

## **Monolith or Mosaic: Using Demographics and Detailed Surveys to Understand the Many and Varied Dimensions of First-Year Female Engineering Students**

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### Abstract

The observation of substantially different retention rates of men versus women in a required first-year, two-course “Introduction to Engineering Systems” sequence at the University of Notre Dame motivated an examination of demographic and survey data to assess retention patterns. In the course of examining these data, it became evident that different sub-groups of women exhibit different retention patterns.

We have used demographic data such as SAT scores and intended major for several years to establish baseline characteristics of first-year engineering students. We have used results-oriented data such as exam scores and GPAs to establish how well students or groups of students perform in the class. More recently, a series of three surveys conducted during the two-course sequence has provided a wealth of information that further informs the significance of the demographic and results-oriented data. Longitudinal comparison of the data also helps to identify key differences from one year to another.

As an example of the utility of these data sources for improving retention, we consider the retention of women within the first-year engineering sequence. By reviewing the original student applications for admission to Notre Dame, we observed that women who identified engineering as an intended major were retained at a rate that closely resembled the retention rate of men, while women who indicated a non-engineering major but nevertheless enrolled in the two-course sequence were historically retained at a significantly lower rate. Yet, in examining results-oriented data such as standardized test scores or course grades, we observed no significant difference between engineering intents and non-engineering intents. These observations led to the conclusion that, because the two groups possess similar entry-level skills and perform similarly well in class, other, less tangible factors impact retention. Adding the three in-class surveys has allowed us to identify a number of areas of statistically significant differences between these two groups, including: their motivations for considering the study of engineering; their pre-college engineering-related experiences; their initial post-graduate plans; and their concerns over roadblocks to completing the engineering degree.

In developing and assessing retention efforts, these data help us to go beyond simply counting

how many students remain in engineering after the first year, to understand which types of students remain and why. These data have affected our approach to increasing the retention of women, as the data have helped us both to identify certain sub-groups of women as at higher risk for leaving engineering and to better understand the composition of each class of female engineering students. In particular, these data have enabled us to increase significantly the rate of retention of those women who had not indicated engineering as their intended major on their application for admission to Notre Dame.

## Introduction

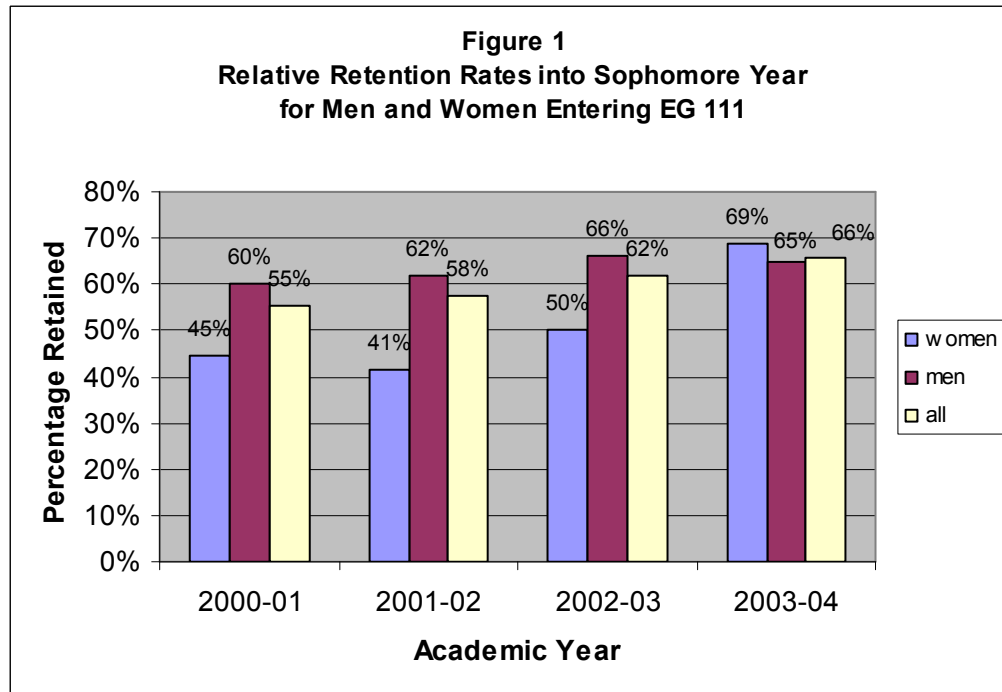
In the 2000-01 academic year, the College of Engineering at the University of Notre Dame introduced a new two-semester, six-credit-hour Introduction to Engineering Systems course sequence (EG 111/112), described in Brockman *et al.*<sup>1</sup> The course, which consisted of four team-oriented projects, moved the introductory engineering course from a faculty-centered teaching paradigm to a student-centered learning paradigm, and radically changed the way that Notre Dame prepared first-year students to begin discipline-specific engineering studies in the sophomore year. Consequently, the College placed significant emphasis on assessing course effectiveness.

