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Integrating an Introduction to Engineering Experience into an University Seminar Course

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Dr. Clara Novoa is an Associate Professor at the Ingram School of Engineering at Texas State University. She has a Ph.D. in Industrial Engineering and her research areas are Dynamic and Stochastic Programming and Parallel Computing to solve mathematical optimization problems applied to logistics and supply chain. Dr. Novoa has 15 years of experience in academia and 4 years of experience in industry. Dr. Novoa is receiving funding from NSF through SPARK and Texas State STEM Rising Stars. SPARK is a four years grant that looks to increase the recruitment and retention of female in engineering, computer science, and related fields by providing scholarships for low-income and talented students. Texas State STEM Rising Stars is a four years grant committed to increase the first and second year retention and graduation rates of students in STEM. Dr. Novoa is also the advisor of the Society of Women Engineers. She is committed to research on strategies to achieve gender equity and cultural inclusiveness in science and engineering.

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Integrating an Introduction to Engineering Experience into a University Seminar Course

Abstract
Retention statistics show that the most drastic decline in retention rates for engineering and engineering technology majors at Texas State University occur after the first and second years. To address this issue, the LBJ Institute of STEM Education and Research at Texas State is employing a multi-faceted approach to implement proven strategies for increasing student retention as a part of an NSF IUSE (Improving Undergraduate STEM Education) grant, *Texas State STEM Rising Stars*. One of these strategies is to introduce a new first-year introduction to engineering/engineering technology course that was designed to support student retention. A new course could not simply be added to the existing curriculum of the university's engineering and engineering technology degrees, however, as state law capped the hours required for an undergraduate degree. Instead, the researchers customized an introduction to the university freshman seminar course for engineering and engineering technology majors. This course design adapted elements from successful first-year introductory classes in Engineering and Engineering Technology at other universities. Besides fostering a learning community between Engineering and Engineering Technology students, the objectives of the new course include: (1) introduction of design and problem solving through project-based learning and (2) familiarization with the careers paths and practices of Engineering and Engineering Technology through tours and talks by industry representatives and faculty and (3) providing a common experience that introduces university resources to support the development of the students and prepares them for academic success. The pilot section of Introduction to Engineering in University Seminar was offered in Fall 2015. As these seminar courses are offered in the fall semesters, the researchers will be able to analyze changes in engineering design self-efficacy over the semester and conduct focus groups with students to refine the course content prior to an expanded second round of experimental sections that will be put in place for Fall 2016. This paper presents this work in progress, including preliminary results and lessons learned from this integration of Introduction to Engineering with University Seminar.

Introduction

According to data provided by Texas State University's Office of Institutional Research, average retention rates for Engineering and Engineering Technology students (for freshman cohorts entering Fall 2009-Fall 2011) were approximately 70% after one year, 55% after two years, and 49% after three years[1]. The data show that the most drastic decline occurs after the first and second years. To address this issue, the LBJ Institute of STEM Education and Research at Texas State is employing a multi-faceted approach to implement proven strategies for increasing student retention as a part of an NSF IUSE grant, *Texas State STEM Rising Stars*. One of these strategies is to introduce a new first-year course, "Introduction to Engineering & Engineering Technology," that was designed to support student retention through exploration of relevant academic and career issues, early contact with faculty as mentors, and development of a learning community with peers in the major. A special challenge for developing this new Introduction to Engineering course is that the state legislature implemented a law[2] that limits the number of hours that can be required for a college degree. As a result, a new course cannot simply be added to the existing curriculum of the university's engineering and engineering technology degrees. Instead, the researchers are customizing a University Seminar (US 1100) section, which is an introduction to the university freshman seminar course, specifically for engineering and engineering technology majors while exploring research questions related to the development of student design self-efficacy. This paper presents this work in progress including preliminary results from pre- and post-project engineering design self-efficacy measures of the initial cohort, lessons learned, and plans for future work.

