AC 2011-1382: WOMEN AS THE MINER’S CANARY IN UNDERGRADUATE ENGINEERING EDUCATION

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Women as the Miner’s Canary
in Undergraduate Engineering Education

Abstract

In this paper, we will examine the metaphor of the Miner’s Canary as it relates to undergraduate women majoring in engineering at a large, Midwestern university. Prior to the existence of sensors that can detect dangerous levels of various gases in mines, miners would carry canaries into the mines with them as a warning system for high levels of carbon monoxide. The canary has a more fragile respiratory system than humans; it is more sensitive to change in the quality of air in an environment. When the canary would begin to struggle for breath, the miners took this as a signal that there was a problem with the atmosphere in the mine. Lani Guinier, Gerald Torres and Susan Sturm have posited the idea that the metaphor of the Miner’s Canary is an important metaphor for viewing the behavior of those in underrepresented minority groups in institutions or career fields and encourage faculty and administrators to look at the behavior of underrepresented minority groups within an institution as sensitive indicators to potentially toxic problems. By using minority group behavior as a diagnostic tool for analyzing the reactions of minority groups, faculty and administration can begin to understand the ways in which admissions criteria, pedagogy, curriculum, and institutional environments need to be changed to not only support the needs of the minority groups but make the environment healthier for all. Women are approximately 18% of all undergraduate students in engineering nationally, and 20% of the engineering student body at this large Midwestern university. These percentages have remained relatively flat for the last 10–15 years, despite years of national and international research as to the cause of women’s underrepresentation in engineering, and increasing numbers of programs and activities intended to improve women’s representation in engineering fields. This paper will explore evidence that indicates the collective behavior of women majoring in engineering at this institution could be more sensitive earlier to subsequent correlated institutional change. It appears that women’s responses are stronger to both positive and negative events at an institution. By using the metaphor of the Miner’s Canary in looking at women’s behavior at this institution, this paper seeks to establish that women engineering students’ collective behavior is a leading indicator of important issues that impact all students in engineering education.

Introduction and Literature Review

“The canary is a source of information for all who care about the atmosphere in the mines – and a source of motivation for changing the mines to make them safer. The canary serves both a diagnostic and innovative function.”

Women are approximately 18% of all undergraduate students in engineering nationally, and 20% of the engineering student body at this large Midwestern university. These percentages have remained relatively flat for the last 10–15 years, despite years of national and international research as to the cause of women’s underrepresentation in engineering, and increasing numbers of programs and activities intended to improve women’s representation in engineering fields. As Dr. Anny Morrobel-Sosa implied in her 2005 Campus Women Lead column for the Association
of American Colleges and Universities, it is likely that women are miner’s canaries in the world of engineering.

Lani Guinier, Gerald Torres and Susan Sturm have posited the idea that the metaphor of the Miner’s Canary is an important metaphor for viewing the behavior of those in minority groups in institutions or career fields. These scholars compare the behavior of minority groups in certain environments to the behavior of the canary miner’s used to carry with them as an early warning signal. Since the canary has a more fragile respiratory system than humans, it is more sensitive to change in the quality of air in an environment. When the canary would begin to struggle for breath, the miners took this as a signal that there was a problem with the atmosphere in the mine. Guinier and colleagues encouraged faculty and administrators to look at the behavior of minority groups within an institution as sensitive indicators to potentially toxic problems for the entire student body. By providing programs that provide assistance to the “canaries”, the remainder of the student body benefits in tandem.

In this paper we expand the notion of the Miner’s Canary, we believe that the canary not only is harmed when in toxic situations but also sings more loudly than the majority in response to positive events. We believe that undergraduate women engineering students serve as a Miner’s Canary for retention issues in the undergraduate engineering environment. We use Guinier, Torres and Strum’s “Miner’s Canary” theory that minority group behavior is an important tool as a leading indicator of change to help provide insight for faculty and administrators interested in understanding the ways in which admissions criteria, pedagogy, curriculum, and institutional environments need to be changed to not only support the needs of the minority groups but make the environment healthier for all.

Moore, Brown & Scarupa reported that indicators are often underutilized in “the broader social policy arena” despite their widespread acceptance in so many other fields. Yet these indicators can provide valuable information to policy makers on the macro, meso, and micro levels. Moore, Brown, and Scarupa asserted that indicators can provide valuable information in the form of: “description, monitoring, goal setting, increasing accountability, and reflective practice” when they are used appropriately. As Moore, Brown, and Scarupa indicated in their report, while correlations may be established, indicators do not provide evidence for cause and effect. Understanding which factors are leading indicators of change helps inform those in program and policy making positions.

