Women in Engineering: Investigating Enrollment, Retention, and Graduation As They Relate to Targeted Support Initiatives

Jessica L. Heier, Malgorzata J. Rys, Kimberly D. Douglas

Kansas State University

Abstract—The objective of the study described in this paper was to frame Kansas State University's Women in Engineering and Science Program in the context of a widespread effort to support women in technical fields. Twenty institutions were selected for comparison based on peer-group status with K-State. Statistics about the engineering degrees granted to women at the target universities, as well as information about programs supporting women in engineering at these institutions, were gathered. The goal of the analysis was to identify which, if any, of the factors could be used to predict the percent of engineering undergraduate degrees granted to women at a given university.

Introduction

Women remain underrepresented among students graduating with degrees in engineering and many disciplines in the sciences. The Engineering Workforce Commission reported that approximately 16.4% of freshman engineering majors were women in the fall of 2003 (EWC 2004). When considering all fields in engineering, as well as physical, computer, environmental, and life sciences, women earned 39% of the undergraduate degrees in 2001 (CPST 2004). The Consortium for Student Retention Data Exchange based at the University of Oklahoma documents retention and graduation in science, technology, engineering, and mathematics (STEM) at 200 public and private institutions across the country. Of the females entering STEM fields between 1994 and 2000, 67.3% continued into a second year of study in these fields compared to 71.1% of males (CSRDE 2002). The six-year graduation rate of females in these fields was 34.8%, where that for males was 39%. By examining these numbers, one may observe that retaining students of both genders is a concern. However, far fewer women than men are entering these fields at all, indicating that action is necessary to break down the roadblock that prevents the science and engineering workforce from mirroring the diversity of the general population.

In an effort to understand and address this situation, colleges and universities across the country have begun programs targeted at recruiting, retaining, and graduating women in engineering and the sciences. The objective of this research was to frame Kansas State University's Women in Engineering and Science Program in the context of a widespread effort to support women in technical fields. The goal of the analysis was to identify which, if any, of a support program's characteristics could be used to predict the percent of engineering undergraduate degrees granted to women at a given university.

To conduct the study, data was gathered about the percent of undergraduate, master's, and doctoral degrees granted to women at each of 20 selected institutions. In addition, the percent of female tenure/tenure-track faculty was identified. Finally, characteristics of each institution's program supporting women in engineering (where one was present) were documented by categories. Upon completion of the data collection, a regression analysis was conducted to determine predicting factors of undergraduate engineering degrees granted to women at the specified universities. This paper describes the method used in this study and the results obtained.

Method

The first step taken to define the scope of the study was to identify universities from which to collect data based on peer group status. Table 1 lists the institutions studied and their categorization. These schools were selected for one or more of the following reasons: the university is a member of the Big 12 Conference, the university is a land grant institution, the school has been identified by the Kansas Board of Regents as a peer institution of K-State, or the institution has a well-established program for women in engineering.

Table 1: Universities Identified for Study

Arizona State University (W)	Pennsylvania State University (LG)
Baylor University (12)	Purdue University (LG)
Colorado State University (LG, P)	Texas A & M University (12, LG, P)
Florida A & M (LG) /Florida State University	Texas Tech University (12)
Iowa State University (12, LG, P)	University of Colorado (12)
Kansas State University (12, LG)	University of Kansas (12)
North Carolina State University (LG, P)	University of Missouri (12)
Ohio State University (LG)	University of Nebraska (12, LG)
Oklahoma State University (12, LG, P)	University of Oklahoma (12)
Oregon State University (LG, P)	University of Texas at Austin (12)

12 denotes Big 12 Conference Universities
LG denotes Land Grant Institutions (NASULGC 2003)
P denotes Kansas Board of Regents' Designated Peer Institutions (KSU Office of Planning and Analysis 2003)
W denotes institutions that have particularly active women in engineering programs but that do not fit other categories

Secondly, the objectives of the study were defined as follows:

- Collect information about programs supporting women in engineering at the target universities from the university websites.
- Collect statistics about engineering degrees granted to women at the target universities.
- Identify best practices.
- Make recommendations to Kansas State's Women in Engineering and Science Program based on results of study.

