The Value of a Comprehensive, Integrated Assessment Program for Improving the First-Year Engineering Experience

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Abstract – The College of Engineering at the University of Notre Dame recently completed the fifth year of its first-year Introduction to Engineering course. Each year, the College assesses the quality of the learning experience using various assessment methods including student surveys, student and faculty interviews, student demographic information, student performance in the course and retention rate into the sophomore year. This combination of assessment methods has allowed the College to direct its efforts toward those areas that appear to have the greatest potential for improvement. Our assessment/course improvement cycle has demonstrated the value of an integrated approach to assessing course effectiveness and student progress toward learning outcomes. We have implemented several modifications to the course that have had a positive impact on the retention of all students and, particularly, on the retention of women. The information has also helped us to identify cultural and systemic issues at the University, outside of the course, that affect the retention of engineering students, particularly women, and have enabled us to effect changes at the University level to address those issues. The information has also led us to characterize the types of students at risk for leaving engineering early, allowing the College to engage in proactive efforts to improve the delivery of information to these groups of students. Any single element of this integrated assessment effort might have provided tantalizing clues for necessary changes. But the value of a comprehensive, integrated assessment program lies in the fact that the College can target changes to an identified need, thus achieving positive results.

Index Terms – Assessment, first-year engineering, retention, women.

INTRODUCTION

In the 2000-01 academic year, the College of Engineering at the University of Notre Dame initiated its new Introduction to Engineering two-course sequence (EG 111/112). The course dramatically changed the way in which the College prepared first-year engineering intents for the sophomore-year, major-specific curriculum. As described in [1], the shift from a one-semester, three-credit-hour course, which taught basic engineering skills but focused on computer programming methods, to a two-semester, six-credit-hour course, which engaged students in learning the engineering process, initiated a new way of educating engineers at Notre Dame. The novelty of the course design, coupled with an increased emphasis on outcome assessment in, for example, the ABET accreditation process, prompted efforts directed at evaluating how well students met the course objectives as described in [1].

Initial assessment efforts consisted of an entry survey given at the beginning of the fall semester course (EG 111 entry survey), and an exit survey given at the end of the spring semester (EG 112 exit survey), along with an evaluation of the retention rate of students who began EG 111 and ultimately matriculated into the College of Engineering as sophomores. As a result of these efforts, we knew how many students and what type of students (in terms of demographics and academic performance in the course) started EG 111 and continued on in engineering as sophomores. We also learned how those who completed EG 112 felt about the two-course sequence. We did not, however, know how those who did not complete EG 112 (first-semester leavers) felt about the course. More importantly, we did not know why most leavers left engineering, because first-semester leavers (who did not participate in the EG 112 exit survey) comprised two-thirds of all leavers.

In the third and fourth years of the course (2002-03 and 2003-04), we undertook a comprehensive effort to use a variety of information-gathering and assessment methods to answer several questions:

• Why did leavers leave?
• When did leavers leave?
• Why did women exhibit a significantly lower retention rate into the sophomore year (~40%) than men (~60%)?
• Could we identify any other subgroups of students that exhibited noticeably different retention rates?
• Could we identify any significant differences among first-semester leavers, those who left engineering after completing EG 112 (second-semester leavers), and stayers?
To answer these questions, over the next two academic years, we added a third in-class survey (EG 111 exit survey), interviewed leavers, tracked leavers on a weekly basis and analyzed the various demographic characteristics of leavers and stayers. With this information, beginning in 2003-04, we made some changes to EG 111/112 and to campus housing [4][6], and continued our assessment efforts to determine whether we had accurately identified factors that negatively affected retention.

It is important to note that, although we made changes to the course, none of those changes moved the course away from its original objectives set out in [1]. We altered only the timing and method of delivery of certain elements of the course and maintained the academic integrity of the course, but we also improved retention rates among certain identified subgroups of students, most noticeably, women.

