

Board 72: Impact on Retention: Integrating Introduction to Engineering Concepts into a Freshman University Seminar Experience

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Work in Progress: Impact on Retention: Integrating Engineering Concepts into a Freshman University Seminar Experience

Abstract

A four-year study meant to analyze the effects of a modified introductory engineering course on two-year retention of women and minorities was conducted at Texas State University. Introduction to Engineering modules were integrated into a general freshman university seminar course. Two experimental tactics were followed. One section type, Early Career Intervention (ECI), focused on giving students resources and contacts such as faculty, student leaders, and industry professional contacts that they could utilize to succeed in their degree plan and later on, their career. The other experimental section type, Design Intervention, included a small design project and introduction to design theory, as well as Early Career Intervention. This work-in-progress sought to discover early data trends that indicate success of the modified introductory class. Early data suggests that Engineering Technology (ET) students may prefer Design Intervention, and Engineering (ENGR) students may prefer ECI. Furthermore, under-represented minorities (URMs) in ENGR majors may prefer Design Intervention, women in ET majors seem to succeed after Design Intervention, and women in ENGR are retained by ECI. Further investigation of these trends is scheduled upon completion of data acquisition.

Introduction

It is commonplace for universities that offer engineering degrees to feature some sort of introduction to engineering course. These courses serve the purpose of providing students the opportunity to integrate into their program, as well as into the university. Astin's involvement model, Tinto's academic and social integration model, and Swail's geometric model suggest that providing students the opportunity to experience and integrate well into all aspects of college life will increase their chances of being retained not only in their field of study, but in their school, as well [1-6].

Texas State University features growing Engineering (ENGR) and Engineering Technology (ET) programs. The University requires all freshman students to take a semester-long seminar course during their first or second semester that introduces the students to general university resources. However, it does not normally offer a seminar or introductory course that is specific to ENGR or ET students. This constraint is due, in part, to the fact that Texas Law dictates that no degree plan can require an excess of 120 credit hours to complete, unless more hours are required for third-party accreditation purposes [7]. As such, Texas State University does not offer a specific Introduction to Engineering course, but instead allows the general freshman seminar to serve as an approximate substitute.

To increase retention for ENGR and ET students, experimental sections of the general university seminar course (US1100) were added that permitted only ENGR or ET students to enroll. These courses were specifically structured to supply the same topics as a typical, semester-long Introduction to Engineering class, and to touch upon all three aspects - the cognitive, social, and institutional factors of the student experience - of Swail's geometric model, with a focus on cognitive and social factors [1]. Texas State University's Colleges of Science and Engineering (COSE) and of Education were awarded a National Science Foundation grant to increase STEM student retention. One strand of this research focuses on the retention of engineering and engineering technology students within COSE, which supplied the funding for this study.

Background

Theoretical Framework

The framework of Astin's, Swail's, and Tinto's models are, in their simplest interpretation, about student involvement in their chosen college and program. Astin's involvement model shows that the academic performance of a student is directly correlated to their involvement level within their college or program [2, 3]. Tinto theorizes that poor integration into the many facets of college life, including academically and socially, is an early indication of a student having a higher risk of dropping out [4-6]. Finally, Swail et al.'s analysis of minority retention in institutions of higher learning yields the Geometric Model of Student Persistence and Achievement, which stresses that a balance of social, cognitive, and institutional factors is vital for student retention. For example, an institution that cannot provide adequate cognitive stimulation is just as dangerous to student success as one that cannot provide adequate social involvement opportunities [1].

Many engineering or other STEM programs seek to enhance student involvement by requiring introduction classes, providing field of study or community-specific tutoring and counseling opportunities, requiring group work on design-based projects, and other creative and innovative tactics [8-14]. The intended impact of these programs or curriculum can range from extremely targeted to very broad. For example, some universities hope to promote retention in certain disciplines of engineering, or for certain minority populations. To do this, students are encouraged to join societies that fit their identity, attend advising and other guidance or tutoring services, and utilize resources provided by their university [9].

One university uses project-based learning in an introductory chemistry class to help teach chemical engineering students the skills they need to be successful in their field of study. Requiring open-ended, group-based projects that necessitate high levels of thinking help students to develop the skills required to solve complex problems without definitive answers, similar to problems they are required to solve in higher level courses and in the workplace. This early-career opportunity to develop necessary engineering skills is argued to help retention by equipping students with what they need to be successful, and therefore retained, in their chosen field of study [8].