We use retention data from the last 9 years to chronicle the trends in undergraduate engineering retention at this large Midwestern university. We wish to understand if the retention behavior of undergraduate women engineering students could potentially provide insight into the health of the undergraduate engineering environment. By exploring these trends and the difference between the group retention rates of men and women we seek to establish that women engineering students’ collective behavior is a leading indicator of the undergraduate engineering programs “health” and a diagnostic tool for understanding the success of the undergraduate engineering program, where success is defined as undergraduate student retention. The data we supply indicates that first-year women engineering students appear to be leading indicators of change within the undergraduate engineering environment.
**Research Question**

Do women undergraduate engineering students function as the miner’s canary: How do the retention rates of first-year and second-year men and women undergraduate engineering students’ compare? If the rates are different, is it possible to look at trends in women’s retention rates as a more sensitive barometer to institutional factors impacting student success in the form of retention?

**Methodology**

For the purposes of this study, we have chosen to evaluate retention rates based on cohort start year. Holloway, Reed-Rhoads, and Groll present a more in-depth discussion of three retention frameworks: cohort start year, official classification, and enrollment in specific courses; we have chosen cohort start year to minimize differences in institutional effects on the data within each cohort.

The cohort each year is defined as the first-time, full-time freshmen officially enrolled for the fall semester in the College of Engineering. A student is considered retained for a year if s/he is still enrolled in the College of Engineering in subsequent fall semesters at the time of the census (typically 21 days into the fall semester). For example, the number of first-year students still enrolled at the time of the census of the second year would measure first year retention, and the number of second year students still enrolled at the time of the census of the third year would measure second year retention.

The data consisted of 10 cohorts entering the university between 2000 and 2009. The number of men in the entering class sized ranged from 1255 to 1464. The number of women in the entering class sized ranged from 261 to 375 with the percentage of women in the cohorts ranging from 15.1% to 22.2%.

The data are graphically represented in several ways. The retention rates of first and second year men and women can be plotted against cohort start year. This type of graph is intended to give an overview of how retention rates differ by cohort year and by sex. Note that this type of representation indicates both institutional effect on retention and differences of the individuals in the cohort. These effects cannot be separated at this time.

Another useful analysis is the gap in retention rates, where gap is defined to be the difference in two particular retention rates for a specific cohort year. For example, the gap in first year retention rates between women and men is the gap between women’s first year and second year retention rates, and gap between men’s first year and second year retention rates. In this way, we try to minimize the year to year differences in cohorts. This type of representation may indicate positive or negative institutional effects on retention.

A third representation of retention rate is the change in retention from cohort to cohort. For example, the difference in first year retention between a particular cohort start year and the one...
immediately preceding it is the change in retention rate, and has both a magnitude and direction. This type of representation may indicate institutional trends in retention rate, but is confounded by differences in the individuals that make up each cohort.

Results and Discussion

First and second year retention rates of men and women for cohort years 2000 to 2009 are plotted in Figure 1. In general, the retention rates are between 74% and 87%. For the last 4 years, the first year retention rates for both men and women have been increasing. At the same time, the second year retention rates for both men and women have been decreasing (except for women in the 2008 cohort, the most recent data available). In comparing men’s and women’s retention rates, we find that the correlation coefficient between the first-year men and the first-year women is 0.280, while the correlation coefficient between the second-year men and the second-year women is 0.858. However when we look at women as a leading indicator, the correlation between the cohort of first-year women and the following year’s cohort of first-year men yields a correlation of 0.762. Making the same comparison between the male and female sophomore cohorts, yields a correlation coefficient of 0.183. In comparing first and second year retention rates, we find that the correlation coefficient between first-year women and second-year women is 0.378, and the correlation coefficient between first-year men and second-year men is 0.050. Table 1 and 2 below presents these correlations coefficients.

![Figure 1. Cohort Retention Rates for 2000 - 2009](image-url)
Table 1. Correlations of Men’s and Women’s Retention Rates

<table>
<thead>
<tr>
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<th>1st Year Men</th>
<th>2nd Year Men</th>
<th>1st Year Women</th>
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<td>0.858</td>
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*NM = No Meaning

Table 2. Correlations of Offset Men’s and Women’s Retention Rates

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<thead>
<tr>
<th></th>
<th>1st Year Men</th>
<th>2nd Year Men</th>
<th>1st Year Women</th>
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<tr>
<td>2000 to 2008 1st Year Women</td>
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<tr>
<td>2000 to 2007 2nd Year Women</td>
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<td>0.183</td>
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*NM = No Meaning