Background

The *Texas State STEM Rising Stars* project is using a three-sided organizing framework, as shown in Figure 1, to guide the interventions and its associated research plan. This framework is based upon Swail's geometric model for student retention[3], which includes cognitive, social, and institutional factors. The four strategies of *Texas State STEM Rising Stars* are shown in Figure 1 with arrows aligned to these factors. The Introduction to Engineering experience is part of the strategy "Provide Early Career Insight" aligned to the cognitive factors.

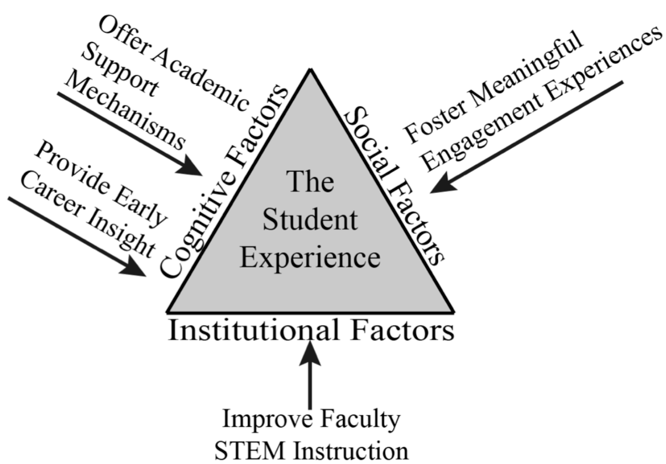

Figure 1: Organizing Framework for *Texas State STEM Rising Stars*

While the framework shown above is used for organizing clarity, the theoretical bases guiding this project are Tinto's academic and social integration model[4-6] and Astin's involvement model[7,8]. Some of the contextual factors considered include: faculty and peer relationships, family and community support, and academic sense of self[9]. Ong et al. suggest these factors are of particular importance in influencing the retention, persistence, and achievement of historically underrepresented students in STEM fields[9].

Tinto's model paved the way for a sociological analysis of retention that has been popular for several decades[10] and postulates that persistence occurs when students successfully integrate into the institution academically and socially. Integration, in turn, is influenced by pre-college characteristics and goals, interactions with peers and faculty, out-of-classroom socialization, and personal family dynamics and acculturation factors[11]. Additionally, Tinto argues that the first year of college – indeed the first semester – is critical to students being incorporated into the college campus, as well as their eventual persistence through graduation. Retention programs, therefore, are most successful when they utilize informal faculty-student contact in order to integrate students into the academic and social life of the college[12]. As such, the integration of an Introduction to Engineering course into the US 1100 program, which is required of students during their first semester of college, takes advantage of this critical time in students' lives and promises to increase retention rates.

Astin's model, based on patterns of behavior exhibited by successful students, asserts that the keys to success and graduation are involvement and connection. Involvement refers to both formal academic or intellectual pursuits as well as co-curricular activities. Among the primary measures of academic involvement is time spent on academic studies and tasks, and the development of higher cognitive skills. Co-curricular involvement includes measures of participation in campus activities and membership in academic/honors associations and social clubs. Connection refers to bonding with peers, faculty, and staff as well as sharing the institution's values[10]. In addition to the positive effects on overall student performance and retention, early connections with faculty may have a particularly positive effect for Hispanic students[13]. Besides fostering a learning community between Engineering and Engineering Technology students, the objectives of the new course include: (1) introduction of design and problem solving through project-based learning and (2) familiarization with the practices of Engineering and Engineering Technology through tours and talks by industry representatives and faculty.

One of the key research questions explored in this study is based on the premise that providing early career insight into engineering and engineering technology design must involve a focus on student hands-on design exploration. Therefore, design was a particular course feature. The research question guiding the scholarly inquiry was: To what extent does early exposure to hands-on design impact students' engineering design self-efficacy?

