Work in Progress: Rethinking How We Teach in Engineering Through a Course Redesign Initiative

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Background

There have been myriad studies that have examined factors that contribute to student retention in engineering programs. These studies have helped guide efforts in implementing effective strategies to increase student retention, persistence, and degree completion. Two common themes related to engineering retention that have emerged from the literature are individual and institutional factors. Individual factors can be summed up as aptitude, pre-college preparation, academic performance, affective factors, personality traits, and satisfaction; while institutional factors include academic engagement, academic and career advising, environmental and social dynamics, and climate (Meyer & Marx, 2014).

Although the traditional response in addressing student preparedness is the strengthening of math and science education at the K-12 level, additional individual factors have been found to play a key role in retention. In addition to aptitude factors, Big Five personality traits (Conscientiousness, Openness, etc.) and affective factors (attitudes, self-esteem, self-efficacy, etc.) have been proven to contribute to retention in engineering programs. According to Hall et al. (2015), "studies have shown internal locus of control, academic self-esteem, self-efficacy, and the [Big Five] personality trait of Conscientiousness have contributed to retention in engineering" (p. 170). In other words, students that have exhibited higher levels of confidence, sense of belonging, determination, and motivation are more likely to persist in engineering. This illustrates that aptitude and academic achievement focused approaches, albeit important, are not the singular solution to the complex retention issues in engineering programs.

In addition to individual factors, there are also several institutional factors that have been found to be associated with student retention in engineering. A common institutional factor found in the literature is the mismatching of a student's expectation of engineering (e.g. curriculum, rigor, support, etc.) with the reality of an engineering program. The mismatch can result in a student's sense of disappointment in an engineering discipline and has been proven to contribute to a student's decision to not persist (Besterfield-Sacre, et al., 1997, Zhang et al., 2004, Litzler et al., 2012, Meyer et al., 2014). One challenge with student disappointment is that it can be triggered at any moment. For example, many students enter an engineering program expecting to immediately learn about the engineering design process (i.e. learning how to design a product) but may not be fully exposed to design during the first two years of the program. This presents a challenge for engineering programs to proactively respond in a timely manner to student misalignment or disappointment. Another shared theme in the literature is a student's belief that the engineering culture is unsupportive as dissatisfaction in academic advising, career guidance, and faculty support are frequently reported by students who leave an engineering program (Seymour et al., 1997, Meyer et al., 2014). Regardless of these challenges it is important for engineering programs to be aware of these realities when developing and implementing retention initiatives.

Temple University's Project SOAR

Traditionally, Temple University has responded to the issue of low rates of success and retention in its engineering courses and programs by providing support interventions for struggling students. In fact, at Temple we have robust student support services, including tutoring, exam review sessions for select courses, peer assisted study sessions, coaching on academic skills development, a writing center, and online math refreshers. These student supports can be effective and necessary for students who find themselves struggling with difficult content or who are unprepared for college work. Yet they are often reactive in nature as they are generally utilized by students only after they have already begun to struggle academically and/or have experienced disappointment in engineering.

Temple's Center for the Advancement of Teaching (CAT) has sought to reframe the problem to address possible underlying issues around course design and pedagogical choices that may contribute to student failure and attrition. With the support of the Vice Provost for Undergraduate Studies, the CAT created Project SOAR (Student-Oriented Active Redesign), a year-long course redesign initiative aimed at improving student outcomes in courses with high DFW rates (grades of "D", "F" or "Withdrawals"). In the first iteration of the project, a total of 11 courses were targeted across the university that had high DFW rates and offered multiple sections of the course each semester, often with high enrollments. Two courses in engineering participated in this inaugural project, including *Engineering Statics* and *Digital Circuit Design*. From Fall 2012 to Fall 2015, the DFW rate in *Engineering Statics* far exceeded the university average, sometimes reaching rates as high as 48.4% (approximately eight times the university average) while the DFW rate in *Digital Circuit Design* also exceeded the university average, topping out at 38.2%. Two engineering faculty members, one from each section of these two engineering courses, were chosen to create the redesigned curriculum based on consistently high student evaluations despite the high DFW rates in their courses. These high evaluations indicated that these faculty members had a good rapport with students and that students perceived them as caring about their development, qualities that we felt were essential to the success of the redesign pilot.

In creating Project SOAR, the CAT researched other similar initiatives around the country that might serve as models for our effort. An excellent resource for these programs is the National Center for Academic Transformation (NCAT) that outlines varying approaches to carrying out this kind of project and reports on findings from other institutions (NCAT, 2017). Based on successful course redesign initiatives carried out with its partner institutions focused on leveraging technological solutions to improve student outcomes, NCAT specifies the elements for a successful course redesign, including promoting active learning, increasing interaction among students, and building in ongoing assessment and prompt feedback (NCAT, 2017). All of these best pedagogical practices provide greater opportunities for the practice and feedback needed to improve a student's chances of success in a challenging course. However, we also sought to intentionally address the affective factors that can impact student performance. Therefore, Temple's model stresses the power of improved motivation and self-regulation to maximize persistence, especially in underrepresented groups of students. This was accomplished by targeting motivational factors such as value, positive learning climate, and sense of self-efficacy as well as helping students build metacognitive skills that can increase one's capacity for self-regulation.

