Rewards of an Engineering Prerequisite Assignment

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Rewards of an Engineering Pre-Requisite Assignment

Abstract

This evidence-based practice paper describes a proposal for an assignment in an introduction to engineering course designed to help students become aware of just what it takes academically to obtain an engineering degree. In an effort to promote this awareness, the authors have instituted an assignment that is designed for the students to explore various universities, their engineering programs, and the prerequisites for those engineering programs. The qualitative data gathered through the assignment reflections were analyzed using criteria-based content analysis.

Students have, to a significant degree, found this assignment to be quite interesting and useful. Students come away with an understanding that engineers are all related in a way that they require almost the same core mathematical skills to obtain their engineering degree. It is often surprising to the students the various science courses that are required, regardless of the engineering degree sought. Some students are not aware of what a prerequisite is. Students frequently remark that this assignment "opened my eyes because if I begin a program at one university and decide to continue the program in another I may be required to take extra coursework to meet the requirements." Other students are convinced that they are going to pursue a particular engineering degree and as a result of the assignment, they choose a totally different engineering degree to pursue. Quite often, students are not even aware of all of the different types of engineering degrees available. This is even after they have covered the various engineering degrees via their textbook readings and assessment. It seems that doing research on their own solidifies the information. Another critical outcome is that some students realize that an engineering degree might not be for them or may not be a realistic goal. It is common for students to be surprised that "an engineering degree is a very complicated goal to achieve."

Along with the requirements of different engineering programs, students learn about various tuition and enrollment statistics for both public and private institutions. As a result of this assignment, students are able to plan better because they are more aware of the requirements and can better gauge a realistic timeline for graduation. This assignment has given the authors a surprising gratifying result, being thanked by students for giving an assignment!

In this paper, the authors will share the idea behind creating the assignment, the assignment itself, and the analysis of the results of the assignment after using it four semesters in both ground and online sections of an introduction to engineering course at Florida SouthWestern State College.

Introduction and Background

While teaching an Introduction to Engineering course, the authors often start the semester by surveying our students as to whether or not they would like to become engineers and if so, which fields of engineering interest them. While many of our students have an answer to that question, we find that most don't really understand the differences between different engineering fields, and fewer understand all the requirements it takes to each a bachelor's degree in engineering. One of the goals of our course is to help students not only gain an appreciation for engineering

and the various engineering opportunities but also to become aware of just what it takes academically to obtain an engineering degree. In an effort to educate students, we have instituted an assignment that is designed for the students to explore various universities, their engineering programs, and the prerequisites for those engineering programs.

Literature Review

One of the current challenges facing the engineering community is the both finding and keeping qualified students. Over the last few decades, significant research has been done on the graduation rates of engineering programs in the United States amidst concerns that we will not have enough engineers to meet the ever-growing need [1] [2] [3]. Increasing the number of graduates from engineering programs will depend both on increasing the number of students enrolling in engineering programs, as well as increasing the year-to-year retention rate so that these students graduate [3].

Studies have shown that a student's motivation for studying engineering are tied to their exposure to the activities that engineers engage in [4]. With the goal of increasing not only the number of student's pursuing an engineering degree but also the quality of the students, many engineering colleges are heavily invested in programs that expose pre-collegiate students to engineering [5]. Additionally, the role of community colleges in increasing the number of students choosing the engineering field is growing. Community colleges are often gateways to a bachelor's degree by offering a low-cost platform from which students might then pursue traditional academic programs in baccalaureate colleges and universities. Many community colleges have transfer agreements with 4-year baccalaureate colleges and universities [6]. This is particularly relevant for increasing minority students in engineering programs. Approximately 44 percent of all U.S. undergraduates enroll in two-year colleges. This enrollment contains a large percentage of underrepresented groups. For example, over half (54 percent and 52 percent, respectively) of Hispanic and American Indian undergraduates were enrolled in two-year colleges in 1996, and 46 percent of African Americans were enrolled in these institutions. Thus, these institutions provide a valuable and diverse source of potential students into engineering programs [7].

Significant studies have further focused on what makes an engineering student successful. Traditional scores, such as high school GPA and math SAT scores, were positively correlated with graduation rates [8]. While some studies focused on having adequate mathematics preparation in high school, others argued that taking (and earning high grades in) such classes as science, physics, social sciences, chemistry, and calculus are significant in predicting retention in engineering programs [3]. Other studies have focuses on the characteristics of the students themselves, citing student's persistence and self-efficacy, defined as "people's judgment of their capabilities to organize and execute courses of action required to attain designated types of performances" as significant [9]. Students with high self-efficacy were only found among groups of students who had pre-engineering classes and engineering hobbies versus students who did not have these experiences. Not surprisingly then, students most likely to complete degree requirements have success in high school math and science courses, an interest in science, and have positive perceptions of engineering [9].