In the first three administrations of the course, in academic years 2000-01, 2001-02 and 2002-03, women exhibited noticeably lower retention rates than men. Table 1 provides the numbers of men and women enrolled at the beginning of EG 111 each year.

**Table 1**  
**Beginning EG 111 Enrollments**  
**(Fall 2000 through Fall 2003)**

	Women	Men
Fall 2000	112 (30.4%)	257
Fall 2001	76 (21.2%)	283
Fall 2002	94 (25.6%)	260
Fall 2003	83 (22.7%)	283

As shown in Figure 1 and described in Pieronek, *et al.*,<sup>2</sup> retention rates for women in the first three administrations of the course ranged from 41 to 50 percent, while retention rates for men ranged from 60 to 66 percent.



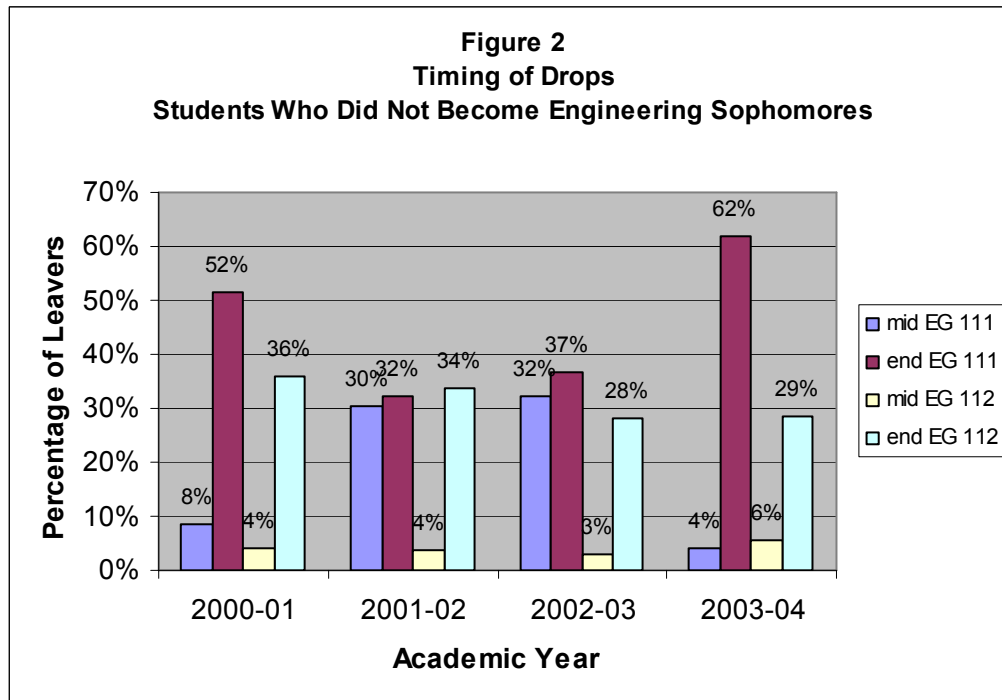
Initial attempts to understand the factors that affect the retention of women consisted of three interrelated activities that focused on the differences between men and women. We looked at information gleaned from EG 111/112 assessment surveys administered to students at the beginning of the first semester (EG 111 entry survey) and at the end of the second semester (EG 112 exit survey). We tracked the timing of drops through the first semester and asked the students, either in-person or by e-mail, why they chose to drop EG 111 or EG 112. We also reviewed student demographic information to determine whether anything in a student's academic history or current academic performance could predict persistence in EG 111/112. While each of these efforts helped us to understand how female students differed from male students, each also raised some questions that the data could not answer.

