# PRESENTATION: EXPLORING GENDER DISPARITIES IN ENGINEERING

**INTRODUCTION.** The under-representation of women in engineering continues to be a cause of grave concern, particularly as international competitiveness and homeland security focus attention on the need to increase native participation in the U.S. science, technology, engineering, and mathematics (STEM) workforce. Comprising 56 percent of all undergraduate and 58 percent of all graduate students, women represent only 20 percent of B.A., M.A. and Ph.D. degrees awarded in engineering (Freeman, 2004; National Science Foundation, 2004). While an improvement over the situation thirty years ago, when women accounted for less than one percent of undergraduate degrees conferred in engineering, the persistent under-representation of women in engineering is puzzling, particularly when female representation in other fields (such as the natural sciences) has enjoyed superior improvement over time. The search for solutions to this problem has led to a panoply of studies that seek to identify the factors associated with student attrition. Before addressing the question of why women leave engineering, however, it is crucial to define that attrition is indeed the problem or, at the very least, a major part of it. This paper contributes new evidence to answer this empirical question. As the scholarly literature provides conflicting information, this study joins the debate by presenting national estimates that contribute to our understanding of the root causes behind female under-representation in engineering, and advance our thinking regarding ways to address it.

This study also applies new analytical tools to the study of recruitment and retention—gender parity and proportionality indices—that capture the relationship of female representation to that of males. Existing studies using institutional data generally focus on indicators that do not take into account the proportionality of outcomes, detracting attention from potential imbalances (or lack thereof) between the female and male cohorts. This research presents odds ratios that contribute a new dimension to the study of female representation in engineering. In the absence of student-level records, these indicators are an important addition to the set of available analytical tools.

Pursuit of this research required the creation of a national data set containing information on all engineering programs in the US. Therefore, unlike most previous work that has focused on specific institutions or a handful of programs, this research analyzes data on the population of undergraduate engineering programs and colleges/universities in the country. The enrollment and degree data used were compiled from three primary sources: the American Society for Engineering Education (ASEE), the Engineering Workforce Commission (EWC), and Engineering Trends. Additional institutional-level data were obtained from the Integrated Education Data System (IPEDS) at the National Center for Education Statistics (NCES) and the National Science Foundation. Merged into a comprehensive dataset of the population of undergraduate engineering programs at U.S. institutions—data cover academic years 1999-2000 through 2004-2005 and are for full-time students.

This analysis is based on program-level and institutional-level data on all undergraduate engineering programs in universities throughout the United States. Data are analyzed at both levels, program/discipline and institution. While there is variation throughout the nation in terms of discipline definitions at different institutions, the present analysis follows the discipline categories established by EWC. The EWC engineering disciplines, also used by NCES, are twenty, not counting the category labeled “Other” or “Pre-engineering.” The results presented here focus on the retention estimates excluding, due to space constraints, related analyses.

**Prevailing Constructs: Retention and Graduation.** Of the quantitative measures used in existing research to study student retention, the most prevalent is the retention rate, whose family of indicators includes the graduation rate. Closely related to each other, retention is a precondition of graduation, while graduation is the ultimate goal of retention. In an ideal situation, individual longitudinal data would be collected on every student enrolled in an engineering program to track outcomes over time (e.g., progress, yearly retention, transfers, etc.) Unfortunately, these data are unavailable at the national level. This leaves few viable options. By and large, researchers have approached this problem by approximating undergraduate retention rates through the following measures: 1. Retention rate in the freshman year (Jacobs, 1999) or freshman and sophomore years (Chang, 2002); 2. Percentage of potential engineering majors completing core courses (Noeth et al., 2003); 3. Number and percent of degrees awarded to women (Chubin & Babco, 2003); 4. Ratio of graduates to enrollment (Goodman, 2002; Chubin & Babco, 2003; Freeman, 2004).