Other universities recognize that certain demographic minorities are not being retained in engineering at the same rates as those who are non-minorities and seek to improve retention for these select demographics [9, 15-16]. These efforts can range from early-career outreach to specially-tailored sections of classes meant to benefit the target demographic. Minority Engineering Programs (MEPs) were founded to help improve the retention rates of Hispanic and Black students in engineering programs at primarily non-minority institutions, and to increase the amount of representation of URM students receiving engineering degrees [9]. In general, successful programs share a few things in common.

According to Swail et al., by providing students a balanced experience of social, institutional, and cognitive factors that make them feel stimulated, included, and cared for help a student be retained. Additionally, students who lack their own financial resources to attend school but are supported by their institution are likely to be retained [1]. By actively trying to provide these resources for URM students in engineering, they are more likely to be retained. These resources may also include faculty members approaching URM students to offer research jobs or support, as one of the reasons URM students pursue a career in engineering is for research, passion for STEM subjects, and the opportunity to

bond with faculty and mentors [15, 18]. URM students who feel that retention efforts come from upper administration, see that societies exist on campus that they can identify and connect with, and are able to find financial, academic, or mentoring support if they need it are more satisfied by their university, and the university is rewarded with higher URM retention rates [9, 15-18].

Context

This study occurred at a Hispanic-Servicing Institution in the southwestern United States. The funding for this study came from an NSF grant that was used to help improve retention rates for women and underrepresented minorities (URMs), as well as general retention in the College of Science and Engineering (COSE). The study was multifaceted and included a portion of the grant that focused on improving retention rates for ENGR and ET through an intervention to give them career insights and/or design experience.

Due to a Texas Law that states that state universities cannot require an excess of 120 hours to complete a degree unless otherwise specified by a third-party accreditor [7], Texas State University does not provide an Introduction to Engineering course to its students. To comply with the time constraints set by the State of Texas and to increase retention in ENGR and ET, the general university introduction class (US1100) was modified to include basic engineering design concepts and early career insights to freshmen in these fields.

All US1100 courses were required to cover common themes and assign three standardized career exploration assignments. Outside of these common requirements, instructors of US1100 sections had the freedom to customize their courses. For the experimental section of US1100, the customization featured elements of typical introduction to engineering courses. Swail's Geometric Model of Student Involvement [1] was used to develop the specialized curriculum used for the experimental sections of US1100 by recognizing the cognitive and social factors of college life for a Texas State University ENGR or ET student. To do this, early career insight opportunities were provided to the students by way of providing occasional plant tours, talking with industry representatives, meeting student leaders of relevant organizations, providing students with engineering faculty as mentors, and finally, introducing them to the design process, working in teams, technical writing, and oral presentation.

More specifically, cognitive stimulation was supplied by introducing the concept of engineering design to the students early in their academic career. In some sections of the experimental US1100 classes, a design project was completed after design theory was taught. Introducing students to design early on in their academic careers has been shown to help students develop crucial skills that they would need throughout the remainder of their education and well into their career, such as critical thinking, working effectively in teams, and technical communication [12-14].

By nature of the course, the social aspect of the college experience was touched on. Students that were involved in the experimental US1100 courses were all ENGR or ET students, and as such, had opportunities to interact with others who had similar interests. Additionally, students were exposed to various engineering-related societies that they were encouraged to join. Students were also given the opportunity to interact with and form mentoring relationships with engineering faculty. By giving the students chances to become involved in the university and to become more familiar with their chosen field of study, it is shown that they have a higher chance of being retained [2, 3]. Additionally, discussion was held in experimental sections regarding implicit biases

regarding what it means to be an engineer and who can become an engineer on occasion when the instructor deemed it necessary.

Methodology

The purpose of this study is to measure how a modified introductory engineering course affects two-year retention of students who took the experimental classes, with the goal of improving retention overall, and with a focus on URM and women in ENGR and ET. The data collection period began in Fall 2015 and will conclude in Fall 2020. Each experimental cohort took place only in the fall semesters (Fall 2015 through Fall 2018), and participants were tracked for two years after their intervention to verify that they were retained within their field of study. For each semester, there were two different types of experimental classes, both aligning to different aspects of Swail's Geometric Model of Student Involvement. There was also a control group to benchmark any effects found on student retention by intervention.

The first type of experimental course was called "Early Career Intervention" (ECI). The purpose of this section was to expose students to as many career opportunities having to do with engineering as possible. This aligned more with the social aspect of Swail's model by supplying students with faculty, student, and industrial network that they could utilize throughout their academic career at Texas State University. Additionally, the students were referred to engineering-specific resources that were at their disposal on campus.