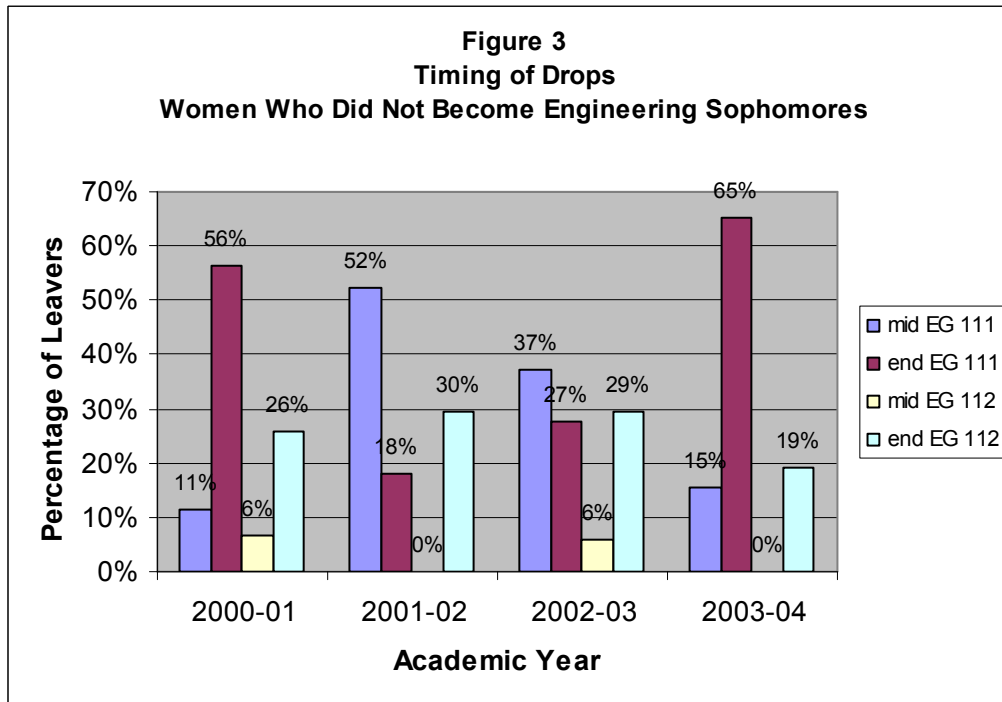
#### Initial Retention Assessment Efforts

The EG 111 entry survey, administered within the first two weeks of the fall semester, gives students the opportunity to tell us about their engineering-related skills and about their interest in engineering. The survey pointed out differences between women and men in areas of skills self-assessment, motivations for studying engineering and prior engineering-related experiences (Pieronek *et al.*<sup>2</sup>). Nevertheless, we questioned how strongly we should rely on these subjective self-assessments when evaluating whether and how to modify course content.

