AC 2009-705: HOW WE MEASURE SUCCESS MAKES A DIFFERENCE: EIGHT-SEMESTER PERSISTENCE AND GRADUATION RATES FOR FEMALE AND MALE ENGINEERING STUDENTS

Matthew Ohland, Purdue University

Matthew W. Ohland is an Associate Professor in the School of Engineering Education at Purdue University and is the Past President of Tau Beta Pi, the engineering honor society. He received his Ph.D. in Civil Engineering from the University of Florida in 1996. Previously, he served as Assistant Director of the NSF-sponsored SUCCEED Engineering Education Coalition. He studies longitudinal student records in engineering education, team-member effectiveness, and the implementation of high-engagement teaching methods.

Michelle Camacho, University of San Diego

Michelle Madsen Camacho is Associate Professor of the Sociology Department and Affiliated Faculty in both the Ethnic Studies Program and the Gender Studies Program at the University of San Diego. She is fluent in both quantitative and qualitative research methodologies and uses theories from interdisciplinary sources including cultural studies, critical race, gender and feminist theories. Her research examines questions of culture, power and inequality through both macro and micro lenses. She has presented and published her research on several projects including: the paradox of "modernization" via state-led development projects in Mexico, narratives of pedagogy and the application of community service learning, and inequalities in education, particularly persistence of women and people of color in engineering education.

Richard Layton, Rose-Hulman Institute of Technology

Richard A. Layton is the Associate Director of the Center for the Practice and Scholarship of Education and an Associate Professor of Mechanical Engineering at Rose-Hulman Institute of Technology. His areas of scholarship include student team management, assessment, education, and remediation, laboratory reform focused on student learning, visualization of quantitative data, and engineering system dynamics. He is a guitarist and songwriter in the alternative rock band "Whisper Down".

Russell Long, Purdue University

Russell A. Long is Associate Director of MIDFIELD and Director of Project Assessment in the School of Engineering Education at Purdue University. He has twenty years experience in institutional research, assessment, strategic planning, and higher education policy. He is a SAS expert and manages the MIDFIELD database.

Susan Lord, University of San Diego

Susan M. Lord received a B.S. from Cornell University and the M.S. and Ph.D. from Stanford University. She is currently Professor and Coordinator of Electrical Engineering at the University of San Diego. Her teaching and research interests include electronics, optoelectronics, materials science, first year engineering courses, feminist and liberative pedagogies, and student autonomy. Dr. Lord served as General Co-Chair of the 2006 Frontiers in Education Conference. She has been awarded NSF CAREER and ILI grants. She is currently working on a collaborative NSF-funded Gender in Science and Engineering project investigating persistence of women in engineering undergraduate programs. Dr. Lord's industrial experience includes AT&T Bell Laboratories, General Motors Laboratories, NASA Goddard Space Flight Center, and SPAWAR Systems Center.

Mara Wasburn, Purdue University

Mara H. Wasburn, is Associate Professor of Organizational Leadership in the College of

Technology at Purdue University. Her research, teaching, and service focus is on the effects of mentoring on both retention and success, particularly on women in technology-related disciplines. She serves as a consultant on workplace diversity issues.

How we measure success makes a difference: Eight-semester persistence and graduation rates for female and male engineering students

Abstract

Recent research has shown that, although stereotypes prevail about women's attrition rates in undergraduate engineering, there is no gender gap in the persistence of engineering students to the eighth semester of study. How "persistence" is measured, however, is of methodological concern as we look at what constitutes success. "Persistence" is reported in the literature in various ways as approximate measures of graduation, which is the ultimate goal.

To examine the relationship between measures of persistence and graduation, analyses were conducted using MIDFIELD (the Multiple-Institution Database for Investigating Engineering Longitudinal Development). The database includes student records from 75,686 first-time-in-college students matriculating in engineering at one of nine public universities in the southeastern United States. We found gender and institutional differences in the six-year graduation rates of students who persist to the eighth semester. An important result of this work is demonstrating how studying different outcomes can tell different stories about the same students: studying eight-semester persistence for aggregate populations can provide a reasonable surrogate for graduation, but may paint an overly optimistic picture at some institutions, and the study of both outcomes can provide new and valuable information about the student experience.