Data

Based on the information gathered from each university, a matrix was created to include 18 categories of program offerings and characteristics. These categories were then used in a regression analysis. The goal of the analysis was to identify which, if any, of the factors could be used to predict the percent of engineering undergraduate degrees granted to women at a given university. The categories and the methods for coding the data are described in Table 2.

Table 2: Factors Considered in Regression Analysis

Factor 1:	*How long has the university program dedicated to the support of women in engineering been in existence?*
	This factor was coded as the difference between the current year (2004) and the year the program was founded.
Factor 2:	*How many mouse clicks does it take to reach the program web page from the university's home page?*
	This was used as a measure of top-level support and visibility of the program. When beginning at the university's home page, the number of mouse clicks necessary to directly reach the program web page was counted. Using a search box was not allowed in this calculation. However, when multiple attempts were necessary to locate the program web page, the number of clicks was determined by restarting at the home page and using the most direct route. This method was used to eliminate the possibility that some users may be better (or luckier) than others at correctly identifying the appropriate links on a given attempt.
Factor 3:	*What percent of engineering undergraduate degrees were granted to women in 2001-2002?**
Factor 4:	*What percent of engineering graduate degrees were granted to women in 2001-2002?**
Factor 5:	*What percent of engineering doctoral degrees were granted to women in 2001-2002?**
Factor 6:	*What percent of tenure or tenure-track engineering faculty positions were held by women in 2001-2002?**
Factor 7:	*Does the program have offerings for elementary school students?***
Factor 8:	*Does the program have offerings for middle school students?***
Factor 9:	*Does the program offer a residential experience for high school students?***
	Examples of residential high school experiences include summer engineering camps.
Factor 10:	*Does the program have other high school offerings?***
	Other high school offerings include special college visit days or programs connecting high school girls with female engineering students in mentoring relationships.
Factor 11:	*Does the program have offerings for elementary and/or secondary school teachers?***
	These offerings include summer learning opportunities and online resource centers.
Factor 12:	*Is there an undergraduate peer mentoring program?***
	The presence of a chapter of the Society of Women Engineers was included in this category.
Factor 13:	*Is there a mentoring program matching undergraduate women with female faculty?***
Factor 14:	*Is there a mentoring program matching undergraduate women with industry professionals?***
Factor 15:	*Is there a residential program for undergraduate women?***
	Examples of undergraduate residential programs include engineering social sororities, residence hall concentration groups, or other living and learning communities.
Factor 16:	*Is an undergraduate class or lecture on women in engineering offered?***
Factor 17:	*Are there undergraduate research opportunities targeted to women?***
Factor 18:	*What is the total number of the preceding categories in which the university has offerings?*
	The coded number for this category was determined by summing the coded values for Factors 7 to 17 for the respective universities. This number represents the breadth of offerings by a given program.

*Factors 3 through 6 were calculated using information in the 2002 Edition *of Profiles of Engineering and Engineering Technology Colleges* produced by the American Society for Engineering Education.

**Factors 7 through 17 were coded as either a "0" or "1" for the purposes of the regression analysis. If a university's program website had information about a given offering, a "1" was used in that category for the university. If not, a "0" was used.

Data Analysis and Interpretation

This section provides a summary of the statistical tests conducted on the data. All of the analysis was conducted using *Minitab Statistical Software: Release 13.31*.

Degrees Granted

Using the data from the NSF WebCASPAR database (2003), several statistical tests were conducted:

1. The Anderson-Darling normality test was conducted on the data summarizing the percent of undergraduate engineering degrees granted to women at each of the target institutions in 1992 and in 2001. While the data from 1992 can be considered normal (p-value 0.340), that from 2001 cannot (p-value 0.000). With the removal of two outlying points with unusually high percentages of degrees going to women, the rest of the data are normal (p-value 0.598). Figures 1, 2, and 3 contain these results.