The EG 112 exit survey, administered approximately two weeks before the end of the second semester, gives students the opportunity to assess both how well the two-course sequence met our defined educational objectives, and how well their engineering-related skills developed

during the semester. In terms of understanding retention, however, this survey provides little useful information because most of the students who leave engineering do so without completing the two-course sequence. As Figures 2 and 3 illustrate, more than 60 percent of all students and more than 70 percent of women who ultimately leave engineering do so before completing EG 112. Thus, the EG 112 exit survey does not capture information about the majority of those students who opted out of engineering during the first year.

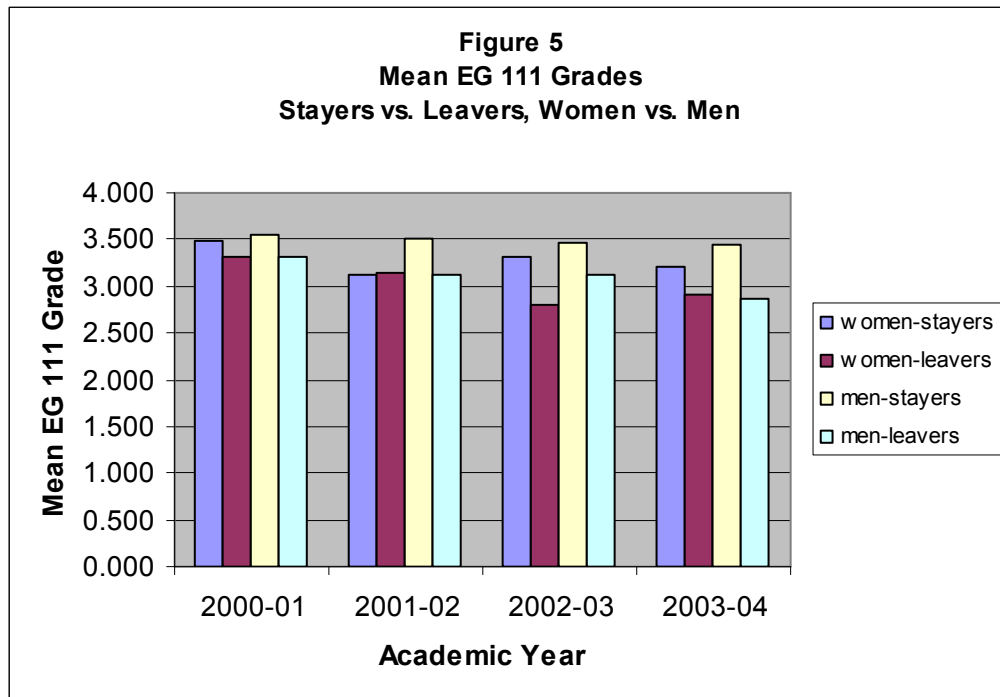
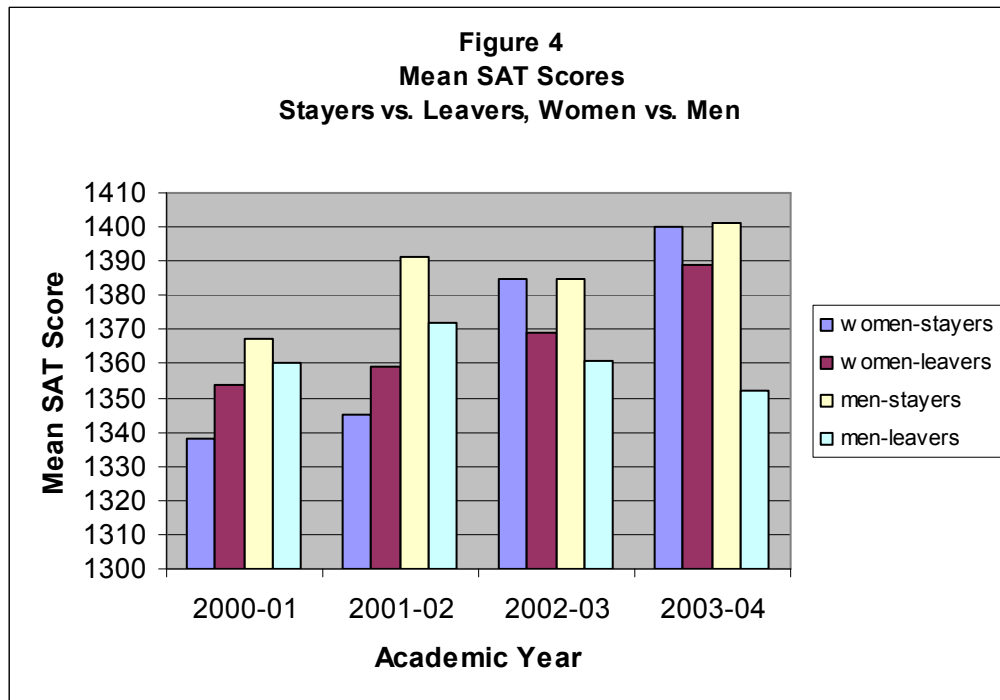