Background

There is disagreement in the literature concerning the existence of a gender gap in the science, technology, engineering, and math (STEM) disciplines in general, and engineering in particular. Although conventional wisdom and a number of studies state that women persist in engineering majors at lower rates than do men,[1,2] numerous studies document that women who matriculate directly into engineering majors persist at the similar rates to their male counterparts.[3,4,5,6] In one study, the authors note that while there are fewer women present at each educational stage, they are more likely to persist in math, science, and engineering (STEM) disciplines.[7]

If standards of student quality are upheld, the most favorable institutional condition is a high eight-semester persistence leading to a high six-year graduation rate. Preliminary findings suggest that while some students may be on a journey of exploration,[8] the combination of a high eight-semester persistence rate and a low six-year graduation rate may be indicative of a systematic process by which students become trapped in unsuccessful pathways. Thus, we suggest that, for a particular six-year graduation rate in engineering, a lower eight-semester persistence rate may be preferable because students who leave engineering are guided to their final outcome (graduation in another field or institutional departure) more quickly.

The study of gender differences in these outcomes reveals institutional differences in the experiences of women in engineering that suggest this approach can provide institutions with a useful benchmark for success in striving for gender equity in engineering. Further, the observed gender differences may provide large-scale quantitative support for earlier qualitative findings.

Methods

Studies of engineering student success are best performed using longitudinal data, which are rarely available. Most studies rely on cross-sectional data or in the construction of synthetic cohorts to model outcomes over time, yielding results that can be challenging to interpret. These approximations are not needed in research using Multi-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD). MIDFIELD is a rich longitudinal database with student-level records for all undergraduate students at nine southeastern public universities from 1987-2005. The MIDFIELD database contains records for 857,001 unique students of whom 462,443 received at least one bachelor's degree, 135,860 who were at some point enrolled in engineering with 71,277 receiving a bachelor's degree in engineering. First-time-in-college students who are U. S. citizens or permanent residents make up approximately half of this population and are the focus of this study.

While many types of institution are not represented in the dataset, MIDFIELD includes data from multiple large public institutions. Thus, the experience of MIDFIELD students is likely to be representative of the experience of a large fraction of U.S. engineering students who attend a similar institution. Therefore, the results may be generalizable on that basis. A more detailed description of the MIDFIELD dataset is available elsewhere[3] as well as a list of publications and a data dictionary.[9] Using whole population data precludes the need for inference statistics.

Findings

At first, eight-semester persistence appears to be a consistent predictor of six-year graduation. Eight-semester persistence has been used in the literature in lieu of six-year graduation.[3,4,10] For the same study period, the use of eight-semester persistence allows the study of more cohorts and more recent cohorts, so there is clear benefit to the practice. In earlier work using the MIDFIELD database, it was anticipated that differences in persistence could accrue by race and gender as students attempted to graduate within six years after persisting in engineering for eight semesters,[3] and we begin our investigation by comparing eight-semester persistence to the six-year time window for graduation established as a standard of reporting by the Integrated Postsecondary Education Data System.[11] Our preliminary exploration of the suitability of the use of eight-semester persistence in our dataset is shown in Figure 1. Each datapoint in this figure represents all the students of a particular gender matriculating in engineering at a particular institution. Log-scale axes ensure that the behavior of smaller populations is not obscured. For women, the slope of the regression line is 0.9261 indicating that, on average, approximately 93% of women persisting to the eighth semester in engineering continue on to graduate in engineering within six years (likely, but not necessarily, in the same engineering discipline). The high R^2 indicates that this persistence to graduation from the eighth semester is consistent for females at various institutions. Men are slightly less likely to graduate after persisting to the eighth semester (89%). Based on this evidence and on the acceptance of the practice in the literature, we proceeded to eight-semester persistence as our outcome of interest in various studies.[12,13]