Variants of these measures include longitudinal expectations (e.g., an expected number of years to graduation; of which an example is the percent of degrees awarded from the incoming freshmen class six years earlier, Chubin & Babco, 2003, or degree completion within 5 years, Freeman, 2004), or cross-sectional assumptions (e.g., that incoming classes do not vary greatly over time and, hence, the ratio of graduates to enrolled students uses statistics for the same year, as Goodman and colleagues do, 2002). Another variant is to average these statistics over several years to produce more stable ratios. This approach was taken in the present research. Retention is measured here as the number of students who graduate from a program divided by the number of students who enrolled in that program four years earlier*. Male and female retention are calculated separately. As needed data combinations are available for three freshman and four sophomore cohorts (graduation between 2002 and 2005, and initial enrollment between 1999 and 2002), reported retention estimates are averages over these cohorts. Both freshman and sophomore retention are estimated and are subsequently used to compute two new indicators, discussed below.

**Flagging Gender Differences Explicitly: New Measures of Graduation Outcomes.** Cognizant of the limitations of retention statistics at the institutional level, and searching for more explicit indicators of the relationship of female to male graduation in engineering, two odds ratios are constructed, called the parity and proportionality indices. *Parity Index*. The first of two measures of proportionality of degree outcomes—the Parity Index is the ratio of female to male retention. A ratio of 1.0 indicates that female and male retention are equal in that discipline or institution. Ratios greater than 1.0 indicate that a higher percentage of female students are retained, while ratios below 1.0 represent greater retention of male students. *Proportionality Index*. The Proportionality Index is also a ratio, but of the share of women who graduated from the incoming cohort of female students four years earlier, to the equivalent ratio for men. A Proportionality Index of 1.0 indicates that the share of women in the graduating cohort is proportional in size to the share of women in the incoming cohort four years earlier. Proportionality Index scores greater than 1.0 indicate that the proportion of women of a given cohort that graduates is greater than that of its incoming cohort; while ratios below 1.0 indicate that the share of women that graduates is lower. Due to differences in institutional counting practices, both proportionality and parity indices are calculated both as freshman-to-degree and sophomore-to-degree. The Proportionality Index captures a slightly different dimension of equity than the Parity Index in that it incorporates the fact that women are typically a small proportion of an incoming engineering class. Consequently, absolute retention rates of women are more sensitive to small fluctuations in numbers than are retention rates of men. The Proportionality Index bypasses this potential limitation by comparing proportions (the proportion of women in a graduating cohort to the proportion of women in the corresponding incoming cohort).

**RESULTS.** Nationally, close to 400,000 undergraduate students enroll in one of 22 fields in engineering, an average estimated between 1999 and 2003. Enrollment varies significantly, however, by discipline. The top five largest fields—Computer, Mechanical , Electrical, Civil and Chemical—attract an average of about 72,000 to 23,000 students each, and together comprise 67% of undergraduate engineering students. In contrast, the five smallest fields—Ceramic, Nuclear, Materials, Petroleum, and Agriculture—each enroll fewer than 2,000 undergraduate students

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**Note: though time to completion ranges from 4 to 6 years, given that these data are cross-sectional, 4 years was the interval selected to construct more cohorts for averaging. Analyses will be reproduced with different cohort sizes.*

nationally and together represent less than 2% of engineering enrollment. This variation is perceived for both men and women enrolled, although among women the bottom five fields include the field of "Marine, Naval Architecture & Ocean" Engineering, with Agriculture being the bottom sixth.

Paradoxically, due to the wide variation in the size of the disciplines, many of the largest fields in terms of absolute numbers of female enrollment are also the fields where the under-representation of women is most severe, both in terms of enrollment and degrees. Mechanical, Computer, and Electrical Engineering programs, in particular, have female enrollments and degrees (12-14%) below the national averages of 20 to 22 per cent, respectively. Disciplines where women are on average over-represented when compared to the national average include Bioengineering (.38), Environmental (.37), Chemical (.35), Industrial, Management and Manufacturing, and Architectural (.29 each).

Despite the fact that female students constituted only 20 per cent of national engineering enrollment between 1999 and 2004, during the same time women represented 22 per cent of degree recipients. In fact, in no engineering discipline do women represent a smaller percentage of degrees than they do of enrollment. This finding indicates that, while the number of students leaving engineering over the course of their college careers may be a general cause for concern, the rate of departures is not greater among female than male students.