By tracking student drops on a weekly basis, we noticed that two-thirds of first-semester drops occurred in the month of October, which, through the 2002-03 academic year, coincided with the introduction of computer programming into the course. Yet, we had no data to indicate whether the drops occurred because of the course content or because of other factors. Thus, we attempted to interview the students either in person or by e-mail to shed light on their reasons for dropping the course. Unfortunately, this effort proved less-than-enlightening, because students responded with very general statements such as: “I don’t like engineering.” “Engineering isn’t for me.” “I can’t see myself sitting behind a computer for the rest of my life.” “I tried engineering because my mom/dad/advisor recommended it even though it wasn’t what I wanted to do.” We did, however, develop a general sense that female students felt somewhat isolated and that they believed (whether or not the belief was objectively accurate) that male students had an easier time forming study groups with other men in their gender-segregated residence halls at Notre Dame. Informal conversations with upper-class women confirmed this sense.

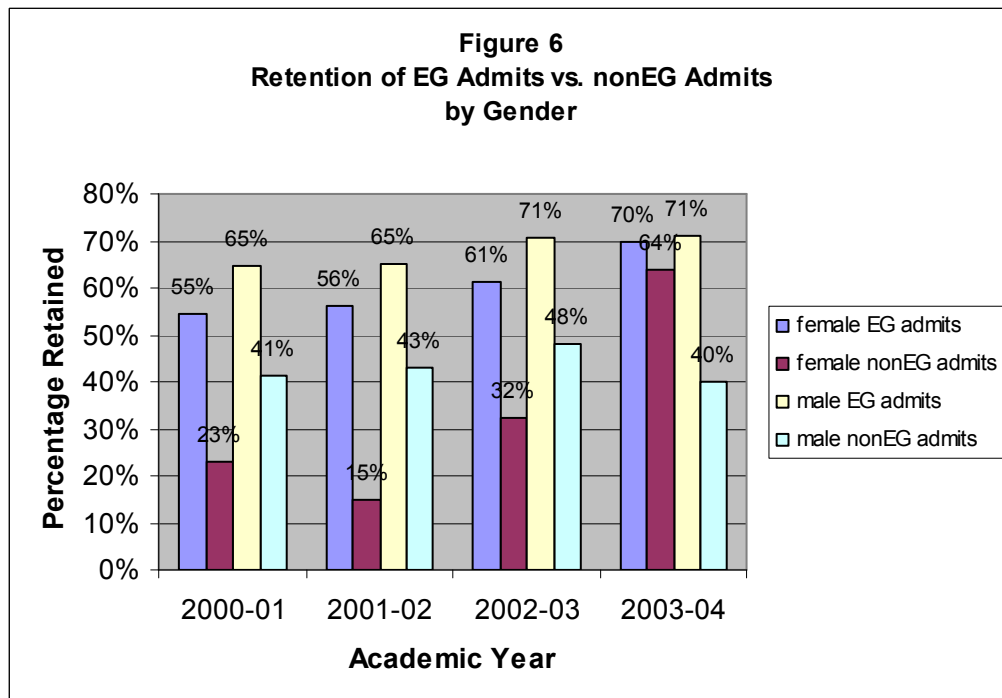
Finally, we reviewed demographic data such as academic history, as measured by SAT scores, and current academic performance, as measured by EG 111 course grades, but could not identify any factors that definitively correlated with persistence. As shown in Figures 4 and 5, while male leavers (those who left engineering prior to the start of sophomore year) and stayers (those who began sophomore year in engineering) followed a predictable pattern in that those who left engineering had lower mean SAT scores and EG 111 grades, female leavers and stayers did not follow a similarly consistent pattern. In fact, female leavers had higher mean SAT scores than female stayers in two of the four years studied, and had higher mean EG 111 grades in one of the years studied. While this analysis identified an interesting difference between women and men,