This paper describes the assessment methods we used and the actions we took in response to the information gathered. It also briefly presents some of the results of our efforts, which we have presented in more detail in other articles [2]-[8], to illustrate the value of our comprehensive, integrated approach to assessment. Through this methodology, we have identified four key benefits to our approach:

- We can make changes to the course in a timely manner. In some cases, we can make changes in real-time, to address issues identified during a particular administration of the course. In most cases, we can make changes for the very next administration of the course.
- We can develop a factual basis for making particular changes, supported by data gathered during the assessment effort and validated by data gathered during the subsequent administration of the course.
- We can identify non-obvious at-risk student populations.
- We can improve retention among at-risk student populations.

Note that, throughout this paper, 2004-05 data reflect results through mid-May 2005. Note also that we recognize that other sources, such as [9] and [10], have carefully explored the reasons why students, in general leave engineering. While Notre Dame students express similar reasons for leaving, our assessment approach has helped us to identify specific aspects of our program and of University culture that have an impact on the retention of our engineering students. It has helped us to identify those factors unique to our program that negatively affect retention. Furthermore, this paper focuses on how we developed this assessment process, rather than on the results of that process.

**EG 111/112 IN-CLASS SURVEYS**

Initial EG 111/112 assessment efforts consisted of two multiple-choice surveys, administered at the beginning and end of the two-course sequence. The EG 111 entry survey captured some information about the students themselves including: their motivations for taking EG 111; their expectations of the first-year experience; their goals; their self-assessment of technical and “soft” skills such as communication and writing abilities; their existing knowledge of engineering; and their prior involvement in engineering and science activities (working on a car, dismantling a small appliance, participating in a science fair, etc.). The EG 112 exit survey did capture some information on the factors the students considered important when selecting a major for the sophomore year (whether or not in engineering), but actually focused primarily on the course itself, asking students to evaluate the course structure and course materials, whether and how the course enhanced their skills in a number of areas, how the students participated in their project groups and what they learned from each of the four projects over the two semesters.

As a result of these surveys, we learned what worked and what did not work in the course itself, but only from those students who actually completed EG 112. And, as Tables I and II show, more than half of those who left engineering prior to the sophomore year actually left prior to completing EG 112, and in most years with higher percentages of women leaving earlier, as explained in [6]. Thus, we did not capture information about the course from the majority of those who apparently did not like engineering well enough to stay all the way through the two-course sequence.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>NO. OF LEAVERS / ENROLLMENT</th>
<th>NO. OF LEAVERS BEFORE END OF EG 112</th>
<th>PERCENT OF LEAVERS WHO LEFT BEFORE END OF EG 112</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-01</td>
<td>165 / 369</td>
<td>106</td>
<td>64%</td>
</tr>
<tr>
<td>2001-02</td>
<td>155 / 359</td>
<td>103</td>
<td>66%</td>
</tr>
<tr>
<td>2002-03</td>
<td>164 / 354</td>
<td>118</td>
<td>72%</td>
</tr>
<tr>
<td>2003-04</td>
<td>126 / 366</td>
<td>90</td>
<td>71%</td>
</tr>
<tr>
<td>2004-05</td>
<td>103 / 376</td>
<td>69</td>
<td>67%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>YEAR</th>
<th>NO. OF LEAVERS / ENROLLMENT</th>
<th>NO. OF LEAVERS BEFORE END OF EG 112</th>
<th>PERCENT OF LEAVERS WHO LEFT BEFORE END OF EG 112</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-01</td>
<td>62 / 112</td>
<td>46</td>
<td>74%</td>
</tr>
<tr>
<td>2001-02</td>
<td>44 / 76</td>
<td>31</td>
<td>70%</td>
</tr>
<tr>
<td>2002-03</td>
<td>51 / 94</td>
<td>36</td>
<td>71%</td>
</tr>
<tr>
<td>2003-04</td>
<td>26 / 83</td>
<td>21</td>
<td>81%</td>
</tr>
<tr>
<td>2004-05</td>
<td>28 / 96</td>
<td>18</td>
<td>64%</td>
</tr>
</tbody>
</table>

Beginning in 2003-04, we added a third in-class survey, the EG 111 exit survey, to capture information from those who left engineering before the end of EG 112. This survey comprised a hybrid of the other two surveys, capturing some information about the students themselves, but also gathering data on how well the first two projects met course objectives. While this survey still missed those who dropped during EG
111, those students comprised a very small segment of leavers in 2003-04 (~4%) and 2004-05 (~5%).