The statistics presented in Table 1, found on page 5, address this issue of differential gender attrition directly. The retention estimates, both freshman to graduation and sophomore to graduation, suggest that attrition from engineering is not greater among female students. In fact, the average freshman retention estimates indicate that, in some fields, female retention is greater than male retention. These fields include chemical, civil, electrical/electronic, mechanical, and industrial[6] engineering, and contribute to the overall average finding of higher female (.75) than male (.68) freshman retention across engineering disciplines. Sophomore retention statistics suggest that, on average across fields, there is no gender difference, although in some disciplines females (environmental) and in others males (nuclear) display large retention rates.

The parity index measures the relationship of female to male graduation explicitly. It is the ratio of female retention to male retention. Both freshman and sophomore ratios are computed. Not surprisingly given the above findings, these indicators show that, on average across fields, male retention is not greater than female retention. As a matter of fact, the freshman parity index of 1.11 would suggest that female retention is greater than male retention, as this value is considerably higher than the general cutoff score of 1.03 (fluctuations of ±3, or .97 to 1.03, are considered equivalent to 1). Since this analysis excludes programs whose data were deemed unreliable, reducing the data set by 28 percent, statistical tests of significant differences were conducted (based on 1,208 programs). The 1.11 freshman parity ratio was not statistically different from 1, weakening the earlier conclusion of greater retention among female students and supporting the finding that there are no observable and statistically significant differences in either freshman or sophomore retention by gender.

The proportionality index contributes to this discussion by showing the share of women who graduate out of the share of women that comprised the incoming cohort. The 1.09 freshman proportionality ratio, and 1.0 sophomore ratio, support the conclusion that women do not have rates of graduation that are disproportionately lower than would be expected given their share in the incoming cohort. In other words, a ratio of 1 suggests that women comprise a share of the graduating class that is proportional to its share in the incoming cohort, while a ratio above 1 would suggest that women comprise a large share of the graduating than the incoming class (i.e., the program is retaining more women than men). As was true with the parity index, these average freshman and sophomore ratios are neither below 1 (if treating these as population statistics), nor statistically different from 1 (if treating these as based on a sample).

Variations in the parity and proportionality index scores are observed by discipline, however. But only in one third of the disciplines do the ratios flag a gender disparity against women. In about one third of disciplines the disparity favors women, with the remaining showing no gender differences. In addition, comparing the freshman versus sophomore statistics (for different disciplines within engineering as well as overall) reveal a tendency for the parity and proportionality ratios to approach a value of 1. This may partly be driven by data quality and selection. The sophomore data are less affected by undercounts due to pre-engineering enrollment, and are therefore more accurate. But sophomore students who enroll in engineering are also more likely to stay in the field than freshmen—which is another way of saying that attrition is greater in the freshman than sophomore years. It is important to note that while the estimates presented—retention, parity and proportionality indices—in some instances appear to overestimate the true population statistics, we have no reason to believe that this bias is affecting male and female statistics differently. Therefore, since the main purpose of this exercise is to compare men to women, the comparison is still useful and valid, even in cases when the actual estimates may appear inflated.

The main conclusion of this analysis is that, *overall*, there is no evidence of lower rates of retention among women than men enrolled in engineering undergraduate programs. This is not true for specific disciplines, a few of which do display some gender differences. The fields characterized by a clear pattern of indicators flagging lower retention among women include engineering science, as well as aerospace, general, nuclear, and mining/material/geological engineering. In most fields, however, there are either no gender differences or, if present, they favor women.

**DISCUSSION.** The empirical question studied here is whether retention in engineering is lower among women than men, as that might perhaps explain gender disparities observed in engineering graduating classes and workforce. The evidence compiled, analyzed and presented in this paper does not support this view. The results, based on a national data set of engineering programs, indicate that low overall participation in engineering among women is not due to greater attrition during college (a finding in line with results cited earlier from Huang and colleagues at NCES). Indeed, the data suggest that at the national level—i.e., on average across engineering fields, as well as on average within most (not all) fields in engineering—retention of women is not lower than male retention. Being an "average" result, it is of course possible (and we have evidence supporting this) that individual institutions as well as certain fields may indeed have a differential retention problem. Nonetheless, retention is clearly not the root cause of the underrepresentation of women nationally. Recruitment is. The results of this research thus re-direct attention from retention to recruitment. It may be that women who pursue studies in engineering are a selective group that, by the very choice of field, demonstrates a commitment and focus that translate into high retention. It may also be that programs in place to increase retention have been effective, i.e., this work partly documents the success of retention efforts. Either way, retention as a strategy has a ceiling, set rather low at the moment. The implication of this is that we need to focus on expanding the pool of women considering engineering as a possible field of undergraduate studies. We need to cast a wider net.