The second type of experimental class included a small design project that emphasized the basic concept of design theory. In addition to supplying the design students with the same resources as the ECI students, this class type sought to teach students the basics of design theory by including a few short lectures on the topic followed by a simple design project. This provided students with a more balanced experience (according to Swail's model) by incorporating cognitive aspects into their first-year experience, as well as social ones. The students were required to work in groups to design a hands-free cell phone holder for their vehicles using the resources at Texas State University's makerspace, Bobcat Made, or elsewhere. This makerspace includes equipment such as 3D printers, a desktop CNC machine, CNC cutters, sewing and embroidery equipment, and more. A hands-free cell phone holder was chosen as San Marcos, Texas, where Texas State is located, had just passed a city ordinance banning hand-held devices while driving and, therefore, the needs for a hands-free holder was timely for the students. Upon the completion of the project, the students were required to write a report about their design, as well as give a short oral presentation to the class. They were also introduced to early career insight opportunities and given resources to succeed in their major.

Control groups were considered by using retention and demographic data from ENGR and ET students that enrolled in the regular version of US1100, which included general university resources and support that is not specific to any college or field of study. These areas of support include the university counselling center, general tutoring services, and more.

Because this study began in Fall 2015 and it is measuring two-year retention, only two-year retention data from the first cohort of the study and one-year retention data from the first and second cohorts of the study were available for analysis. Students who were enrolled in ENGR or ET were considered in their respective cohorts, and their major was recorded. An anonymous numerical ID was used to identify which students were enrolled in the experimental and control

sections of the US1100 course, their URM status, first generational status, gender, and retention status.

IBM’s SSPS software was used to analyze the retention data. Retention data was analyzed in a variety of ways by comparing single or multiple combinations of identifying characteristics of students to one and two-year retention status. The data was examined by individual demographic of the overall population, as well as by major. Chi-square testing was used to determine the driving factors of retention (or lack thereof). If a sample size was too small to qualify for chi-square testing, Fisher's Exact test was used to look for statistical significance of trends.

Results & Discussion

Because this analysis took place in Spring 2018, only one-year retention data for Fall 2015 and Fall 2016 cohorts were available, and two-year retention data for only the Fall 2015 cohort was available. As such, analysis was limited due to sample sizes. While only few statistically significant results were achieved, it should be noted that this section will discuss trends in the data that were found that could not be verified statistically due to issues with sample sizes. A breakdown of sample sizes per each demographic group analyzed is available in Figure 1. Since sample sizes were so limited, one-year retention data was examined in an effort to produce the largest sample sizes for more accurate testing. Investigation on the effects of both types of intervention for two-year retention will commence when more data is available.

ENGR			Females ENGR			Males ENGR		
Control	Design	ECI	Control	Design	ECI	Control	Design	ECI
182	21	36	36	3	4	146	18	32
ET			Females ET			Males ET		
Control	Design	ECI	Control	Design	ECI	Control	Design	ECI
243	23	21	35	2	6	208	21	15
All			Females All			Males All		
Control	Design	ECI	Control	Design	ECI	Control	Design	ECI
425	44	57	71	5	10	354	39	47
URM ENGR			Non URM ENGR			First Gen ENGR		
Control	Design	ECI	Control	Design	ECI	Control	Design	ECI
102	15	16	80	6	20	148	15	27
URM ET			Non URM ET			First Gen ET		
Control	Design	ECI	Control	Design	ECI	Control	Design	ECI
110	15	14	133	8	7	194	17	17
All URM			All Non URM			First Gen All		
Control	Design	ECI	Control	Design	ECI	Control	Design	ECI
212	30	30	213	14	27	342	32	44
Non First Gen ENGR								
Control	Design	ECI						
34	6	9						
Non First Gen ET								
Control	Design	ECI						
49	6	4						
Non First Gen All								
Control	Design	ECI						
83	12	13						

Figure 1: Sample Sizes

For no intervention, students in both major types were retained at approximately the same rate as each other (that is, somewhere around 78%), as shown in Figure 2. However, analysis of retention by major grouping yielded different results. Though statistical analysis did not yield a significant trend, there is a large retention gap between ET and ENGR students who underwent Design Intervention.

