Work in Progress: Improving First-Year Retention Through Support and Engagement

Prof. Petra Bonfert-Taylor, Dartmouth College

Dr. Petra Bonfert-Taylor is a Professor and an Instructional Designer at the Thayer School of Engineering at Dartmouth College. She received her Ph.D. in Mathematics from Technical University of Berlin (Germany) in 1996 and subsequently spent three years as a postdoctoral fellow at the University of Michigan before accepting a tenure-track position in the Mathematics Department at Wesleyan University. She left Wesleyan as a tenured full professor in 2015 for her current position at Dartmouth College. Dr. Bonfert-Taylor has published extensively and lectured widely to national and international audiences. Her work has been recognized by the National Science Foundation with numerous research grants. She is equally passionate about her teaching and has recently designed and created a Massively Open Online Course “Analysis of a Complex Kind” on Coursera. Her teaching was recognized through the awarding of the Binswanger Prize for Excellence in Teaching at Wesleyan University and the Excellence in Teaching Award at the Thayer School of Engineering. Dr. Bonfert-Taylor has a strong interest in broadening access to high quality higher education and pedagogical innovations that aid in providing equal opportunities to students from all backgrounds.

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Introduction

With the continued demand for a highly skilled and diverse engineering workforce the problem of understanding factors that influence retention in engineering remains significant. Becoming an engineering major requires students to spend considerable amounts of time and effort building up their knowledge base in mathematics, physics, chemistry and computation. As a result, many students at the Thayer School of Engineering at Dartmouth College do not take actual engineering classes until their sophomore year. Based on campus data, the majority of our students who switch out of engineering do so after poor performance in a prerequisite mathematics or science course in their first year; hence they leave the engineering program often before they have had the chance to take a single engineering class. Based on our data, underrepresented minority students, especially females, are disproportionately affected. We hypothesize that this student cohort often exhibits lower levels of confidence in their mathematical abilities leading them to the conclusion they are ‘not good enough’ to succeed in mathematics classes. This is also paired with the belief that if they don’t do well in math they will not succeed in engineering. We are exploring remedies to help these students - those who want to be engineers but may not be as well prepared in math and science - persist. In this paper, we will focus on group study sessions, which were implemented in the fall of 2016, to provide both academic and emotional support to students as they build their knowledge base in the prerequisite classes.

Project Motivation and Relevant Literature

Despite continued efforts to attract and retain students, the percentage of students from underrepresented groups earning degrees in engineering remains low nationally (NSF, 2015). Women earned close to 60% of all bachelor’s degrees in 2012 but less than 20% of those degrees were in engineering (NSF, 2015). And Hispanic, Native American, and African American students combined earned <14% of the engineering degrees in 2012 (ASEE, 2014), though they comprised over 30% of the population (NSF, 2015).

While the program described in this paper aims to increase retention in engineering for underprepared students, this goal is intricately connected with the goal of increasing retention for underrepresented students. Of all students who matriculated with an engineering interest at the Thayer School of Engineering at Dartmouth College over a 4-year period, 27% are minority students. A significant proportion (39%) of these students were underprepared in mathematics (defined by the level of introductory mathematics course in which they placed), compared to only 21% of non-minority students. As we will show below, engineering dropout rates are significantly higher for students who are underprepared in mathematics, and we indeed see the
effects of being underprepared for our underrepresented student groups in Table 1: The percentage of students from underrepresented groups graduating in or expecting to graduate in engineering between 2014 and 2017 ranges only from 8% to 19%.

<table>
<thead>
<tr>
<th>Year Graduating</th>
<th>Total number of students graduating in engineering</th>
<th>African American (AA)</th>
<th>Hispanic (H)</th>
<th>Native American and Alaskan (NA)</th>
<th>Total (AA, H, and NA)</th>
<th>AA, H, and NA students as a % of all students graduating in engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>104</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>8</td>
<td>7.7%</td>
</tr>
<tr>
<td>2015</td>
<td>77</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>8</td>
<td>10.4%</td>
</tr>
<tr>
<td>2016</td>
<td>117</td>
<td>6</td>
<td>11</td>
<td>5</td>
<td>22</td>
<td>18.8%</td>
</tr>
<tr>
<td>2017 (tentative)</td>
<td>102</td>
<td>10</td>
<td>7</td>
<td>1</td>
<td>18</td>
<td>17.6%</td>
</tr>
</tbody>
</table>

*Table 1: Graduation rates (2014-2017) for undergraduate engineering students.*

For this study, we consider students with the following ethnic and racial backgrounds to be underrepresented: African American, Hispanic, American Indian, and Native Alaskan students. At the Thayer School of Engineering, women are not included in our definition of underrepresented since the percentage of women in engineering at our school is approaching gender parity (52% of our graduating engineering students were women in 2016, the tentative percentage of female graduating engineering students for 2017 is 41%).