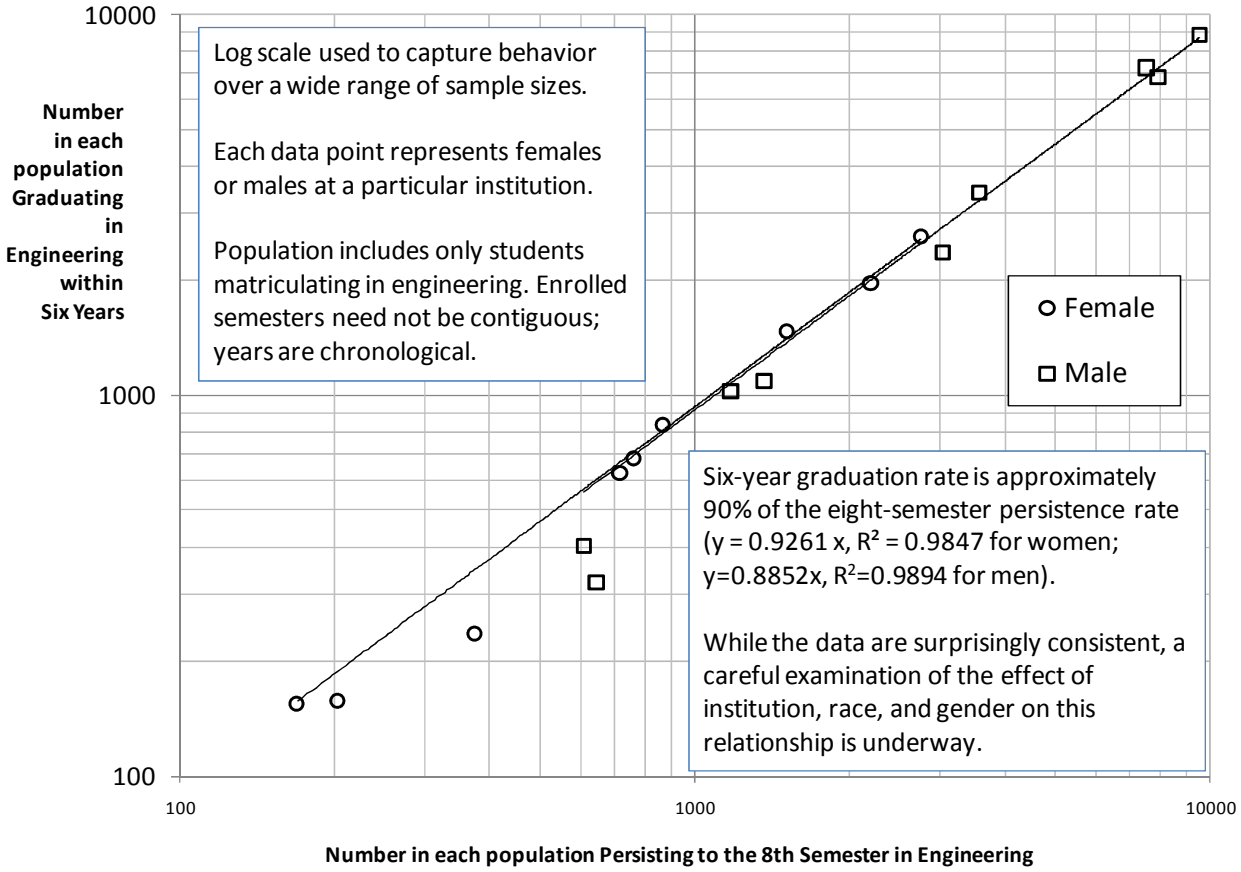

Figure 1. At first, eight-semester persistence in engineering appears to be a consistent predictor of six-year graduation.

There are gender differences in graduation rate after eight-semester persistence. Figure 2 was developed to accentuate population differences compared to the treatment in Figure 1. The log scale in Figure 1 has the side effect that departures from the line are greater than they appear, so Figure 2 instead uses population percentages to display large and small populations on the same scale. By plotting the percentage of each population graduating ***after having persisted to eight semesters*** on the ordinate, we can distinguish the experience of populations with the same overall graduation rate. The institutions are labeled in order of the six-year graduation rate for women at the group of institutions. Institution 1 has the highest six-year graduation rate for women, and institution 9 has the lowest six-year graduation rate. The aggregate persistence of the female population at institution 1 is shown on the graph as "F1" and the male population at institution 1 is labeled with "M1." The new graph design in Figure 2 has other advantages. The product of the two variables plotted is the six-year graduation rate.

$$Six-year\ graduation\ rate = \left(\frac{\#\ graduating\ in\ 6\ years}{\#\ persisting\ to\ the\ 8th\ semester}\right)\left(\frac{\#\ persisting\ to\ the\ 8th\ semester}{\#\ matriculating}\right)$$

For women at institution 2 (F2), for example, the six-year graduation rate is 62%, which is the product of 90% (the value on the vertical axis) and 69% (the value on the horizontal axis).