it pointed out that we needed a better understanding of the factors that influence the retention of women as distinct from the factors that influence the retention of men.



Even if we had seen a consistent pattern of higher-scoring or higher-performing students staying and lower-scoring or lower-performing students leaving, however, we still would have questioned the utility of these particular demographic and performance data to predict retention. With regard to SAT scores, even the College Board<sup>3</sup> acknowledges that SAT scores do not correlate well with academic performance. With regard to using EG 111 course grades, three problems exist: first, women do not exhibit consistent behavior with regard to course grades and dropping engineering; second, this particular parameter fails to capture class performance information about those who left prior to completing EG 111; and third, the data do not indicate whether a student dropped the course because of a low grade, or whether a student earned a low grade as a result of slacking off toward the end of the semester after the student had already decided not to continue in engineering.

We have, however, identified one additional demographic indicator that has provided some clues regarding factors that influence retention. As reported in Pieronek *et al.*<sup>4</sup> and shown in Figure 6, a student's "intended major" on the application for admission to Notre Dame has historically correlated with retention into the sophomore year. Students who selected an engineering major on their application (EG admits) exhibit higher retention rates than those who selected a non-engineering major but who nevertheless enrolled in EG 111/112 (nonEG admits). The retention rate of female EG admits has historically varied from 55 to 61 percent, close to the male EG admit retention rate of 65 to 71 percent. On the other hand, from 2000-01 through 2002-03, the retention rate of female nonEG admits varied from 15 to 32 percent, much lower than the retention rate of female EG admits (55 to 61 percent) and male nonEG admits (40 to 48 percent).



## Actions Taken in Response to Data

As described in Pieronek *et al.*,<sup>4</sup> this information led to several changes to the first-year engineering experience beginning in the 2003-04 academic year to improve the retention of women through the first year and into sophomore year:

- First, as described in Pieronek *et al.*<sup>4</sup> and McWilliams *et al.*,<sup>5</sup> based on the timing of course drops during the first semester, the in-person and e-mail interviews, and the information on skills self-assessment gathered in the EG 111 entry survey, the EG 111/112 course director reorganized the course to move the apparently daunting and confidence-challenging computer-programming exercises into the second semester. This has given students more time to adjust to the many new challenges they face in the first semester of college life before tackling this demanding aspect of the first-year engineering curriculum. It has also pushed back the time at which most students, including women, drop engineering. While 70 percent of the total number of drops still occurs before the end of EG 112, nearly all who eventually leave have now completed at least EG 111 (Figures 2 and 3).
- Second, the EG 111/112 course director added two lectures at the beginning of EG 111 to discuss the relevance of engineering to society. These lectures focused on inspiring some of those students unsure of their initial commitment to engineering by discussing some of the more interesting engineering challenges we face.
- Third, as described in Pieronek *et al.*,<sup>4</sup> the University's Office of Residence Life agreed to house first-year female students enrolled in EG 111 (both EG and nonEG admits) in fewer than half of the women's residence halls on campus, thereby doubling the concentration of female engineering students in those halls to help them to form a stronger community for the purpose of studying and mutual support.