Procedure

The University Seminar Program is a student retention program of Texas State University, which has specific goals of helping students explore their career options, getting involved in campus life, developing life-long learning skills, and building a sense of community amongst the freshman class. In early Spring 2015, the authors worked with the University Seminar program to request and justify a restricted section of US 1100 for Engineering and Engineering Technology majors. Upon receiving approval for the section, the lead author worked with the chair of Engineering Technology to schedule the section in the Engineering & Engineering Technology building, in hopes of fostering a sense of community and belonging amongst these freshmen. The authors advertised this special section of US 1100 to incoming freshmen that were invited to attend special orientation sessions on STEM during Texas State's New Student Orientation program. As well, all of the academic advisors for the College of Science and Engineering were notified of the special section to encourage eligible students to register.

As this approach to implementing an Introduction to Engineering experience was customizing an established seminar program, the authors that served as instructors attended required training sessions for US 1100 instructors and were careful to cover the required content for the seminar course. The engineering design project included two class meetings in the university maker space, Bobcat Made, to introduce making and the resources available to them for the prototyping phase of their projects. Pre-surveys of engineering design self-efficacy were administered as part of the semester's design project for the pilot semester, but they are recommended to be administered on the first day of the semester in the future. The post-surveys of engineering design self-efficacy were administered on the last class day. The instructors discussed lessons learned at the conclusion of the semester and have made adjustments to the syllabus for use in the fall of 2016.

Preliminary Results

The sample for this pilot section was small as University Seminar sections are limited to twenty students each, and the pilot Engineering/Engineering Technology section had an enrollment of eighteen students (n=18). The student population in this section, however, was diverse as there was no race or ethnicity making up the majority of the class, which had 28% of the class self-identifying as African American, 28% as Hispanic/Latino, and 44% as White as shown in Figure 2. As the students in this special section were allowed to select more than one race or ethnicity on their demographics survey, the percentages shown in Figure 2 add up to more than 100%. This diversity is an approximate reflection of the university's undergraduate demographics, which includes approximately 9% of the population self-identifying as African American, 35% as Hispanic/Latino, and 49% White as of Fall 2015[14]. For the university numbers, students identifying with more than one race were categorized as multi-racial (3% of the undergraduate student population)[14]. The class was comprised of 83% male students and 17% female students, reflecting the student population of the engineering and engineering technology departments (84% male and 16% female)[1].