These correlation results potentially indicate a number of issues. Our first observation is that the retention rates of first-year men do not correlate well with either first-year women or second-year men. However, when we use first-year women as a leading indicator, the correlation between the cohort of first-year women and the following year’s cohort of first-year men is strong (0.762). This suggests that first-year women are indeed a leading indicator for first-year retention rates in engineering. At the same time, while second-year women in the same cohort year have a strong correlation, the same is not true when the two groups are offset by one year. Sophomore women do not appear to be leading indicators of retention. These data indicate that in looking specifically at first-year women’s retention rates, insights gleaned from that data may be able to be used to make conclusions that are applicable to the whole population. Given the hypothesis that women are the miner’s canary in undergraduate engineering education, this is a particularly important point.

Figure 2 presents the gap in first- and second-year retention rates between women and men, where a positive gap indicates that women’s retention rates are higher. Note that the gap in first-year retention rates from cohort years 2006 – 2009 are all less than 1 percentage point. Interestingly, this corresponds to the timeframe in which significant curricular changes were made in the first-year engineering program. Given that over these years, the first-year retention rate is generally increasing, this data indicates that what is a positive influence on women’s retention is also a positive influence on men’s retention, at least within the first-year of undergraduate studies. Stated another way, what has worked to increase retention among the women has worked for the men. The second-year retention rate gaps in that same timeframe were larger, though still under about 2 percentage points. No notable changes were made to the second-year curriculum; however, it is in this timeframe that the College of Engineering as a whole began to track and communicate retention rates among all of the engineering disciplines.
Figure 3 presents the gap in women’s and men’s retention rates between the first and second years, where a positive gap indicates that second-year retention rates are higher. Note that the second-year retention rate is higher than the first-year retention rate in cohort years 2001 – 2006, which fits with traditional wisdom that the greatest number of engineering students will leave in the first year, and less will leave in the second year and beyond. However, in cohort years 2007 and 2008, the second year retention rate is less than the first year retention rate, meaning that more students left the second year than the first. The average gap over those two years is greater for women. Over this same time period, first-year retention rates are increasing (see Figure 1). Obviously this is an observational study and cause and effect cannot be established. However, correlations can be discussed. Normal variation with a few percentage points are to be expected. It is when the changes appear to be trending that the indicator becomes important. One major change over this time period was a curricular change in the first year program, outside of the scope of this paper, where efforts were made to change the message of engineering and to create a gender neutral learning environment in a new facility that focuses pedagogically on active and collaborative hands-on engineering design. Perhaps similar changes in the second year curriculum would yield similarly positive results.
The magnitude and direction of the changes in retention rates for men and women comparing one cohort year to the one immediately preceding it are shown in Figures 4 (second-year retention rate changes) and Figure 5 (first-year retention rate changes). In comparing the magnitude and directional changes in retention rates for men and women, we consider higher magnitudes of change and changes in direction as potential leading indicators of change. Figure 4 shows, for example, changes in the direction of second-year retention rates for women in cohort years 2002 (negative), 2005 (positive), 2006 (negative), and 2008 (positive). These changes in direction can also be seen as positive or negative slope changes in the graph in Figure 1. Note that these directional changes occur for women either the same year or one year preceding the directional changes for men. If the directional change for women occurs in the same year as the men, the magnitude of the change is higher than that of the men. Additionally, for both first- and second-year retention, the magnitude of the change from year to year is generally higher for women than it is for men. This indicates that women are more sensitive to both positive and negative institutional events/changes that affect retention rates making them lead indicators of change. Additionally, these graphs show that women’s behavior vis-à-vis retention also appears to be a leading indicator of the change of direction of the retention trends. In these two ways, greater sensitivity to institutional events/changes and early indications of changing trends, undergraduate women in engineering function as the canary in the mine for the first year of the undergraduate engineering environment.
Figure 4. Change in Second Year Retention Rate from Previous Cohort Year

Figure 5. Change in First Year Retention Rate from Previous Cohort Year
Knowing that women function as leading indicators for retention in the College of Engineering has implications for those in key positions to make policy, programmatic and curricular changes, and provides further evidence that what has a positive effect on women has a positive effect on everyone. These persons would include instructional personnel, faculty, staff, and administrators.

**Future Research**

Future research will be looking particularly at retention in the sophomore year. Given that first year retention rates have been increasing in recent years, there is a growing concern about the gap between first and second year retention rates. This does follow a national trend to study what has been coined as the "Sophomore Slump" at the institutional level. However, very little is known or understood about the nuances of second year retention in a professional field such as engineering\textsuperscript{10}.

**References**