Since making these substantive changes, we have seen an improvement in the retention of women. As shown in Figure 1, the overall retention rate of women into the sophomore year for the class entering in 2003-04 (Class of 2007) improved over the Class of 2006 from 50 to 69 percent, and actually exceeded the 65 percent retention rate for men. Furthermore, because of the significantly low retention rate for female nonEG admits observed in prior years, we also reviewed whether these changes impacted the retention of that group. As shown in Figure 6, while the retention rate of female EG admits increased from 61 to 70 percent, we saw an even more impressive change in the retention rate of female nonEG admits, from 32 to 64 percent.

Additionally, two changes to our survey mechanisms have provided greater insight into the differences between female EG and nonEG admits, and female leavers and stayers. The first change involved a modification to the EG 111 entry survey for the Class of 2007 in an effort to identify whether and how these groups differed. The modified survey asked students to select their first and second reasons for studying engineering from a list of five options:



- (1) Important people in my life expect me to study engineering;
- (2) Engineering will make the best use of my skills, interest and abilities;
- (3) Engineering will lead to a high-status career;
- (4) Engineering will best enable me to serve my community and help others; and
- (5) Entering college as an engineer leaves my future study options open.

Overall, 54 percent of all women selected (2) as their first choice, and 26 percent selected (4) for their second choice. But looking at female EG and nonEG admits, as well as at female leavers and stayers, points out some interesting differences in these groups:

- For their first choice, 59 percent of female EG admits selected (2), while 22 percent selected (5). For female nonEG admits, the percentages reversed: 59 percent selected (5), while 32 percent selected (2).
- For their second choice, 29 percent of female EG admits selected (4), while 32 percent of female nonEG admits selected (2).
- For their first choice, 61 percent of female stayers selected (2), while 25 percent selected (5). For female leavers, 39 percent selected (5), while 33 percent selected (2).
- For their second choice, 29 percent of female stayers selected (4), while 28 percent of female leavers selected (2) and (3) each.

These results indicate that EG admits and eventual stayers select engineering because it fits with their academic skills, interests and abilities, but also recognize that it provides them with maximum flexibility in their eventual choice of a major. On the other hand, nonEG admits and eventual leavers select engineering primarily because it provides maximum flexibility in their eventual choice of a major, even though, based on their second-choice answers, these women likely also have the skills needed to succeed in engineering. Thus, we know that a segment of the female engineering population may be capable of studying engineering but initially exhibits a lower level of commitment to the program.

The modified EG 111 entry survey also asked students whether they strongly agreed, agreed, disagreed or strongly disagreed with, or were neutral towards, the statement “I expect to complete my engineering degree.” Overall, 71 percent of female students indicated that they agreed or strongly agreed with the statement, but the survey did reveal significant differences between EG and nonEG admits, and between stayers and leavers, as shown in Table 2:

**Table 2**  
**Responses to “I Expect to Complete My Engineering Degree”**  
**Female EG vs. nonEG Admits; Female Stayers vs. Leavers**

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Female EG Admits	36%	42%	17%	5%	0%
Female nonEG Admits	14%	36%	45%	5%	0%
Female Stayers	36%	47%	17%	0%	0%
Female Leavers	17%	17%	50%	17%	0%

Thus, near the beginning of EG 111, female EG admits and female stayers have a higher level of confidence than female nonEG admits and female leavers that they will persist in engineering. Most interestingly, two-thirds of those who ultimately leave selected either “neutral” or “disagree” in response to the statement. Adding this question to the survey has, thus, provided some insight into how the female students themselves view their potential for persistence in engineering.