From this mid-year survey, stayers and second-semester leavers differed in only one statistically significant respect (significance level < 0.1) in that the latter group felt more “overwhelmed by the intelligence of fellow students,” as explained in [7]. However, first-semester leavers differed from second-semester leavers and stayers in several significant respects including those reported in [7]:

• First-semester leavers expressed more negative feelings about EG 111, including feeling “overwhelmed by the intelligence of fellow students” and “intimidated by the engineering environment.”
• First-semester leavers reported a lower rate of developing relationships with new people during the course.
• First-semester leavers were less likely to take a leadership role in group activities in the course.
• First-semester leavers were less likely to enter calculations into a calculator or programs into a computer.

We also developed a general sense that first-semester leavers dropped engineering because of their low self-confidence in their ability to handle the material, while second-semester leavers had more confidence in their abilities, but simply didn’t find engineering satisfying. We had originally thought that the first semester should concentrate on developing interest in engineering, while the second semester should concentrate on developing skills, but these survey data indicate the exact opposite is true. To retain more students through to completion of EG 111/112, we need to focus on skills-building in the fall and interest-building in the spring. Thus, we identified a change to the course that has affected the delivery of course content.

These surveys also help us to identify the effects of course changes from year to year. For example, we saw a dramatic increase in the retention of women between 2002-03 (~50%) and 2003-04 (~69%), and needed to know whether jump resulted from changes to the class or whether it occurred because the women in the two classes differed in significant respects. We used the EG 111 entry survey to compare the self-assessments of the two groups. We did notice some significant differences (significance level ≤ 0.1) between the two groups as reported in [6]. These differences include the fact that women who took the class in 2003-04 were more likely to rely on advice from their parents in deciding to study engineering, were less likely to have an engineer in their immediate families, but had more confidence about their knowledge of engineering. They reported more pre-college engineering-related experiences including installing computer software, navigating the Internet and dismantling or repairing small appliances. They also expressed a lower level of concern over the time commitment necessary to succeed in engineering. While we do not fully understand the implications, if any, of these differences, we do intend to continue to track these parameters to see how they vary from year to year, and to see whether these variations at all correlate with any changes in retention.

**Tracking the Timing of Leaving**

Each year, approximately 60 to 70 percent of all leavers discontinue engineering either during or at the end of EG 111. In 2000-01, the first year of the new EG 111/112 course sequence, only 8 percent dropped during EG 111, before the last drop date in the semester near the end of October. In 2001-02, however, 30 percent dropped before the midterm drop deadline. In an effort to understand whether changes to the course made between 2000-01 and 2001-02 had an impact on drops, beginning in the 2002-03 academic year, we began to track drops on a weekly basis, to pinpoint the time at which most students decided to leave.

This weekly tracking indicated that two-thirds of fall-semester leavers dropped in October, coincident with the introduction of computer programming into the course. Conversations with students who dropped EG 111 around this time also identified the computer programming requirements as one of the primary reasons for discontinuing engineering. Many students reported no prior exposure to computer programming of any kind, data supported by the survey administered at the beginning of EG 111. Other students expressed frustration with the idea of engineers “sitting in front of a computer all day,” and decided that they did not want to pursue engineering any further.

Thus, we had evidence that the delivery of the computer programming aspect of the course presented some challenges for students. As a result of this information, we made two changes to the delivery of the computer programming content of the course. First, we moved computer programming to the start of the second semester, after students had had an opportunity to develop some confidence in their skills as college students and as potential engineers. Second, we altered the way in which the instructor presented the material. Rather than using the learner-centered model employed successfully in other aspects of the course, which required students to apply computer programming skills to problem-solving, we returned to an instructor-centered model for this aspect of the course alone, to give students a solid grounding in the fundamentals of computing before asking them to apply their computer skills to solve an actual problem [4].