At 58%, the retention rate for female students at our school is actually slightly higher than that for male students (54%). On the other hand, the retention rate for underrepresented minority students is only at 46%, and a closer look at the data (see Table 2) reveals that this is mainly due to an exceedingly low retention rate for female minority students (40%).

<table>
<thead>
<tr>
<th>Students who matriculate with an engineering interest</th>
<th>Overall retention rate</th>
<th>Retention rate for female students in this group</th>
<th>Retention rate for male students in this group</th>
</tr>
</thead>
<tbody>
<tr>
<td>All students</td>
<td>53.9%</td>
<td>57.7%</td>
<td>51.3%</td>
</tr>
<tr>
<td>Minority students</td>
<td>46.2%</td>
<td>39.6%</td>
<td>51.5%</td>
</tr>
</tbody>
</table>

*Table 2: Retention rates for undergraduate engineering students (Classes of 2014-2017).*
Students have many reasons for choosing a non-engineering major despite having an initial interest in engineering. The most commonly cited reasons at our schools are related to prerequisite courses. Indeed, the list of prerequisite courses for engineering is rather long and includes 3-4 mathematics courses, two physics courses, one chemistry course and a computing course. It is easy to lose sight of one’s engineering goals when all one does is take prerequisite classes and other college requirements. Students from underprepared backgrounds tend to struggle especially hard during their first year and often end up dropping their plans to study engineering quite early on in their college career. These students are especially vulnerable during their first year here since, after having been high achievers in their high schools, they now might experience their first class in which they struggle and receive a poor or even failing grade. Students’ confidence often drops after one such event, and it is our goal to supply the academic and emotional support to prevent a first poor grade from derailing a student’s path through our school.

The Thayer School of Engineering is not unique. Many studies on student persistence in STEM fields have been performed, for example a three-year study to “…discover and establish the relative importance of the factors with the greatest bearing upon the decisions of undergraduates at four-year colleges and universities to switch from science, mathematics, and engineering (SME) majors into disciplines which are not science-based” (Seymour & Hewitt, 1997). In this study of 335 students, the reasons most often cited for leaving science, math, and engineering included: “…loss of interest in science; belief that a non-SME major holds more interest, or offers a better education; poor teaching by SME faculty; and feeling overwhelmed by the pace and load of curriculum demands.” We believe that at our school the “pace and load of curriculum demands” is the culprit, and it is the goal of our current program to address this problem.

Many schools facing similar issues have developed programs targeted at first-year students, including seminars (e.g., Montgomery et al., 2003), special courses (e.g., Olds and Miller, 2004; Mourtos and Furman, 2002; Hatton et al., 1998), mentoring (e.g., Meyers et al., 2010), learning communities (e.g., Zhao and Kuh, 2004), and research opportunities (e.g., Courtney and Courtney, 2012). Such programs are typically tailored to the individual institution. Many have demonstrated at least modest improvement towards retention of students from underrepresented backgrounds.

Other studies focus on factors such as gender, financial situation, extracurricular activities and social networks, amongst others. Takahira, Goodings, & Byrnes, 1998, identify GPAs and SAT-math scores as the primary factors associated with student persistence. A model that identifies significant pre-college characteristics relevant for freshman engineering student success and retention is developed in Veenstra, Dey, & Herrin, 2009. The impact of different types of financial aid on student commitment, their integration into the academic and social components of the institution and on college persistence is addressed in Alon, 2005, and Cabrera, Nora, &
Castaneda, 1992, as well as Chen & DesJardins, 2008. Attitudes and perceptions that influence engineering retention is another important area of study: Alon & Tienda, 2005, address the claim that minority students, even if their preparation is below that of the average attendee, thrive at selective postsecondary institutions, and Burtner, 2005, shows that “confidence in college-level math/science ability and the belief that an engineering degree enhances career security at a respectable salary were found to be significant predictors of both short-term and long-term persistence in engineering.” French, Immekus, & Oakes, 2005 examine student success and persistence in the engineering major in relation to a variety of cognitive and non-cognitive factors such as motivation, which was found to be highly correlated with retention. Studies that focus on individual institutions include Lackey, Lackey, Grady, & Davis, 2003, who attempt to relate student scores on a non-technical freshmen assignment to retention in the major and Ohland, Frilaman, Zhang, Brawner, & Miller, 2004, analyzing the effects on retention and student success of entrepreneurship programs.