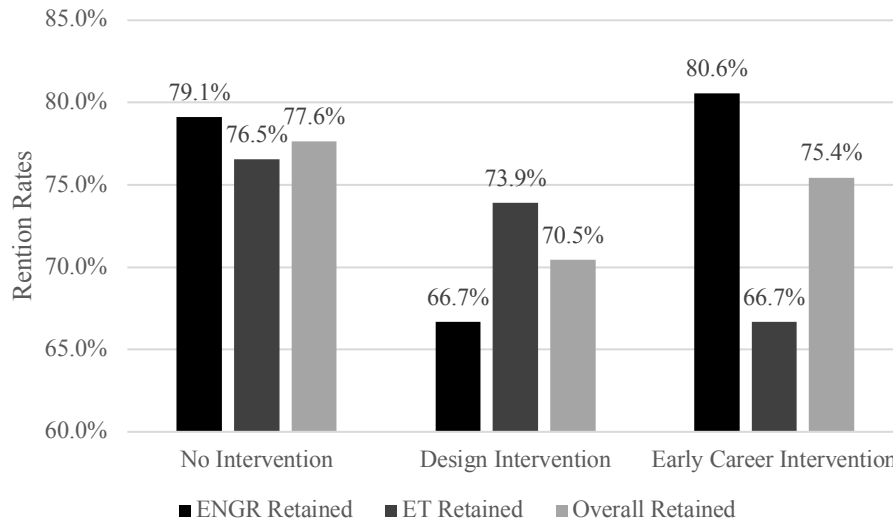


Figure 2: Overall, ENGR, and ET Students First Year Retention Rates by Intervention Type

ENGR students who participated in the design group were less likely to be retained, at 66.7%, to ET's 73.9%, as shown in Figure 2. This could be due to the hands-on nature of Texas State University's ET department, and ET students' desire to "learn by doing." This is further evidenced by the fact that 80.6% of ENGR students were retained to ET's 66.7% after Early Career Intervention. By simply talking about career opportunities available to ENGR and ET students as opposed to practicing a hands-on approach of what they would likely be doing after graduation, ET students were driven away from their chosen major. This is a troubling trend, and one that warrants further investigation as more data becomes available. Perhaps exposing ET students to interactive learning opportunities early on has the potential to increase retention and should be investigated.

Texas State University, like many other universities, struggles with the underrepresentation of women and minorities in STEM. As a result, studying the effect of intervention types on females and URMs was difficult due to the small sample sizes available to analyze, and statistical significance was not shown for these minority groups. However, it was encouraging to find that women, though less represented, seem to be as persistent about being retained compared to their male counterparts, with a retention rate hovering near 78%. Additionally, percentage trends indicate that women were retained at 80.0% after ECI. Unfortunately, female retention in ENGR and ET combined drops to 60.0% after Design Intervention. Due to sample sizes, further investigation is needed to determine definitively what effects intervention had on women in ENGR and ET.

Along this same vein, non-statistical percentage trends of URM retention in ENGR and ET combined is 10.0% lower than that of non-URMs, which sits at 82.6%. Interestingly, this trend is reversed after ECI, where URM students were more likely to be retained than non-URM students at 80.0% retention, to non-URM retention rates of 70.4%. This represents a 7.4% increase in retention of URM students after ECI compared to the control group, which is a promising result.

The reason these students were more likely to be retained remains to be seen after more extensive analysis.