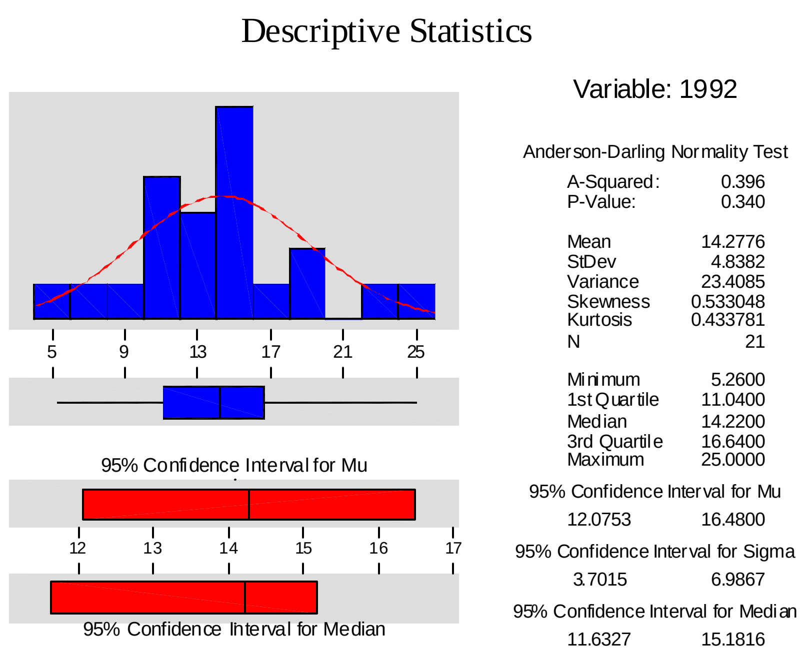

Figure 1: Test for Normality – Degrees Granted in 1992

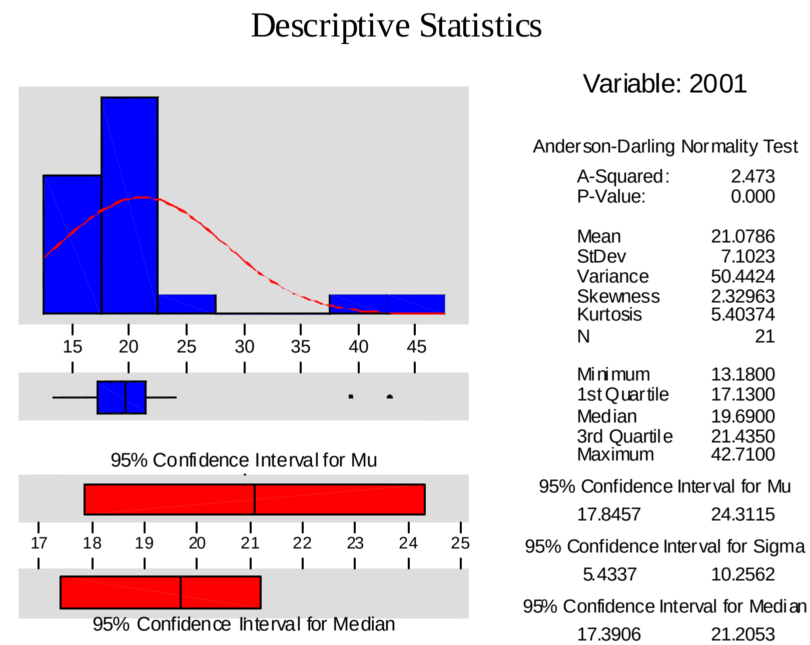

Figure 2: Test for Normality – Degrees Granted in 2001

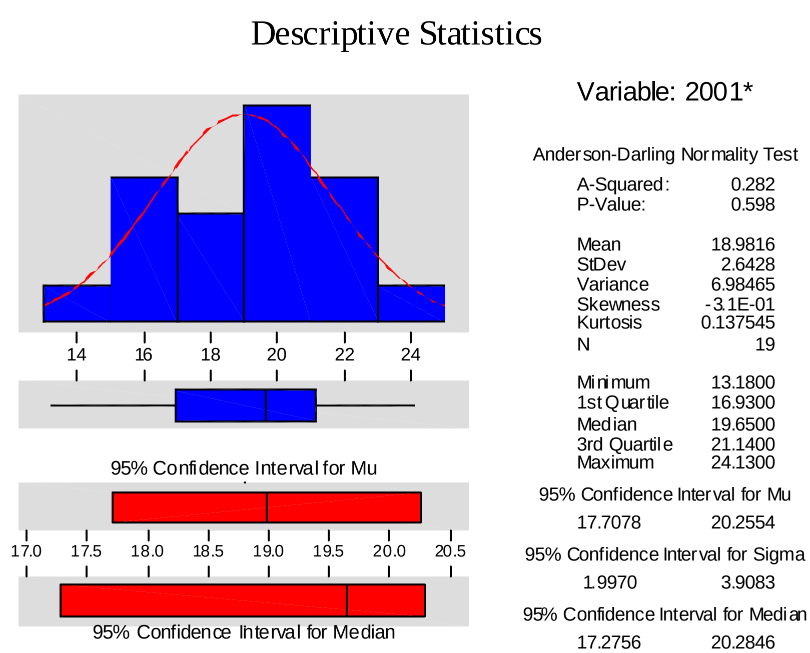

Figure 3: Test for Normality – Degrees Granted in 2001 Excluding Outliers

2. A two-sample t-test was used to determine if the mean number of degrees granted to women in 1992 is significantly different than the mean of those granted ten years later in 2001. Due to the results of an F-test for variances, the t-test did not assume equal variance

between the samples. Once again, the outlying points were excluded from this analysis. The 95 percent confidence interval on the difference in the means, which indicates the range of increase in the percent of degrees granted to women over the decade studied, is 2.22 to 7.19. Additionally, the means are significantly different with a p-value of 0.001.

Correlation and Regression of Undergraduate Degrees

The correlation between the percent of engineering undergraduate degrees granted to women in 2001-2002 and all of the individual factors in Table 2 was determined. Regression was performed on each of the factors and on combinations of multiple factors. Table 3 shows the p-values and R^2 values for each of the factors and combinations.

Table 3: Correlation and Regression - Predictors of Percent Undergraduate Degrees Granted to Women

Factors	Correlation with F3: %Ugrad Degrees to Women	P-value	R^2-value (adjusted)
F1: Years in Existence	0.518	0.125	17.7%
F2: Clicks from Univ. Web Page	0.679	0.008	41.6%