The study attached to the project, therefore, aims to examine changes in the DFW rates, but also measures shifts in student beliefs of self-efficacy, task value, and growth mindset. This includes their belief that they can learn the material and succeed in the course, and that they can overcome obstacles they may face. Students in both the pilot redesigned sections and the non-redesigned sections of the courses were surveyed at the end of the first week of classes and again at the end of the semester. Surveys were developed using items from Dweck's Implicit Theories of Intelligence Scale, which has shown good internal consistency, $\alpha = .88$ and test-retest reliability, $\alpha = .79$ (Dweck, Chiu & Hong, 1995). We also used items from Pintrich's Motivated Strategies for Learning Questionnaire, which has also shown good internal consistency, $\alpha = .89$ (Pintrich, Smith, Garcia, & Mckeachie, 1993). The scales were adjusted to use a 7-point Likert scale (*1 = not at all true of me to 7 = very true of me.)*. The number of items per scale were reduced to not overburden participants. The students in the redesigned sections also completed a memo exercise with open-ended questions twice per semester to gather qualitative data on their feelings of self-efficacy, task value, and mindset. In the memos, students were asked to write about their thoughts, feelings, and emotions about the course, how they felt the course was preparing them for future engineering courses, and whether their experiences in the class related to life outside of the classroom. They were also asked to provide feedback on which class and homework activities they found most and least helpful, and which assignments helped them understand the material better.

The two engineering faculty participated in the Institute and worked with faculty developers and instructional technology specialists throughout the process of redesigning the course, yet they were given the freedom to implement the principles of course redesign as they saw fit. In this way, there was some clear unevenness to the implementation which we believe accounts for the differences in the DFW outcomes seen. For instance, in *Engineering Statics*, the professor created a more positive syllabus in which he explained why *Engineering Statics* is the first engineering course they take, gave guidance to students on how to succeed in the class, and helped students to understand the value of the assignments they must complete. The professor also added more class demonstrations and tied what they were learning to everyday applications. Lastly, he added some opportunities for low-stakes assessments in the form of quizzes and short writing assignments. But structural changes to the class were less robust and his teaching methodology did not differ markedly from his previous methods. Additionally, and perhaps most importantly, he did not implement any of the strategies for building metacognitive skills in students, something that we feel is essential for enhancing student success and persistence.

In *Digital Circuit Design*, the faculty member chose a more significant structural redesign, partially flipping the classroom by creating videos on fundamental concepts for at-home viewing with active learning embedded in the videos, designing in-class collaborative work aimed at providing targeted opportunities for practice and feedback, redesigning the syllabus to make it more positive, and intentionally addressing students' metacognitive skills and the ability to self-regulate their learning. To that end, the instructor began the semester with a reflective exercise that asked students to read Robert Leamson's (2002) essay "Learning (Your First Job)," comment online about their impressions of the article, and be prepared to discuss in class. The reflective comments from students regarding this essay were revealing: “These are all things that were not explicitly obvious to me as a student and I would have very much liked to have read this as a freshman.” This piece is especially important as we believe it made an important difference in students’ capacity to persevere in this class.

The difference in DFW outcomes between the two engineering courses for this first semester’s pilot is striking. While the *Engineering Statics* course saw no improvement in DFW rates, the *Digital Circuit Design* course showed significant improvement, with a 14% drop in DFW rate. We are just beginning the process of interpreting the qualitative and survey data we collected, which will give us information on student self-efficacy and mindset that we believe helps students achieve successful outcomes.

A shortcoming of our pilot attempt at course redesign was the uncertainty about pushing more forcefully for more robust changes to curricular structure and implementation. Therefore, in the second year of SOAR we will be pushing harder for these changes and then following up by assessing the activities, assessments, and assignments from the course. Also, there were unforeseen consequences of the Institute. The opportunity to discuss one’s teaching with colleagues in a three-week intensive institute naturally results in real problem-solving around teaching challenges. In fact, the professor from *Engineering Statics* asked to meet with the three of us to discuss exploring more sweeping changes to the entire introductory engineering course sequence, something that will be considered for the future. In addition, because of perceived improvement in faculty satisfaction, we have begun to collect data on faculty attitudes in teaching these redesigned courses, something that we had not intended at first to pursue. Despite the shortcomings, we are encouraged by the progress made in *Digital Circuit Design* and that both engineering instructors reported applying the principles to other courses that they teach (outside of SOAR’s purview). We are also optimistic that these two courses are moving in the right direction as both instructors are methodically refining their redesign strategies, which they will continue to implement this semester and in future semesters. Our goal is to continue our efforts in both courses and hope to find the right formula for improving them – especially the DFW rate in *Engineering Statics* – as we move ahead with the project. We look forward to reporting our complete results at the conference in June as well the direction of future engineering course redesign efforts at Temple University.

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