Though all of these studies vary widely in approach and methodology, many conclude that crucial factors in a student’s retention are the feelings of belonging and being accepted. A meta-analysis of 50 attrition studies from engineering programs further identifies six factors involved in driving students to leave engineering, amongst them self-confidence, high school preparation, race and gender (Geisinger, 2013). Zhang et al (Zhang, 2006) in particular study the role of academic performance in engineering attrition.

Purpose of Study

In this paper, we describe an intervention currently in development at the Thayer School of Engineering, to prevent students from leaving engineering, in part due to their struggles in prerequisite courses. For the purpose of this study, we define the retention rate as the percentage of students who matriculate with an interest in engineering and ultimately declare an engineering major. In contrast, the dropout rate is the percentage of students who matriculate with an interest in engineering but end up declaring a non-engineering major. Note that dropout does not imply leaving our school: for the purpose of this study it means choosing a non-engineering major.

Research Questions

Through this project, we hope to better support first-year aspiring engineering students, especially those from underprepared backgrounds. We hope to accomplish this by providing increased academic and emotional support as well as integrating first-year aspiring engineering students better into our school’s engineering community earlier in their academic careers. Via these activities, we hope to retain students’ interest in engineering through this foundational period of study. We will research the following questions, in particular as they pertain to our new support program:
• How do we support the development of meaningful relationships for underprepared first-year students within their engineering experience?
  In order to approach this question we will survey students about interpersonal experiences with peers as well as interpersonal experiences with faculty and TAs.

• How do we increase the persistence rate in engineering at our school?
  We will track persistence, grades and major/minor choices of our first-year students.

• How do we promote the use of the variety of resources we offer for underprepared first-year students?
  We will track first-year sign-ups for our program and will track group study session attendance.

Thayer School-Specific Retention Data

Data (collected over four years - Classes of 2014-2017) at the Thayer School of Engineering indicates that amongst students who matriculate with an interest in engineering, those who are mathematically less prepared are significantly more likely to drop out of engineering during their first two years of college than their better-prepared classmates. At our school, the majority of engineering majors (67%) have a sufficiently advanced high school calculus background that allows them to begin their mathematics study with integral calculus, multivariable calculus or an even higher-level class. The engineering dropout rate amongst these students is 38%. On the other hand, amongst aspiring engineering students who start with pre-calculus or differential calculus (the majority of whom have no high school calculus background), the dropout rate is 70%. We note that a bad experience in this introductory calculus class appears to be central to the decision to leave engineering: Table 3 shows the average grade in introductory calculus for aspiring engineering students who remained and for those who left engineering.

<table>
<thead>
<tr>
<th>First mathematics class</th>
<th>Number of students with engineering interest who started in this class</th>
<th>Percentage of these students who remained in engineering</th>
<th>Average grade in this class of those who remained in engineering</th>
<th>Average grade in this class of those who left engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precalculus</td>
<td>8</td>
<td>0%</td>
<td>N/A</td>
<td>2.37</td>
</tr>
<tr>
<td>Differential</td>
<td>113</td>
<td>32%</td>
<td>3.34</td>
<td>2.65</td>
</tr>
<tr>
<td>Integral</td>
<td>152</td>
<td>59%</td>
<td>3.02</td>
<td>2.94</td>
</tr>
<tr>
<td>Multivariable</td>
<td>195</td>
<td>64%</td>
<td>3.29</td>
<td>3.27</td>
</tr>
<tr>
<td>Other</td>
<td>18</td>
<td>39%</td>
<td>3.69</td>
<td>2.97</td>
</tr>
</tbody>
</table>

Table 3: Average grades in first mathematics class for aspiring engineering students (Classes of 2014-2017).
It is evident that there is a strong grade discrepancy between the group of students who remained in and those who left engineering. In contrast, the discrepancy in average grade amongst students who stayed in and those who left engineering is less stark for students with a more solid mathematics foundation, for example students who started in Integral Calculus or even Multivariable Calculus. We conclude that a bad experience in an introductory non-advanced mathematics class is related to engineering dropout.