F4: %Grad Degrees to Women	0.669	0.001	41.6%
F5: %Doctoral Degrees to Women	0.252	0.283	1.2%
F6: %Women Ten/Ten-Track	-0.216	0.361	0.0%
F7: Elem School Program?	0.072	0.763	0.0%
F8: Mid School Program?	0.082	0.731	0.0%
F9: High School Res. Program?	0.141	0.553	0.0%
F10: High School Other Program?	-0.107	0.655	0.0%
F11: Teacher Program?	0.300	0.199	3.9%
F12: Ugrad Peer Mentor/SWE?	-0.016	0.947	0.0%
F13: Ugrad/Faculty Mentor?	0.016	0.947	0.0%
F14: Ugrad/Prof Mentor?	0.088	0.711	0.0%
F15: Ugrad Residential Program?	0.021	0.931	0.0%
F16: Ugrad Class/Lecture?	0.265	0.259	1.8%
F17: Ugrad Research Program?	0.019	0.936	0.0%
F18: Total Offerings	0.159	0.503	0.0%
F1, F2, & F4	--	0.007	77.9%
F1 & F2	--	0.002	78.3%

Results

The results of the statistical analysis of data show that, of the factors considered, the number of clicks to the program website and the number of years the in existence (Factors 1 and 2) were the best predictors of the percent of engineering undergraduate degrees granted to women. The following equation is the result of a best subsets linear regression:

$$\%UDW = 0.0275 + 0.00196(YE) + 0.0270(CUW)$$

where %UDW = Percent of Undergraduate Degrees Granted to Women
YE = Years in Existence (Factor 1)
CUW = Clicks from University Web Page (Factor 2)

This equation has an R^2 value of 83.1% (adjusted R^2 = 78.3%) and a p-value of 0.002, leading to the conclusion that, although not outstanding, this equation quantifies the relationship between support program characteristics and the percent of undergraduate degrees granted to women.