That net may capture students already at the institution (transfers in) or incoming (from high schools and community colleges). Students already at the institution, particularly those enrolled in mathematics and science courses, could be targeted through outreach activities within the institution. The net may also benefit from successful recruitment and outreach in middle schools and high schools, many of which are ongoing. Community colleges are another potential source of students. Depending on the degree of selectivity of recruitment criteria or, to put it in another way, how wide that net is cast, student support services may need to be provided to avoid generating a retention problem. Ironically, success in recruitment may result in a retention problem. Lastly, even that approach (a wider net) has a limit. Unlike biology, chemistry, physics and mathematics, engineering is generally not a subject taught in school. It is not, therefore, an intuitive choice of studies for those who are not somehow exposed to engineering—for example, have a relative who is an engineer. To succeed in increasing the number of native born engineers, we must find creative ways to permeate the lower echelons of the educational system to provide more exposure to engineering as a profession, doing so in a way that institutionalizes this effort and fosters its dissemination throughout the nation. As a field, engineering cuts across multiple disciplines with which students are familiar, but connections are often not explicit. One alternative, already practiced in some high schools, is to offer engineering as a course. Another alternative, that may reach even more students, is to incorporate into existing math and science courses special units on engineering applications. This would allow students to see real life applications of theoretical knowledge acquired in math, physics and others subjects, while also exposing them to opportunities in the engineering professions. In other words, outreach within institutions, across institutions, and into curricular reform in K-12 will all be needed to address what is, at its very core, a recruitment problem.

**REFERENCES.** Available upon request. **ACKNOWLEDGMENTS.** Supported by the National Science Foundation Directorate for Education and Human Resources.