In Table 4 we further examine the Differential Calculus results and see this data broken into different student groups. We note that the average grade discrepancy between students who remained and those who left engineering is largest for white male students. On the other hand, for women and underrepresented minorities, while still significant, the grade discrepancy is less severe than for white male students. One interpretation of this finding is that white male students are more resilient towards a perceived bad experience in a mathematics class, whereas it takes less of a bad experience in order for women and minority students to conclude they don’t belong in engineering.

<table>
<thead>
<tr>
<th>Students with engineering interest who started in Differential Calculus</th>
<th>Total number</th>
<th>Percentage of these who remained in engineering</th>
<th>Average grade in Differential Calculus of those who remained</th>
<th>Percentage of these who left engineering</th>
<th>Average grade in Differential Calculus of those who left</th>
<th>Difference in average grades between those who remained and those who left</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>113</td>
<td>32%</td>
<td>3.34</td>
<td>68%</td>
<td>2.65</td>
<td>0.69</td>
</tr>
<tr>
<td>White</td>
<td>43</td>
<td>35%</td>
<td>3.45</td>
<td>65%</td>
<td>2.72</td>
<td>0.73</td>
</tr>
<tr>
<td>White Male</td>
<td>29</td>
<td>24%</td>
<td>3.57</td>
<td>76%</td>
<td>2.52</td>
<td>1.05</td>
</tr>
<tr>
<td>White Female</td>
<td>14</td>
<td>57%</td>
<td>3.35</td>
<td>43%</td>
<td>3.43</td>
<td>-0.08</td>
</tr>
<tr>
<td>Minority</td>
<td>45</td>
<td>22%</td>
<td>3.14</td>
<td>78%</td>
<td>2.58</td>
<td>0.56</td>
</tr>
<tr>
<td>Female</td>
<td>41</td>
<td>34%</td>
<td>3.22</td>
<td>66%</td>
<td>2.77</td>
<td>0.45</td>
</tr>
<tr>
<td>Male</td>
<td>72</td>
<td>31%</td>
<td>3.42</td>
<td>69%</td>
<td>2.59</td>
<td>0.83</td>
</tr>
</tbody>
</table>

*Table 4: Average grade for aspiring engineering students starting in differential calculus (Classes of 2014-2017).*

Further information is provided by qualitative survey results in which students who left engineering reported feeling unsupported and lost in their mathematics classes which led to a feeling of not belonging and being discouraged.
In the fall of 2014, prior to our quantitative evidence, a program was initiated at our school to attempt to remedy the perceived problem. The program was a response to qualitative observations of higher dropout rates amongst students from underprepared backgrounds. Note also that prior to this attempt, another program with the goal to increase retention was put into place in 2007 but eventually discontinued (Hansen 2008). The 2014 program aimed to provide academic support and mentoring for first year students who come to our school with an interest in engineering and are less prepared in mathematics than the typical student whom we admit. The hope was to help these students persist in engineering by both helping them succeed in the prerequisite courses and helping them see beyond the prerequisites by engaging them with people and activities at our school. Students in the program were paired, one-on-one, with student coaches, and it was expected that tutoring arrangements as well as social engagements (paid for through our program) would be made by the student-coach pairs. We saw mixed results with this arrangement. Overall the number of students who registered for the program was rather small (about 30 students per year). There were a few very successful student-coach pairings, in which the students felt very supported and engaged and appreciated the efforts. The majority of student-coach pairings, however, did not function properly. Students found it difficult to regularly meet with their coaches, especially during times of need (such as around midterms, when coaches also tended to be busiest). While students appreciated the thought of the program, it didn’t appear to make a difference for most.