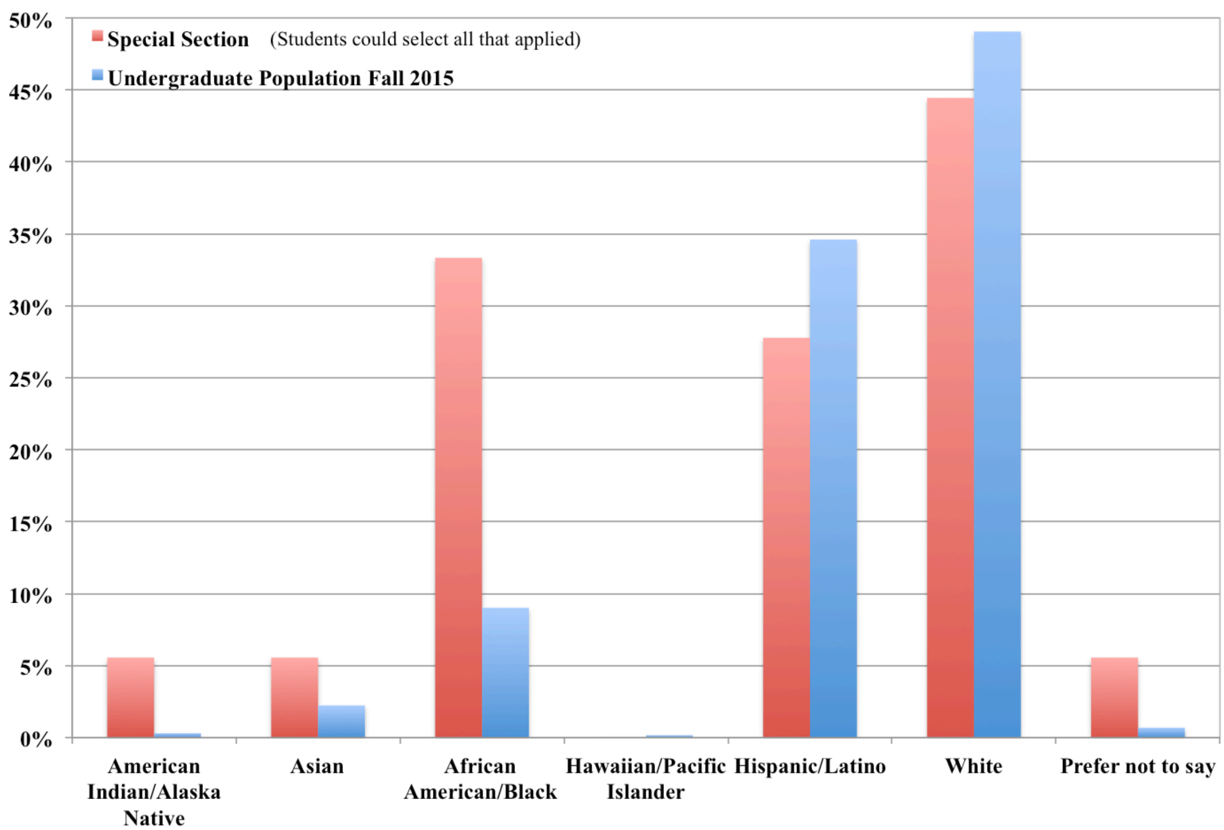

Figure 2: Student Reported Racial/Ethnic Demographics for Special Section and the Undergraduate Population

The surveys that the students completed before and after the design project (i.e. pre- and post-surveys) contained the validated engineering design self-efficacy instrument[15]. This instrument evaluates the students' self-efficacy by examining a set of nine engineering design steps through four lenses: confidence, motivation, anticipation of success, and anxiety[15]. The class averages for each lens are presented in Figures 3 through 6, respectively. Figure 3 shows the average pre- and post-ratings for the self-efficacy questions related to students' assessing their confidence in their abilities to perform various aspects of engineering design. The average ratings often increased by 20 points (on a scale from 0 to 100, where the students had to select a number by the tens: 0, 10, 20, etc.). Based upon a paired t-test of the class averages for each element of the confidence measure, the overall increase in confidence (shown in Figure 3) in performing engineering design was statistically significant at a 95% confidence level with a p-value of 5.2E-08. This increase in student confidence was a desired result for the intervention.