One other change to the course in part attempted to address the issue of self-confidence with programming. As described in [5], we implemented the use of an Audience Response System (ARS) in the course for several purposes, one of which helped us to convey to the 300-400 students in the EG 111/112 lectures that their own confidence level did not differ significantly from that of their classmates. At one point in the computer programming course module, for example, the instructor asked students to use the ARS to indicate their level of confidence in their programming skills. The vast majority of students expressed moderate to low confidence. Although not a scientific survey of the students,
this exercise showed all of the students how their peers felt about the material and may have had a positive effect on self-confidence and, in turn, on persistence.

In 2003-04, the first year for which we implemented these changes, the percentage of those who left engineering during EG 111 dropped dramatically, from around 30 percent in 2001-02 and 2002-03 (47 and 53 students, respectively), to only 4-5 percent in 2003-04 and 2004-05 (5 students each year).

Drawing on a variety of information sources helped us to address a serious situation in a short period of time. We identified a problem with the computer programming content of the course, we supported our understanding with several data sources, implemented a change in the very next academic year and validated that change by the end of that next year.

**IDENTIFYING REASONS FOR LEAVING**

In 2002-03, we also began a comprehensive effort to understand the reasons behind students’ decisions to leave engineering. We attempted to interview, either in person, by phone or by e-mail, all of the students who left before the end of the first semester. Generally, as discussed in [6], the answers proved fairly unenlightening. We did learn about the challenges presented by computer programming, but otherwise, comments about why students dropped the EG 111 course took the vague form of: “I just didn’t like it.” “It wasn’t for me.” “I took it because someone else (usually a parent or an advisor) told me to try it.”

We did, however, develop a general sense that female students, in particular, felt isolated, and that they believed (whether or not it was objectively true) that male students both had more experience with the subject matter and had an easier time forming study groups with other engineers in their all-male residence halls. Thus, we identified a non-engineering factor, campus housing, that appeared to affect the retention of a subgroup of students, in this case, women.

On average, each men’s residence hall has approximately 20 to 25 first-year engineers, compared with approximately 5 to 7 in each women’s residence hall. Thus, we worked with the University’s Office of Residence Life to consolidate first-year female engineering intents into fewer than half of the women’s residence halls (cluster halls), thereby doubling their concentration and (hopefully) facilitating the formation of study groups. Because of other housing-assignment issues, we could accommodate only 80% of the first-year female engineering intents in the cluster halls. In 2003-04, the first year of this new housing system, the retention rate for the women in the cluster halls jumped to 75%, compared to 60% retention for the women in the non-cluster halls – both of which, however, exceeded the 2002-03 retention rate of 50% for all women. Similarly, in 2004-05, we housed 83% of the women in the cluster halls and, at the end of the spring semester, had retained 75%, compared to 50% retention for those in the non-cluster halls.

We have also made one other change to the way we gather this particular anecdotal information. Rather than asking students why they left, we have shifted to asking them, in the context of improving the course for next year, what about the course we could have done differently to make it more appealing to them. We have received much more interesting answers to this line of questioning. Students still reveal what about the course did not appeal to them, but in a manner that addresses aspects of the course rather than themselves. Students will talk about the pace at which the instructor delivered the material, the experience with computers, how the project teams worked out, etc., and actually put some thought into evaluating what suited them and what did not.

**EVALUATING STUDENT DEMOGRAPHIC INFORMATION**

Finally, we looked at student demographic data to see whether we could detect any patterns regarding the likelihood that certain subgroups of students would continue in engineering. Although we acknowledge that SAT scores do not predict subsequent academic performance, we looked at the data because the scores provide one ostensibly objective means of comparing student credentials upon admission to the University, before course work and campus life have any effect on them. We also evaluated course grades in EG 111, as a way of learning whether poor performance in the course correlated with retention. And, we looked for other indicators. Ultimately, as explained in [3], we concluded that the only demographic factor that correlated with retention was the student’s “intended major,” as indicated on the student’s application for admission to the University.

