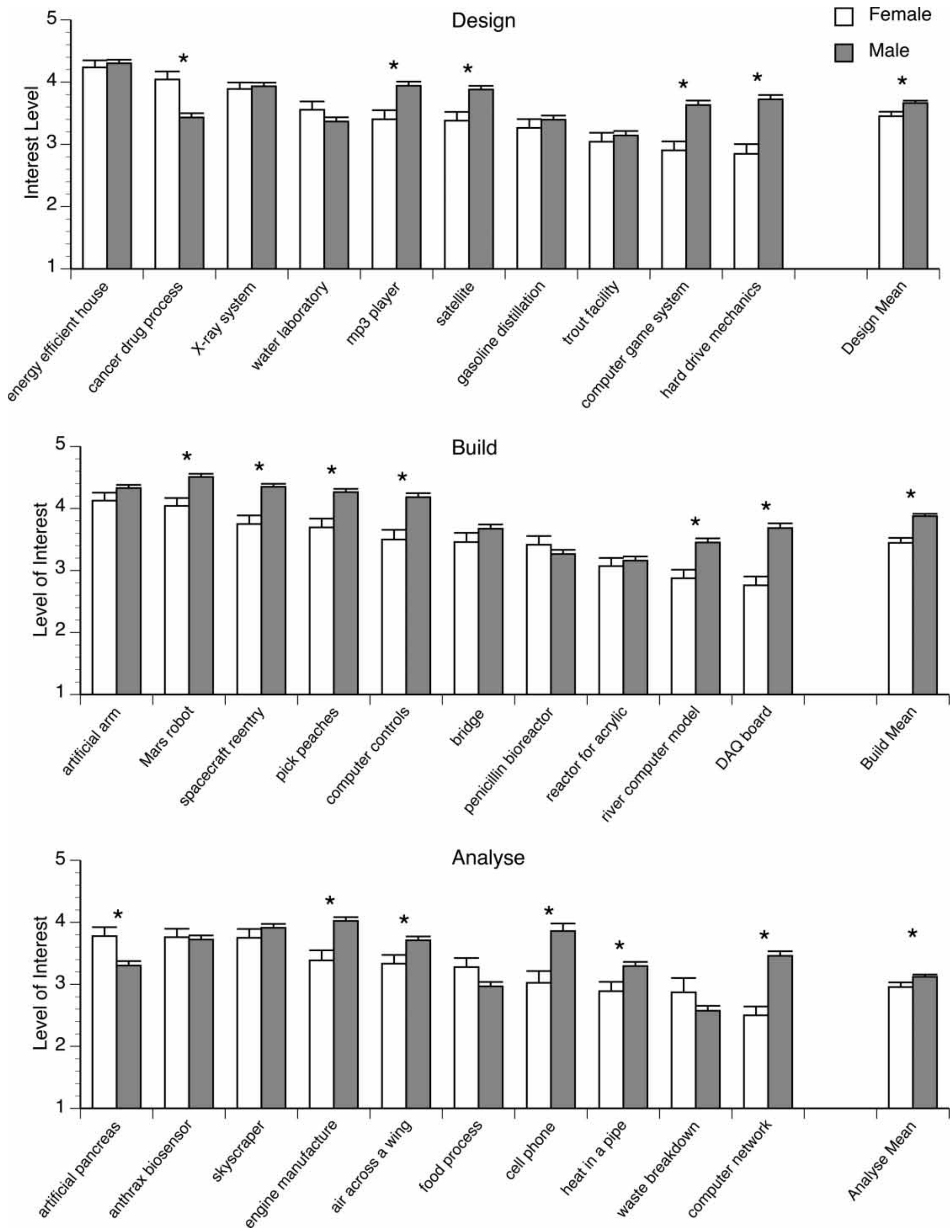

Figure 6. Individual item DBA interests of by gender: the mean is the average score of all participants for all questions in the category. Statistically significant differences between men and women are indicated with an asterisk and error bars indicate the standard errors.

items, while men were interested in engineering things and equipment. The exception to this rule was in the area of space exploration.

These results suggest that there may be benefits to the creation of gender-balanced materials for recruiting and retention. The authors wish to differentiate between gender-balanced and gender-neutral materials. While both approaches recognize the differences in gender interests, in gender-balanced material, equal amounts of material chosen to interest men and women are beneficial.

Gender-neutral materials are items that are of interest to men and women. Choosing only gender-neutral items severely restricts what is included in the materials. For example, of the 15 items in our list, which were of high interest to men *or* women, only 6 items were of high interest to men *and* women.

It is also important to avoid a negative impact from curricular and recruiting materials. Our results suggest that this is more likely to occur in women engineering students than in men engineering students. When the items with a general lack of interest were considered, two trends appeared. The first of these is a lack of interest in computers on the part of the women. The second is that women expressed a lack of interest in a total of seven items from the three activities while men expressed a lack of interest in two items in only one activity. This second trend suggests that women are likely to be more sensitive to the application areas than men.

5. Conclusions

Men and women are equally prepared academically to pursue undergraduate and graduate programs in engineering. Men and women are being "fed" into the pipeline and are likely to succeed in these engineering programs. Although this finding confirms previous studies, the common assumption that women are somehow less prepared to go into engineering makes it worth reiterating.

While men and women in our sample of engineering students are prepared in terms of academic coursework, there are gender differences in how comfortable they feel in pursuing their coursework. Although these gender differences may be outweighed by other factors, they lend some credence to previous claims that self-assessment plays a role in career decision-making and, in related fashion, in occupational segregation by gender (Xie and Shauman 1997, 2003, Clewell and Campbell 2002, Committee on Equal Opportunities in Science and Engineering 2004, Correll 2004).

A separate and related concern is that men in our sample indicated a significantly higher comfort level using computers, tools, and machines. This finding is an important reminder that it is not simply women's lack of self-confidence in the areas of math and science that may dissuade them from pursuing a career in engineering, but their lack of comfort and, perhaps, lack of experience with various tools and machinery that are a part of engineering.

This may help explain not only the under-representation of women in engineering as a whole, but also their concentration in sub-fields such as biological engineering. It is also worth exploring how these differences might inform curriculum development and recruitment strategy. Gender-specific recruitment materials and courses that emphasize engineering's various applications are worthy of consideration.

Perhaps, equally important is the lack of significant gender differences in many areas of this study. Responses to the DBA questions indicate that the men and women surveyed were similarly interested in pursuing the same kinds of activities associated with engineering. This finding indicates that, as educators, we need not worry about the willingness of our students to learn engineering skills and that the creation of a gender-balanced curriculum for engineering disciplines can (and should) be achieved without sacrificing basic engineering skills.

Although no significant gender differences emerged in terms of fundamental engineering activities (i.e. DBA), our analysis indicated key gender differences in interest in specific engineering activities. These differences suggest several methods to improve the representation of women in engineering programs. First, we need to diversify the areas in which engineering is applied. For example, the inclusion of biomedical engineering and biotechnology applications into courses has the potential to improve the retention of women in engineering programs. An emphasis should be placed on the direct human benefits of engineering practice, a recommendation consistent with those of Beraud (2003). As a side benefit, this will broaden the base of engineering firms that can employ our graduates (Salminen-Karlsson 2002). Second, these data suggest that these approaches should also be included in our recruiting materials.

Overall, this analysis suggests that gender is important to consider in some respects. The way in which gender matters is the significance of this study. Gender does not explain any difference in academic preparation, as the pipeline theory would suggest. Rather, it explains part of the difference in how comfortable students feel in various aspects of engineering education. Gender also helps explain the various motivations for going into engineering and the various interests for pursuing a career in engineering.

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