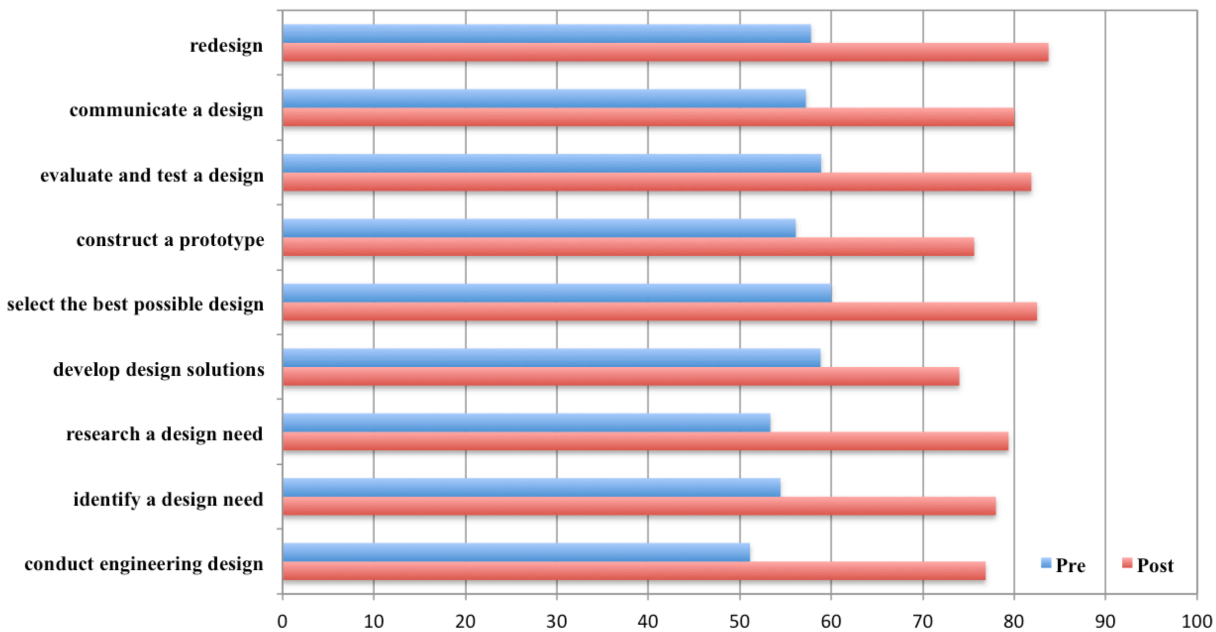

Figure 3: Average Student Confidence in Engineering Design Abilities

Figure 4 presents the average response to how motivated the students were to complete the engineering design steps. The pre-test responses to this category were higher than the other three aspects of this self-efficacy instrument. This situation is not surprising considering the students in this special section all declared an intention to pursue engineering or engineering technology upon admission to the university. The average student motivation to engage in engineering design did go up for each category as a result of this intervention. As well, the average student motivation results were statistically significant using a paired t-test with a p-value of 1.3E-05.

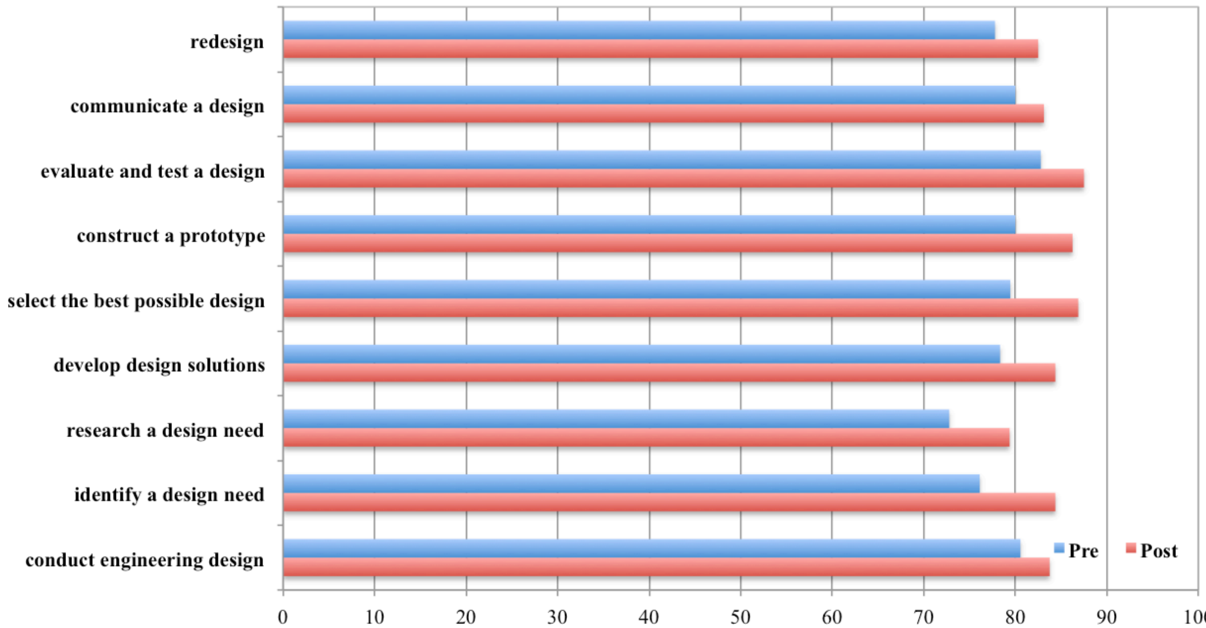

Figure 4: Average Student Motivation to Conduct Engineering Design

The average class response as to the students' anticipated success in conducting engineering design also showed large gains from pre- to post- surveys as shown in Figure 5. These results broadly mimic the results from the students' confidence responses, shown in Figure 3. The gains in average responses were statistically significant using a paired t-test of the averages (p = 2.9E-09) for this grouping of anticipated success questions.