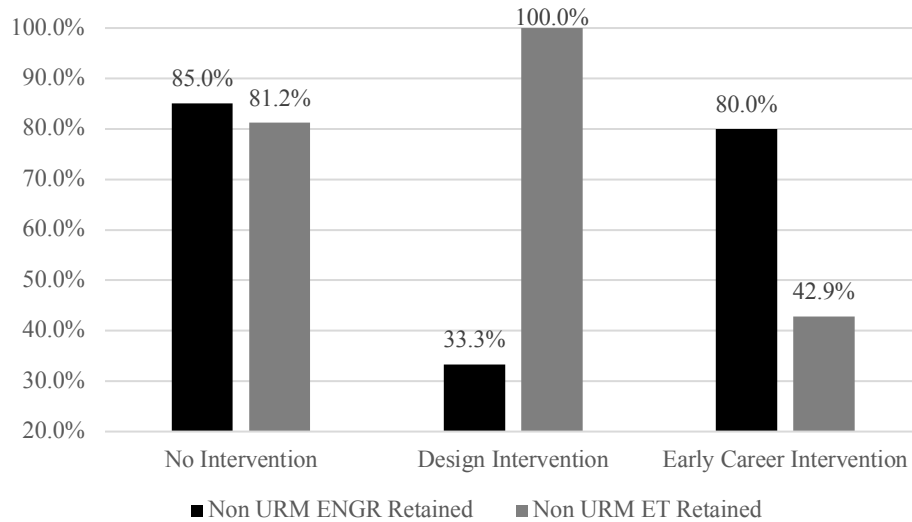


Figure 3: Non-URM ET vs. ENGR Students Retention Rates by Intervention Type

Due to sample size limitations, it was difficult to obtain statistically significant results, and there were very few that were valid. Interestingly, the non-URM group in ENGR and ET were the subjects of these statistically significant results. Non-URMs in ENGR were heavily influenced to leave their chosen majors by Design Intervention compared to the control group, as shown in Figure 3. Only 33.3% of non-URMs were retained after Design Intervention, while 85.0% of non-URMs in the control group were retained ($p = 0.010$). Statistical analysis of this same demographic comparing participants in Design Intervention and ECI was nearly significant ($p = 0.051$), where 33.3% of Design students were retained to 80.0% of ECI students. For engineering technology, non-URMs were less likely to be retained by ECI. Non-URMs in ET who participated in ECI were 42.9% retained, while non-URMs in ET that were in the control group were retained at 81.2% ($p = 0.034$). Lastly, non-URMs in the all ET majors were statistically more likely to be retained by Design Intervention than ECI. 100.0% percent of the ET students who participated in Design were retained, compared to 42.9% of those who had ECI ($p = 0.026$). These percentage trends can be found in Figure 3.

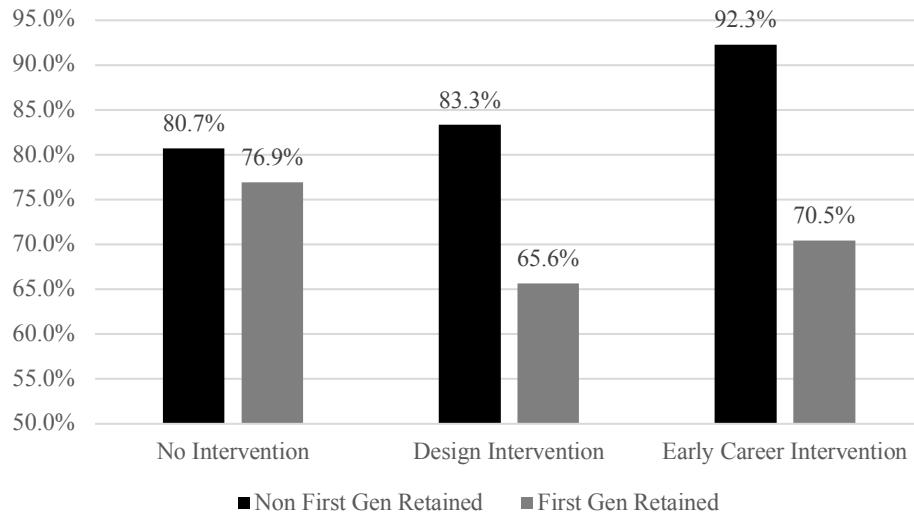


Figure 4: First Generation vs. Non-First Generation Retention Rates by Intervention Type

First generational students are at a higher risk of not being retained in any college major, let alone in engineering, citing their lack of preparedness, lack of integration into postsecondary education, and lower self-efficacy than their non-first generational peers [19-20]. While the original purpose of this study was not to increase first-generational retention rates, the prospective results of intervention were enticing enough to warrant further investigation. Analysis shows that non-first generational students are retained better by intervention than first-generational students, though the result of this test was not significant. Furthermore, this trend, which is shown in Figure 4, was one of the only results that showed a relatively strong positive impact on any demographic without being statistically significant and could be a result of non-first generational students being more likely to be retained in the first place. While also not statistically significant, non-first generational students were retained at a higher rate by Design Intervention by 2.6%. More significantly, this boost in retention is heightened by 11.6% after ECI. Retention rates for first-generation students were negatively impacted by both Design Intervention and ECI. Trends for first generation student retention can be found in Figure 4.

Conclusion

Ultimately, more data is necessary to determine precisely the effects of both Design Intervention and ECI on two-year retention rates. However, preliminary data shows that both interventions may not be as successful for general retention efforts as previously anticipated. There is some slight evidence supporting Design Intervention for ET students at Texas State University, as well as evidence supporting ECI for ENGR students, and particularly women. Strangely, both intervention types had a particularly negative effect on non-URMs, non-first generation students, males, or a combination of any of these demographics, which typically represent the dominate groups in engineering programs.

Future work will complete this study with the full data set and seek corrective action for the troubling trend of intervention driving students away. Additionally, more tailored approach to each major type may be necessary in order to prevent negative consequences of intervention.

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