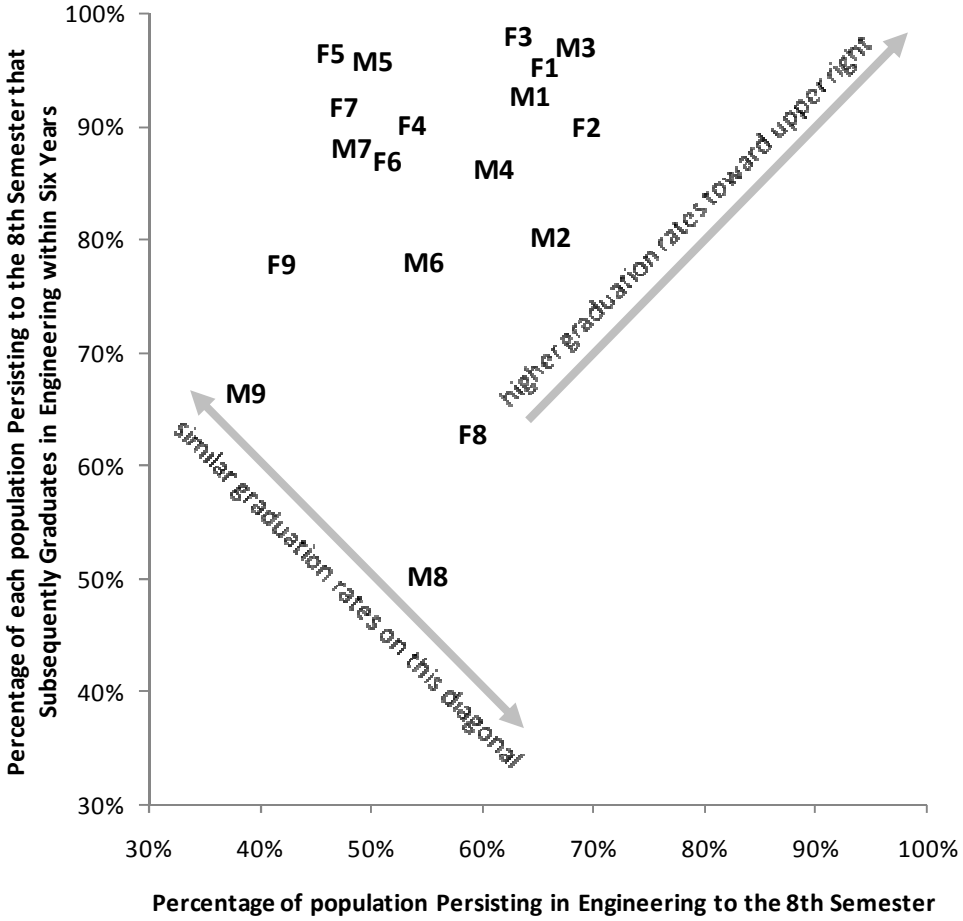

Figure 2. Populations with similar graduation rates may have widely varying experiences. Population identifiers: F=female, M=male; each number represents a particular institution.

Since the highest product results from having larger values for each variable, higher six-year graduation rates are found toward the upper right of the graph as indicated by the arrow with a +45º orientation shown in Figure 2. The same graduation rate can result from various combinations of these variables; datapoints located on any line transverse to that arrow (example shown in Figure 2 with -45º orientation). The use of population labels in place of data markers conveys information at each datapoint—the institution and the gender of that sub-population, as well as the institution's rank in the graduation rate of females. Population sizes would reveal the institutions and cannot be shown. Multiple layers of information can be assessed from this graph:

- comparing the female and male populations of the same institution
- clustering patterns of the datapoints for the female and male populations
- comparing the relative position of institutions