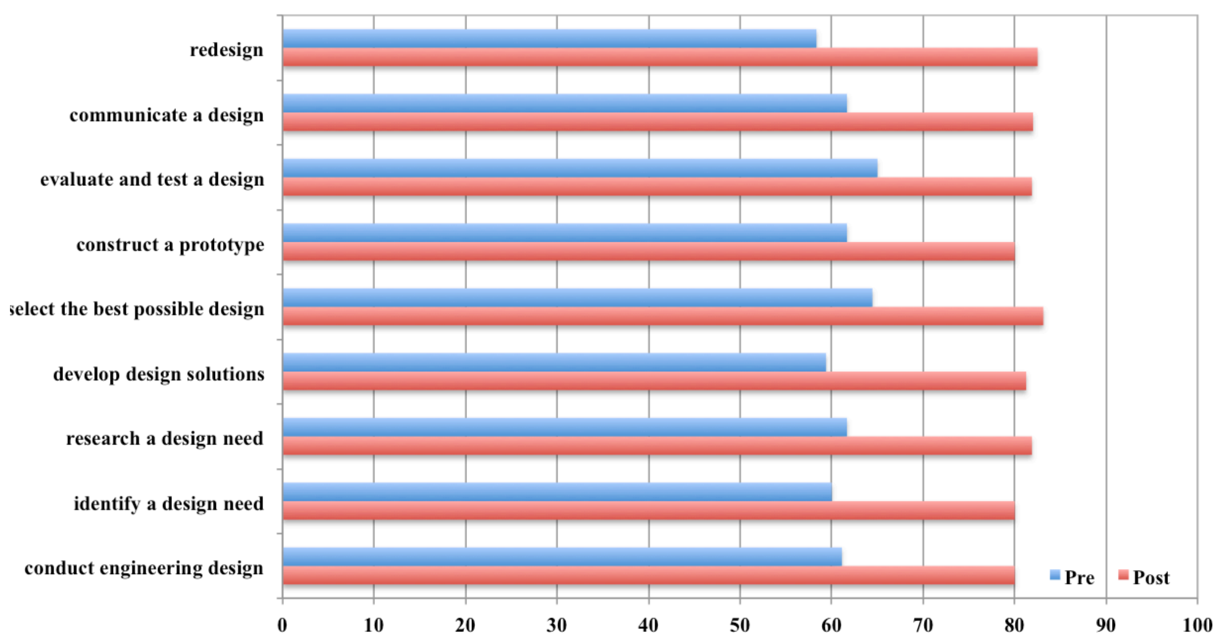

Figure 5: Average Student Anticipation of Success in Conducting Engineering Design

Figure 6 presents the students' average response to their level of anxiety when conducting engineering design. As desired, this sample exhibited a decrease in the average of the students' reported anxiety conducting engineering design. While the change was not as dramatic as seen in the changes in confidence and anticipation of success, the change here was still statistically significant using a paired t-test of the averages for each element of engineering design with a p-value of 0.00027.