With regard to SAT scores, as explained in [3], we could not identify a consistent pattern of leavers having lower mean SAT scores than stayers, as shown in Table III:

<table>
<thead>
<tr>
<th>Year</th>
<th>All Stayers</th>
<th>Female Stayers</th>
<th>Male Stayers</th>
<th>All Leavers</th>
<th>Female Leavers</th>
<th>Male Leavers</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-01</td>
<td>1359</td>
<td>1338</td>
<td>1354</td>
<td>1367</td>
<td>1360</td>
<td></td>
</tr>
<tr>
<td>2001-02</td>
<td>1377</td>
<td>1345</td>
<td>1359</td>
<td>1391</td>
<td>1372</td>
<td></td>
</tr>
<tr>
<td>2002-03</td>
<td>1377</td>
<td>1385</td>
<td>1369</td>
<td>1385</td>
<td>1361</td>
<td></td>
</tr>
<tr>
<td>2003-04</td>
<td>1387</td>
<td>1400</td>
<td>1389</td>
<td>1401</td>
<td>1352</td>
<td></td>
</tr>
<tr>
<td>2004-05</td>
<td>1393</td>
<td>1381</td>
<td>1315</td>
<td>1411</td>
<td>1384</td>
<td></td>
</tr>
</tbody>
</table>

Although male leavers in each year had lower mean SAT scores than male stayers, female leavers and stayers exhibited no such consistent pattern, with leavers having higher mean SAT scores than stayers in 2000-01 and 2001-02. Interestingly, however, while the class mean increased by 34 points from 2000-01 to 2004-05, the mean SAT score for female stayers increased 43 points, and for male stayers by 44 points, indicating that some of the changes initiated in 2003-04 had a positive impact on those notionally at the top of the class.
With regard to EG 111 course grades, as shown in [3], a pattern did appear to emerge for both men and women, with stayers generally having higher mean EG 111 course grades than leavers, except for women in 2001-02.

### TABLE IV

<table>
<thead>
<tr>
<th>Year</th>
<th>All Female Stayers</th>
<th>Female Leavers</th>
<th>Male Stayers</th>
<th>Male Leavers</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001-02</td>
<td>3.345 3.125</td>
<td>3.142</td>
<td>3.516</td>
<td>3.128</td>
</tr>
<tr>
<td>2002-03</td>
<td>3.311 3.326</td>
<td>2.800</td>
<td>3.464</td>
<td>3.129</td>
</tr>
<tr>
<td>2003-04</td>
<td>3.212 3.199</td>
<td>2.909</td>
<td>3.434</td>
<td>2.866</td>
</tr>
<tr>
<td>2004-05</td>
<td>3.218 3.147</td>
<td>2.852</td>
<td>3.374</td>
<td>2.977</td>
</tr>
</tbody>
</table>

We do, however, question the usefulness of this grade information. We do not know whether leavers had less capability with the material than stayers, because we have no way of knowing whether the lower mean grades resulted from a lower level of knowledge of the subject, or from students spending less time on the material once they had decided to discontinue engineering [3]. It is interesting to note, however, that the 66% retention rate for the class entering in 2003-04 and the 71% retention rate for the class entering in 2004-05, as shown in Table V, exceeded the 55% retention rate for the class entering in 2000-01 by 20%, even though the mean grade for the class has dropped by over two-tenths of a grade-point over time.

Finally, we looked at other information available on the student’s application for admission to Notre Dame. We noticed that both male and female students who selected an engineering subject as their intended major (EG admits) exhibited a higher retention rate than those students who selected something else (nonEG admits) but nevertheless enrolled in EG 111. As shown in Table V, and as described in [3], [6] and [8], through 2002-03, male EG admits exhibited the highest retention rate each year, followed by female EG admits, male nonEG admits and female nonEG admits. Additionally, we discovered that female EG admits exhibited a retention rate close to that of male EG admits. Thus, we learned something new about the persistence of this subgroup of women.

### CONCLUSION

We also learned that the lower retention rate among the entire group of female students resulted, not from a dramatically lower retention rate of female students predisposed to studying engineering, but rather, because of an incredibly low retention rate of female students who had not considered studying engineering prior to becoming a first-year student and enrolling in EG 111. Because female nonEG admits comprise a greater proportion of all female students (30% to 40% each year) than male nonEG admits comprise of all male students (15% to 20% each year), the lower retention rate of female nonEG admits had a dramatic impact on the retention rate of the entire female population, as explained in [3], [6] and [8].