Our first impression of Figure 2 is that it has quite a bit of scatter, showing notable differences between females and males within an institution and among institutions when focusing on populations of a particular gender. The inclusion of data for six-year graduation following eight-semester persistence helps highlight differences in the experiences of various sub-populations that were not noticeable previously. Particularly in the cases of institutions 2, 8, and 9, small gender gaps in eight-semester persistence (3-4%) are related to larger gender gaps in six-year graduation rate (7-10%). As shown in Table 1, institutions 1, 3, 4, 5, 6, and 7 show a very small (1 – 4%) gender gap in six-year graduation rate. Note that for seven of the nine institutions, this gap is less than 5% and for six of the nine institutions, women do ***better*** or have a higher six-year graduation rate than men.

Table 1. 6-year graduation rate for female and male engineering matriculants by institution. Last column shows the difference in graduation rate by gender. Numbers are rounded.

	6-year graduation rate		Difference
Institution	**Female**	**Male**	**Female - Male**
1	63%	59%	4%
2	62%	53%	9%
3	62%	64%	-3%
4	49%	52%	-4%
5	45%	48%	-3%
6	44%	43%	2%
7	43%	42%	1%
8	38%	28%	10%
9	33%	26%	7%

Studying multiple outcomes reveals qualitative differences among population experiences. As pointed out earlier, populations on the -45º diagonal in Figure 2 have the same six-year graduation rate. Nevertheless, their experiences may be quite different. Populations to the lower right are lingering in engineering programs with a smaller likelihood of graduation, whereas populations to the upper left are more likely to leave engineering earlier. Presumably, students in the latter scenario leave engineering while they still have more options. Notably, women are less likely to persist to the eighth semester for the same six-year graduation rate. This is true of institutions 1, 3, 4, 5, 6, and 7—while women at the remaining institutions (2, 8, and 9) show similar pathways to the men at those institutions (the datapoints representing female and male populations are close together), but higher rates of persistence in all cases. It is also interesting to compare Institutions 8 and 9. The six-year graduation rates of females at the two institutions are nearly equal. The same is true of the males at those institutions. Yet, in the case of both gendered sub-populations, institution 8 exhibits a qualitatively worse experience by the rationale above since more students persist to the eighth semester but do not graduate within six years. Because graduation rates increase on the +45º diagonal, it is difficult to compare the graduation rate of two populations directly using Figure 2. Of students who persist to eight semesters, women are (from 1% to 13%) more likely than men to graduation within six years. If a more precise comparison of graduation rates is needed, a graph in the design of Figure 2 can still be used as an exploratory tool.

Discussion and Conclusions

What does this mean for women in engineering? This study provides large-population quantitative evidence for earlier qualitative results by Seymour and Hewitt (1997) describing gender differences in the reasons students leave engineering for other majors or leave the university. Women and men derive self-efficacy from different sources. Women build self-efficacy primarily through vicarious experience and verbal persuasion, whereas men are more likely to develop self-efficacy through mastery experiences, as summarized from a broad literature review by Royal and Mameril.[14] We hypothesize that unfavorable social comparisons (to professors, to professionals, and to talented peers) drive women out of engineering early, explaining why the female populations tend to have lower eight-semester persistence rates for the same six-year graduation rate. Men, conversely, will derive self-efficacy from a diverse set of achievements, including simply passing their classes. Attributing failures to the professor, bad luck, or other sources bolsters the self-efficacy of men at times beyond reasonable limits, resulting in their languishing in degree programs and, at times, exhausting their options. We will continue our work to test this hypothesis by examining the populations with high eight-semester persistence rates but low six-year graduation rates to determine if they do indeed have fewer options available to them when they leave engineering as measured by their academic standing at their departure from engineering.