The second change to the survey mechanisms involved adding a third survey at the end of the first semester, the EG 111 exit survey, to capture the attitudes of students who had decided to leave at some point before completing EG 112 (McWilliams *et al.*<sup>6</sup>). This survey shares one flaw with the use of grades to predict retention in that it fails to capture information on those students who leave in the middle of the first semester, but it has provided another level of data that gives some insight into the differences between EG admits and nonEG admits, as well as between leavers and stayers, regarding their attitudes toward engineering. We have used this survey and standard statistical methods to identify statistically significant differences (significance level  $\leq 0.1$ ) for female leavers and stayers in the following areas:

- Stayers, to a greater extent than leavers, cited positive experiences in EG 111, mathematics and chemistry as very or somewhat important factors in their decision to remain in engineering.
- Leavers, to a greater extent than stayers, frequently or occasionally felt intimidated by the engineering environment and felt less confident expressing their ideas in the learning environment.
- Even before the formal introduction of programming, which now occurs in EG 112, stayers indicated that they had more hands-on experiences with computer programming, and to a greater extent than leavers rated themselves good or very good at programming in the two languages used in the class.

Thus, the mid-year EG 111 exit survey points out other differences between leavers and stayers. Some of those differences involve how they perceive their experiences in key foundational classes, while other differences involve their own self-confidence.

### Understanding the Results

The dramatic shift in retention patterns for women from 2002-03 to 2003-04, prompted further investigation into whether the women in the Class of 2006 and the Class of 2007 differed in any objective ways or in any statistically significant ways gleaned from the EG 111 entry survey. We noted the following objective differences:

- Female nonEG admits comprised a larger proportion of the female population of the Class of 2006 (39 percent) compared to the nonEG admits among the female population of the Class of 2007 (27 percent).
- The Class of 2007 had a higher mean SAT score (1397) than the Class of 2006 (1377).
- The Class of 2007 had a lower mean EG 111 grade (3.118) than the Class of 2007 (3.164).

The EG 111 entry survey also identified several statistically significant differences (significance level  $\leq 0.1$ ) between the two groups of women

- In deciding to major in engineering, the women in the Class of 2007 relied on their parents' advice to a greater extent than the women in the Class of 2006.
- The women in the Class of 2007 were less likely to have an engineer in their immediate family than the women in the Class of 2006, yet, the women in the Class of 2007 had more confidence in their knowledge about engineering than the women in the Class of 2006.
- The women in the Class of 2007 indicated that they had more engineering-related experience and more experience with computers than the women in the Class of 2006, citing more frequent involvement in activities such as dismantling and repairing small appliances, installing computer software, gleaning information from Internet sources and purchasing products on the Internet.
- The women in the Class of 2007 expressed less concern about whether engineering would consume too much time.

Thus, some differences do exist between the women in the Classes of 2006 and 2007, but we do not yet understand the implications, if any, of these differences. Some differences might indicate that members of the Class of 2007 would be more likely to persist in engineering, while others

might indicate the opposite. Because of this conflicting data, we have concluded that the improved retention rate of women in the Class of 2007 has resulted, to a large degree, from the changes we made to the course structure and to the support system for female engineering students. We consider impacts from differences in the student pool to be secondary, but continue to study these issues.

## Conclusion

Knowledge of the differences among groups of female engineering students has proven crucial to our ability to improve the retention of women in the College of Engineering at the University of Notre Dame. While initial retention efforts focused on understanding how women differed from men, our new approach, arrived at through identifying the subgroups of female EG and nonEG admits, focuses on understanding how various groups of female students differ from each other. We now have data that describes our female students not as a one-dimensional monolith, but as a mosaic – a whole made of many different parts who come to Notre Dame with different experiences and different levels of interest in engineering. We have adapted our support systems to reflect these differences, and have made course changes that work to bridge the differences among the groups and, consequently, have seen a dramatic improvement in the retention of women.

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