Table 1: Engineering Statistics and Student Retention Analysis

| | Nationwide Engineering Statistics | | | | | | | | | Engineering Student Retention Analysis by Discipline | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Programs | Undergrad Enrollment* | | Female Enrollment* | | | Female Undergrad Degrees* | | | Programs | | Retention | | | | Parity Index | | Proportionality Index | |
| | | | | | | | | | | | | Fresh. | | Soph. | | | | | |
| *Engineering Discipline* | *N* | *Total* | *Mean* | *Total* | *Mean* | *%* | *Total* | *Mean* | *%* | *N* | *% incl* † | *F* | *M* | *F* | *M* | *Fresh.* | *Soph.* | *Fresh.* | *Soph.* |
| Aerospace | 68 | 12,085 | 178 | 2,089 | 31 | 16 | 341 | 5 | 16 | 53 | 90 | 46 | 50 | 73 | 76 | 0.93 | 0.96 | 0.92 | 0.95 |
| Agriculture | 40 | 1,946 | 49 | 519 | 13 | 20 | 151 | 4 | 24 | 17 | 85 | 60 | 69 | 70 | 79 | 0.86 | 0.89 | 0.92 | 1.08 |
| Architectural | 17 | 3,083 | 181 | 891 | 52 | 29 | 168 | 10 | 32 | 15 | 94 | 71 | 64 | 84 | 87 | 1.10 | 0.97 | 1.12 | 1.02 |
| Bioengineering*** | 102 | 11,092 | 109 | 4,528 | 44 | 38 | 859 | 10 | 40 | 54 | 75 | 74 | 69 | 81 | 83 | 1.07 | 0.98 | 1.07 | 1.00 |
| Ceramic | 9 | 520 | 58 | 125 | 14 | 21 | 36 | 4 | 24 | 3 | 43 | 72 | 48 | 89 | 62 | 1.50 | 1.45 | 1.53 | 1.46 |
| Chemical | 164 | 23,003 | 140 | 8,273 | 50 | 35 | 1,964 | 12 | 36 | 114 | 76 | 77 | 68 | 91 | 87 | 1.13 | 1.04 | 1.08 | 1.04 |
| Civil | 231 | 37,940 | 164 | 8,000 | 35 | 22 | 1,904 | 8 | 24 | 166 | 81 | 55 | 57 | 76 | 77 | 0.95 | 0.98 | 0.97 | 0.98 |
| Computer** | 259 | 71,891 | 278 | 10,334 | 40 | 13 | 2,244 | 9 | 14 | 137 | 67 | 93 | 82 | 97 | 93 | 1.13 | 1.04 | 1.14 | 1.06 |
| Electrical & Electronic | 292 | 59,957 | 205 | 8,331 | 29 | 13 | 1,990 | 7 | 14 | 178 | 72 | 92 | 74 | 91 | 88 | 1.25 | 1.04 | 1.19 | 1.03 |
| Engineering Sci. | 93 | 4,811 | 52 | 1,154 | 12 | 20 | 262 | 3 | 20 | 41 | 70 | 38 | 47 | 66 | 72 | 0.81 | 0.91 | 0.82 | 0.88 |
| Environmental | 73 | 2,142 | 29 | 836 | 11 | 37 | 229 | 3 | 41 | 31 | 66 | 97 | 86 | 92 | 89 | 1.13 | 1.03 | 1.10 | 1.04 |
| General | 134 | 21,240 | 159 | 3,752 | 28 | 17 | 297 | 4 | 17 | 38 | 81 | 30 | 41 | 47 | 55 | 0.72 | 0.86 | 0.82 | 0.77 |
| Industrial, Manag. & Manuf | 149 | 13,221 | 89 | 4,416 | 30 | 29 | 1,312 | 9 | 30 | 52 | 46 | 100 | 75 | 93 | 95 | 1.34 | 0.98 | 1.27 | 1.02 |
| Marine, Naval Arch & Ocean | 18 | 1,982 | 110 | 286 | 16 | 18 | 62 | 3 | 19 | 11 | 73 | 93 | 68 | 92 | 82 | 1.38 | 1.12 | 1.26 | 1.08 |
| Materials & Metallurgical | 31 | 1,176 | 38 | 313 | 10 | 25 | 255 | 4 | 28 | 176 | 75 | 87 | 73 | 91 | 88 | 1.18 | 1.03 | 1.18 | 1.04 |
| Mechanical | 275 | 65,409 | 238 | 7,980 | 29 | 12 | 1,849 | 7 | 13 | 15 | 68 | 64 | 67 | 80 | 87 | 0.96 | 0.92 | 0.79 | 0.91 |
| Mining, Material, & Geological | 72 | 3,405 | 47 | 924 | 13 | 25 | 83 | 3 | 23 | 33 | 62 | 72 | 68 | 91 | 95 | 1.07 | 0.96 | 1.06 | 1.04 |
| Nuclear | 22 | 863 | 39 | 157 | 7 | 16 | 27 | 1 | 19 | 11 | 69 | 63 | 79 | 77 | 84 | 0.80 | 0.91 | 0.80 | 0.89 |
| Other | 160 | 28,171 | 176 | 5,420 | 34 | 18 | 331 | 4 | 20 | 41 | 79 | 50 | 52 | 54 | 66 | 0.97 | 0.82 | 1.11 | 0.83 |
| Petroleum | 18 | 1,540 | 86 | 271 | 15 | 19 | 50 | 3 | 19 | 11 | 73 | 65 | 66 | 95 | 92 | 0.99 | 1.04 | 0.94 | 1.01 |
| Systems | 28 | 2,521 | 90 | 524 | 19 | 19 | 165 | 7 | 23 | 11 | 69 | 88 | 59 | 84 | 92 | 1.50 | 0.92 | 1.14 | 1.03 |
| *Pre-engineering* | *148* | *22,914* | *155* | *4,957* | *33* | *11* | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| TOTAL | 2403 | 390,913 | 163 | 74,079 | 31 | 20 | 14,581 | 7 | 22 | 1208 | 72 | 75 | 68 | 84 | 84 | 1.11 | 1.00 | 1.09 | 1.00 |

Notes: *Full-time undergraduate students only, averaged from 1999-2003; **includes computer science and computer engineering; ***includes biomedical. † Excluded observations with retention rates greater than 130% as well as those missing information on key variables.

Source: Analysis of EWC data.