The other results were disappointing in that no strong conclusions can be made about the effectiveness of particular program offerings. In addition, the numbers of female postgraduate students and of tenure/tenure-track faculty are not reliable predictors of undergraduate degrees awarded. The values for p and R^2 for each correlation and regression are given in Table 3.

There may be several reasons that the program characteristics cannot serve as effective predictors of the number of degrees granted to women at a given university. First, most of these programs are still exceptionally new. Students that may have participated in elementary, middle, or high school programs are only now entering college. The extent to which they pursue and complete degrees in engineering has yet to be seen. Second, this is a relatively small sample of universities. Missing data points in some of the categories compound this problem. Finally, there may be other factors not measured by this study that contribute to women's completion of engineering degrees. Some examples could include the overall student support atmosphere at a particular college, women's rate of participation in the programs offered, or participation in other extracurricular activities that provide support for perseverance toward the degree.

Conclusions and Future Work

The analysis did demonstrate that women earned a higher percentage of the undergraduate engineering degrees at the target universities in 2001 than they did ten years earlier. However, this increase has not been enough to achieve parity and work remains to be done. Because the preceding analysis did not yield strong conclusions about the effectiveness of individual program offerings, this stage of the research concluded with several possible avenues for future work.

- First, the design and implementation of a system to track participants in pre-college outreach programs and undergraduate support programs through degree completion could be considered. This data-driven approach could help quantify the effect that individual programs have. In addition, continued contact with and interest in students may provide a strong sense of the resources available to women in engineering.

- Second, since the factors that did prove significant in this study measured aspects of an institution's climate and the top-level support for women in technical fields, efforts could be focused on continuing to improve this environment. While this is a large task, one way to accomplish this is to continue to develop women for future faculty roles in engineering fields.

- Finally, there were some universities in the study that exhibited unusually high percentages of undergraduate engineering degrees granted to women. Further investigation into the circumstances present at these universities may be warranted to identify successful approaches.

At this time, these courses of action are being considered within the context of the objectives of the Kansas State University Women in Engineering and Science Program.

References Cited

American Society for Engineering Education. (2002). *Profiles of Engineering and Engineering Technology Colleges 2001 Edition*. Washington, DC: ASEE.

American Society for Engineering Education. (2003). *Profiles of Engineering and Engineering Technology Colleges 2002 Edition*. Washington, DC: ASEE.

Commission on Professionals in Science and Technology. (2004). *Professional Women and Minorities 15th Edition*. Washington, DC: CPST.

Consortium for Student Retention Data Exchange. (2002, September). *The Retention and Graduation Rates of 1994-2000 Freshman Cohorts Entering Science, Technology, Engineering and Mathematics Majors in 200 Colleges and Universities*. Retrieved October 15, 2003, from University of Oklahoma CSRDE website: http://www.occe.ou.edu/csrde/index.html.

Engineering Workforce Commission of the American Association of Engineering Societies, Inc. (2004). *Engineering and Technology Enrollments Fall 2003 Edition*. Washington, DC: AAES.

Kansas State University Office of Planning and Analysis. (2003, April). *Annual Report on the Status of Faculty Salaries at Kansas State University*. Retrieved October 29, 2003, from http://www.k-state.edu/pa/Salary02/index.htm.

National Association of State Universities and Land Grant Colleges. (n.d.). *NASULGC Member Land-Grant Institutions*. Retrieved October 29, 2003, from http://www.nasulgc.org/About_Nasulgc/members_land_grant.htm

National Science Foundation. Degree Statistics Table Generated at WebCASPAR Database. Retrieved December 14, 2003, from http://caspar.nsf.gov/cgi-bin/WebIC.exe. Data Source: Earned Degrees, AY 1966-98, 2000-01 summarizing data from The Higher Education General Information Survey (HEGIS) and the Integrated Postsecondary Education Data System (IPEDS) conducted by the Department of Education's National Center for Education Statistics (NCES).

Contact Information

Jessica L. Heier, jheier@ksu.edu
Malgorzata J. Rys, malrys@ksu.edu
Kimberly D. Douglas, kdd@ksu.edu