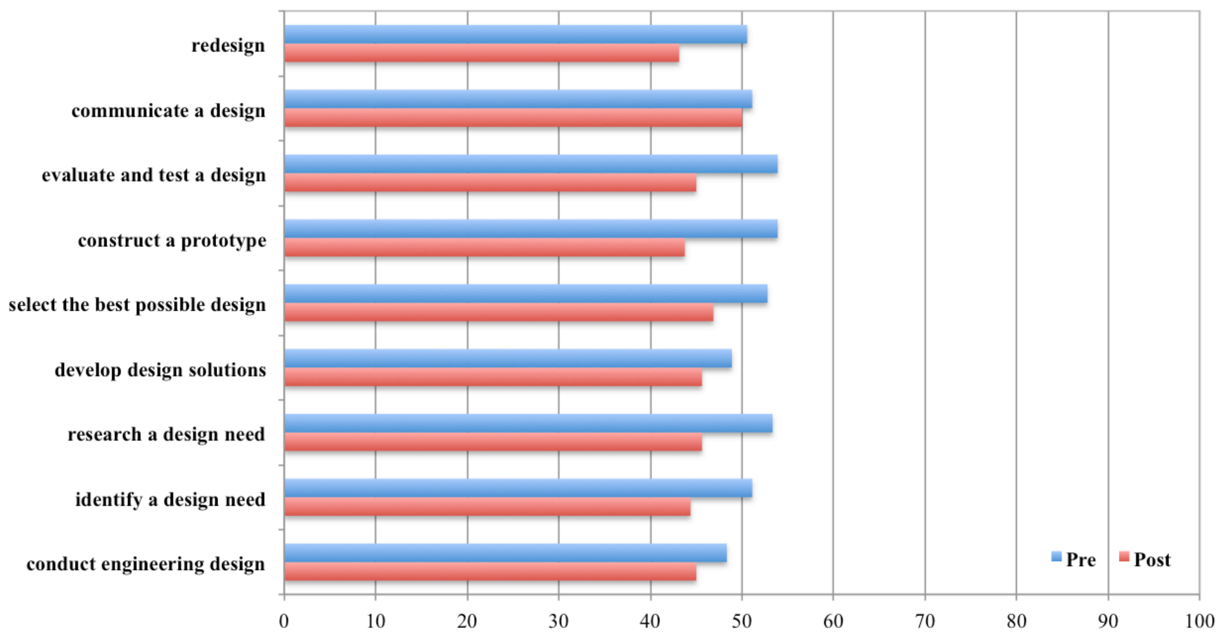

Figure 6: Average Student Anxiety in Conducting Engineering Design

Lessons Learned

- The 50-minute lecture developed to support weekly instruction of this course needs to be extremely well organized in order to meet all instructional objectives.

- Introduce the engineering design cycle and the design project as early as possible and before going to the maker space. In this way, the time in the maker space can be used more effectively, allowing the students more time to learn about the equipment and work on their design projects.

- Review the balance of course assessment elements to include a better balance between writing assignments, design projects, and both short-answer and multiple choice quizzes so that the students are evaluated on the required course elements while not exceeding the amount of work expected of a one-semester hour course.

- Assure that all resources possible to support the engineering design project be prepared well ahead of time and include links to a complete list of the software that will operate the maker space's hardware in order for the students to work on their own computers/computer labs in other buildings to complete the design project. This information is expected to help the students with time management and to create meaningful connections between their prior software experiences and the maker space equipment. For this project, this need will likely to be met as the university's fledgling maker space matures and additional information and training is available online.

- Take advantage of special [and free] opportunities created for University Seminar to both illustrate the many aspects of engineering careers and to introduce the students to campus resources. For instance the pilot section was able to take a glass bottom boat tour of a spring-fed lake, schedule a stress management presentation from student health services, and even a tour of the football stadium through the athletics department.

- A serious challenge for expanding this model will be in identifying enough engineering faculty to volunteer to teach a special section. The course sections in the described study were limited to 20 students in order to preserve the discussion format and foster community building. The pilot section was team taught, and one faculty experienced in teaching this course will team teach with another faculty member who is new to teaching this course in future sections. With this approach, new faculty teaching this course can ease into this new opportunity and with more faculty members involved, the program will be able to reach the academic careers of as many engineering students as possible.

Future work

As this pilot study involved a small sample size (n=18), the intervention will need to be repeated in subsequent semesters. This repetition will permit the research team to see if these early indications of potential success of integrating an Introduction to Engineering and Engineering Technology experience into a University Seminar course, such as the one described in this paper, becomes a trend across semesters and different instructors. Any impacts on individual-level student retention rates will take time to measure. In addition, the assessment of student retention rates will likely reflect the synergy of several concurrent strategies implemented through the *Texas State STEM Rising Stars* project.

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