New Program Development

During the summer of 2016, building on our prior experience, researching programs at other schools, and after speaking with many students, both those who persisted and those who left engineering, we have developed a new program, targeted at first-year students interested in engineering, that aims to support these students through their prerequisites, both academically and emotionally. Rather than individual student-coach pairings we now hold nightly 3-hour drop-in group study sessions in order to provide free, high-level and high-quality support and mentoring for aspiring engineering students who are taking prerequisite classes. We carefully select and train our TAs so as to provide academic as well as emotional support to our students. Many of our TAs have experienced difficulties during their initial time at our school themselves, which makes them more empathetic (as well as credible) with our current students. We instruct our TAs to guide students to find resources on their own so as to eventually become more independent. During weekly TA meetings, we talk about arising situations. For example, now that our program has grown in popularity, two TAs might find themselves with 10 students seeking advice on three separate subjects. Our TAs then become the guides on the sides as they group students into study groups by subject matter and rotate amongst the different groups. We believe that an added benefit of this model is that it empowers students, it helps students to get to know each other, it helps students learn and study, and it helps to form lasting bonds amongst students. We have initiated a strict tracking program, the data of which will eventually allow us to verify whether our efforts are increasing student retention and satisfaction.
In addition to the nightly group study sessions we provide special advising sessions to help students with their often more complicated course plans (given that they have a longer list of prerequisite courses to complete, which makes for an even longer time until they take their first actual engineering class). In order to recruit students effectively into our program we continuously send targeted messages to engineering students registered in introductory mathematics classes, we reach out to instructors of these classes and ask that they refer students in need to us, we advertise broadly during open houses and in first-year dorms, and we contact advisors of first-year engineering students. In addition to academic support we hope to build excitement about engineering amongst our students by inviting them to interesting events at our school such as project presentations, lab tours and community-building social events.

Preliminary Results

We have collected data for each student visit to our Study Center and report here some preliminary results on student behavior, visit frequencies, etc. Note that the prerequisite chemistry class was not offered during this first term of our Study Center.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Total number of visits</th>
<th>Number of distinct students</th>
<th>Number of infrequent students</th>
<th>Number of frequent students (greater than or equal to 3 visits)</th>
<th>Average number of visits per student (for frequent visitors)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precalculus</td>
<td>12</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Differential Calculus</td>
<td>75</td>
<td>16</td>
<td>6</td>
<td>10</td>
<td>6.6</td>
</tr>
<tr>
<td>Integral Calculus</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Multivariable Calculus</td>
<td>35</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Physics I</td>
<td>41</td>
<td>10</td>
<td>6</td>
<td>4</td>
<td>8.5</td>
</tr>
<tr>
<td>Programming</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>175</strong></td>
<td><strong>43</strong></td>
<td><strong>22</strong></td>
<td><strong>21</strong></td>
<td><strong>7</strong></td>
</tr>
</tbody>
</table>

*Table 5: Fall 2016 Study Center visit data by subject*

As can be seen from Table 5, overall the majority of students visited the Study Center to receive help with Differential Calculus. It is illuminating to analyze the timing (throughout the term) of these student visits, see Figure 1. For clarity of the display we omitted the few students who sought help with programming from this graphic.
Over the first three weeks, few students visited the Study Center. We attribute this to several factors: The Study Center was not yet well known to students; many students (especially those in lower-level mathematics courses) did not expect to need help with their course work; even when students realized they needed help they may not have been ready to admit this; students did not know the Study Center was a useful source of help. Broken up by subject, here is our preliminary analysis:

- **Precalculus**: Students did not start visiting the Study Center until week 6 (out of 10) of the term. Students starting in this course do not typically persist in engineering (see Table 4).
- **Differential Calculus**: A few students checked out the Study Center early on, but the majority didn’t start coming regularly until the first midterm (week 4) of the class. From then on, these students dominated the Study Center.
- **Integral Calculus**: A few students tried out the Study Center early on but must have not found it useful to them as they did not return.
- **Multivariable Calculus**: Once students learned about the program, a small number of them started coming consistently for help to the Study Center.
Physics I: These students were the most consistent visitors of the Study Center. They sought out help right from the start and kept returning regularly throughout the term.

Conclusion

While we do not yet have data on students’ grades and persistence we do see that the program has become increasingly popular. Are we reaching the targeted students who are underprepared? We hope so and have been coaching the TAs to focus their help on the students seeking help in the lower-level courses and to make all students feel welcome. Student visit numbers have increased drastically in the current term. We take this as an indication that students find the Study Center useful. We need to continue to understand how to reach students in Precalculus. It is encouraging to see so many students in Differential Calculus who are visiting the Center. Based upon the limited amount of data available to us at this time we conclude that the program has been successful. At the end of this year we plan to correlate Study Center visits with grades in pre-requisite courses and persistence in engineering.

Further Steps

We have initiated a number of additional programs to help students from underprepared backgrounds succeed in engineering. Amongst these initiatives are opportunities for students to participate in events at our engineering school, a voluntary bridge course (no course credit) to help students transition from Differential Calculus to Integral Calculus, an optional 4-day course on programming internet-connected devices, an optional 4-day course on engineering of musical instruments, and an opportunity for students to get together and speak about their experiences through guided storytelling. We will report on the results of these programs at a later date.

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