In 2003-04, as a result of the efforts noted above to provide more support for female students by, for example, housing them in particular residence halls, we saw the retention rate of female nonEG admits double from the previous year, to 64%. Although that rate dropped somewhat in 2004-05, it still exceeds the retention rate of male nonEG admits for that year.

From this information, we have learned that different subgroups exist within the groups of women and men. We know that female nonEG admits have, historically, exhibited incredibly low retention rates, but that with some efforts directed toward improving the campus experience for all women enrolled in EG 111, we have made some progress in improving the retention rate for this group of students. Most interestingly, however, we have now identified male nonEG admits as perhaps our most at-risk population currently, although we do not yet have plan to act in light of this information.

The EG 111/112 assessment effort began with two in-class surveys aimed at determining how well this new two-course sequence met the learning objectives as defined in [1]. Four years later, this limited assessment effort has grown into a comprehensive effort that not only assesses course effectiveness and student progress toward learning objectives, but also identifies the factors that influence student retention.

As described in [2], the EG 111 entry survey provides a wealth of information about student experiences prior to entering Notre Dame, and the EG 112 exit survey provides a good understanding of the aspects of the course that most effectively prepared students to begin their major-specific course work in the sophomore year. We realized, however, that the EG 112 exit survey did not provide us with sufficient information about the experiences of the majority of students who ultimately left engineering, and thus added the EG 111 exit survey to deepen our understanding of how the course affects student retention. This mid-year survey now gives us good information on how first-semester leavers differ from second-semester leavers, particularly in terms of their confidence levels and their reasons for leaving [6]-[8].
new information took the reasons for leaving out of the realm of speculation, and changed our own assumptions about the reasons students leave engineering. We used several methods of information-gathering to confirm the impact that computer programming had on retention. We tracked the timing of student drops in the first semester on a week-by-week basis, which allowed us to identify the point in class at which most students become either frustrated enough by or disinterested enough in the subject matter to take some action. Through student interviews, we learned that students coming into college do not have sufficient pre-college experiences with computer programming, and that we need to ease them into the challenging material over time. We therefore concluded that we could not expect them to apply a computer to solve an engineering problem at the same time as they were learning how to program computers, and therefore altered the course configuration to teach a separate, stand-alone computer programming module, which we moved to the second semester, as discussed in [4]. This multi-faceted approach took the issues with computer programming beyond mere student complaints about something difficult and new and challenging, and provided us with sound reasons for making a needed change. 

Student interviews also identified some systemic and cultural issues at the University that impacted student persistence in engineering. We worked to address these issues, particularly in the assignment of housing for female engineering students, and immediately saw positive results, as shown in [3], [6] and [8]. Additionally, changing the way in which we asked students about their reasons for leaving, helped to uncover information about the aspects of the course that leavers found too challenging or not interesting enough. While we might not act on all of these suggestions because of our desire to keep the course focused on the original course objectives, we do have a better sense of the issues that students consider when leaving engineering. 

Finally, as discussed in [3], our review of the usual sorts of demographic information did not help us to identify whether anything in a student’s academic background (as measured by SAT scores) or in a student’s academic performance (as measured by EG 111 grades) had an impact on retention. By delving deeper into potentially relevant demographic information, however, we did identify the fact that EG admits historically exhibited a significantly higher retention rate than nonEG admits. Moreover, while changes to our program as discussed in [3] – primarily the systemic and cultural changes at the University level – have helped to improve the retention rate of female nonEG admits, we have also identified male nonEG admits as an at-risk population and can now take steps to work toward improving their retention rate as well. The effort expended on thoroughly understanding the background of the students in the class has focused our attention on a group of students identified as most at-risk for leaving engineering.

The comprehensive and integrated nature of our efforts have given us a way to identify needed changes in a timely manner and to support those changes with data. We now have the ability to make changes and to assess the impact of those changes in the short-term. We have a system that will enable us to continue these efforts year after year, to monitor the effects of any subsequent changes to the course and to identify any significant differences in the student populations each year. Any one of these evaluation methods might have provided us with some interesting avenues to explore. But coupling all of them together into a comprehensive package has enabled us to act quickly to make necessary changes and to see results and verify the effectiveness of the changes in a timely manner.

REFERENCES