What does this mean for engineering education and for the rest of higher education? When eight-semester persistence is studied as an academic outcome, caution should be taken when interpreting results. Further, if the research and the dataset permit, six-year graduation should be used directly, rather than any persistence measures used to approximate it. The comparison of both outcomes in Figure 2 reveals additional information about the experience of a population. We anticipate future work that will explore these issues in a way that disaggregates race and gender, requiring a more complicated graph design. Differences by discipline and with time are also relevant and will begin to emerge from this work. Future research could include further investigation of the sensitivity of institutional findings to the six-year graduation time window established as a standard of reporting by the Integrated Postsecondary Education Data System[11] by considering a longer graduation time-window. We will continue to develop a toolbox of special graph designs to facilitate data exploration and analysis. To the extent possible, we will repeat earlier studies using MIDFIELD that drew conclusions based on eight-semester persistence to assess to what degree this new knowledge might affect earlier conclusions, particularly in our understanding of women in engineering, including the study of women disaggregated by race.

Acknowledgements

This material is based on work supported by the National Science Foundation Grant No. REC-0337629 (now DRL- 0729596) and EEC-0646441, funding the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD, a collaboration of nine partner universities) and a collaborative NSF Gender in Science and Engineering Research Grant (0734085 & 0734062). The opinions expressed in this article are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

[1] Astin, A. W., and Astin, H. S., (1992) *Undergraduate science education: The impact of different college environments on the educational pipeline in the sciences.* (Final Report) Los Angeles, CA: University of California Higher Education Research Institute. (ERIC Document Reproduction Service No. ED362404)

[2] Adelman, C. and United States. Dept. of Education. (1998). *Women and men of the engineering path : a model for analyses of undergraduate careers.* Washington, DC, U.S. Dept. of Education : National Institute for Science Education.

[3] Ohland, M. W., Sheppard, S.D., Lichtenstein, G., Eris, O., Chachra, D., Layton, R. A., (2008). Persistence, Engagement, and Migration in Engineering. *Journal of Engineering Education* **97**(3).

[4] Seymour, E. and N. M. Hewitt (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, Colo., Westview Press, p. 21.

[5] Hartman, H., and Hartman, M., (2006) Leaving Engineering: Lessons from Rowan University's College of Engineering, *Journal of Engineering Education,* 95(1), pp. 49-61.

[6] Linden, K. W., Jagacinski, C. M., LeBold, W. K., and Shell, K. D., (1985) Predicting Persistence in Engineering for Undergraduate Women, *Third International girls in science and technology conference.* London: Centre for Science and Mathematics Education.

[7] Hilton, T. L, and Lee, V. E., (1988) Student Interest and Persistence in Science: Changes in the Educational Pipeline in the Last Decade, *The Journal of Higher Education,* 59(5), pp. 510-526.

[8] Ohland, M. W., Zhang, G., Thorndyke, B., and Anderson, T. J., "Grade-Point Average, Changes of Major, and Majors Selected by Students Leaving Engineering," *Proc. 2004 Frontiers in Education Conference*, Savannah, Georgia, November, 2004, paper 1478.

[9] Long, R. A., The Multiple-Institution Database for Investigating Engineering Longitudinal Development. http://engineering.purdue.edu/MIDFIELD/

[10] Richardson, J., and Dantzler, J., (2002). Effect of a Freshman Engineering Program on Retention and Academic Performance. *Proc.2002 Frontiers in Education Conference,*. Boston, MA, October, 2002, S2C, pages 16-22.

[11] U.S. Department of Education (2007). The Integrated Postsecondary Education Data System (IPEDS) glossary. Retrieved December 12, 2007, from http://www.nces.ed.gov/ipeds/glossary/.

[12] Lord, S., Brawner, C., Camacho, M., Layton, R., Long, R. Ohland, M., and Wasburn, M., "Work in Progress: A Study to Investigate the Effect of Climate and Pedagogy on Persistence of Women in Undergraduate Engineering Programs," *Proc. 2008 Frontiers in Education Conference*, Saratoga Springs, NY, October, 2008, 2 pages.

[13] Lord, S., M., Camacho, M., M., Layton, R, Long, R. A., Ohland, M. W., and Wasburn, M. H., "Who's persisting to the eighth semester in engineering? A comparative analysis of female and male Asian, Black, Hispanic, Native American and White students," under review at *Journal of Women and Minorities in Science and Engineering*, Manuscript JWM-323.

[14] Royal, K. and Mamaril, N., (2008). Women and Minorities in Engineering: A Review of the Literature. *Paper presented at the annual meeting of the MWERA Annual Meeting, Westin Great Southern Hotel, Columbus, Ohio.* October 15, 2008.