The question then becomes why so engineering students leave engineering programs to pursue other degrees. Some studies cite that engineering students' retention in programs is comparable to other majors, but that students do not transfer into engineering at comparable rates, and that those who leave are disproportionately from groups underrepresented in engineering, including first-generation college attendees. This results in a smaller and less diverse graduating class [4]. Many other studies cite student preparedness, or lack thereof, as a major reason student leave engineering [10] [11] [12]. Other studies suggest that students who leave engineering are often doing well academically, citing not only inadequate high school preparation as a major reason for leaving, but also such factors as unwelcoming academic climate, conceptual difficulties with core courses, a lack of self-efficacy or self-confidence, insufficient interest-in or commitment-to the field of engineering or a change in career goals, and racism and/or sexism [3]. Furthermore, other studies cite institutional factors such as disappointment with engineering advising as significant, as academic advising to guide students through the proper sequence of classes is very important to student success in engineering [13] [14] [15]. Specifically, students felt the information provided by advisers on course requirements was inaccurate, that advisers did not make students aware of programs for help on coursework and financial aid, and that students were not informed of career opportunities [16]. Further studies focused specifically on the challenges of students transferring from community or state colleges and found similar themes of informational setbacks from dissatisfactory advising, as well as imperfect program alignment with four-year institutions. These factors often were found to contribute as students took unnecessary courses or could not get into courses in a timely manner, resulting in lost time, money, and credit. An accumulation of delays is particularly detrimental to STEM women and men, given the sequential nature of their programming, and the community college transfer pathway to a bachelor's degree often taking much longer than four years [17]. Overall, transfer students reported significantly lower levels of motivation to study engineering for financial reasons than non-transfer students [4]. Finally, some literature suggests retention rates are tied to the complex relationship among learning styles, study habits, and performance [18].

In order to improve retention, many different institutions and programs have instituted programs and methodologies to address many of the reasons discussed above. Many institutions focus on the preparedness of incoming engineering students with the development of university learning center to provide student support and tutoring, mentoring programs [19], programs specifically developed for at-risk students, and programs specifically for first-year students and career awareness [10]. Others are looking to redefine the way in which engineering mathematics is taught, with the goal of increasing student retention, motivation and success in engineering [20]. Many focused on improving engineering advising [12] [17] [15] [16]. Some focused on changing the climate of the engineering classroom by changing teaching methods [21] [22] to more active teaching methods that focused on the idea of learning how to learn [23]. Finally, some proposed the incorporation of an entrepreneurial mindset to improve student success, stating "Career paths in science, technology, engineering, and mathematics (STEM) disciplines are increasingly entrepreneurial. . . Having a firm grounding in entrepreneurship with an emphasis on innovation and invention may be the best way for science students to prepare for the 21st-century workforce" [24] and "while not all students want to start a business, all students can benefit from being entrepreneurial in their daily lives. Yet, when you retrace the steps taken by entrepreneurs', you find they are driven by a problem they are compelled to solve. They engage

in a search process of discovery to find a solution that creates value for their organizations and communities" [25].

Our Institution and Our Course

Our institution, a state college, is often the starting point for many students they begin their undergraduate education, with approximately half of our student perusing an association in arts degree with the intent to transfer to a university to earn a bachelor's degree. Although we do not offer any bachelor's degrees in engineering, as part of a few of our associate's degree program the student's take our Introduction to Engineering course. The course has also become popular as a general education credit towards the associates of arts degree with both our dual enrollment students and our students wishing to transfer to a university offering degrees in engineering. The course is now offered both in a traditional ground setting and online. Some of the goals of teaching the course are to expose our students to the different engineering fields, examine the engineering design process, explore the challenges facing engineers today, and hopefully inspire them to pursue engineering majors as they transition to universities. As part of that process, we also want students to become aware of just what it takes academically to obtain an engineering degree, as well as help them create a path to achieve their educational goals. As part of that process, we have created an engineering assignment that is designed for the students to explore various universities, their engineering programs, and the prerequisites required for those engineering programs.

The demographics of Florida SouthWestern include a headcount of 16,830, with 36.3% full-time and 63.7% part-time students. In terms of age, 74.8% of students are 24 years old or younger and 25.2% of students are over the age of 24. The gender breakout is 61.9% are female, 37.9% are males and 0.2% is unknown. Race statistics are 46.0% are White, 32.0% are Hispanic/Latino, 10.9% are African American, and 4.9% are other minorities. The number of dual enrollment numbers is the only demographic available for the course that utilized this assignment. The dual enrollment numbers for the online course are 10% in the fall of 2016, 20% in the spring of 2017, 22% in the fall of 2017, and 21% in the spring of 2018. The dual enrollment numbers for the ground course are 11% in the fall of 2016, 0.05% in the spring of 2017, 11% in the fall of 2017, and 33% in the spring of 2018. Dual Enrollment students comprise 18.4% of the entire student body. While do not track the demographics of the students within our courses, we do believe our students are representative of the school's demographics in most areas, with the exception of the female to male ratio. There are usually more males than females in the course.

Reasoning Behind the Assignment

The assignment was developed initially to have students conduct background research about the requirements of various engineering programs as part of their effort to propose a new pre-engineering program at our institution. It was also of interest to discover how knowledgeable the students were about the requirements for obtaining an engineering degree. The course instructors believed that developing an assignment that required the students to identify the requirements for obtaining an engineering degree at several different universities was original and of interest to the engineering education community. After the initial success of the adding the assignment to

the course, the assignment was refined and incorporated into both the ground and online sections of the course.

At the time of the semester when the students received this assignment, they had learned about the history of engineering, the different engineering majors, and their related statistics. While learning about the various engineering fields, the textbook and lectures introduce the importance of mathematics and physics to obtaining an engineering degree. Once presented with the information, the students take a quiz over the information regarding engineering majors. At this point in the semester, the students are to complete the assignment, called Requirements For Engineering Majors Assignment.

The design of the assignment itself was meant as an active learning assignment in the hopes that students would be able to learn where to find degree requirement information on their own, gain a true understanding of course pre-requisites, how pre-requisites fit into the curriculum of various engineering programs, and begin thinking about what the importance of transferring credits. In essence, we hope to teach the skills they would need to gather the information they needed to have meaning interactions with their advisers, or to be able to research and create realistic educational plans for themselves.

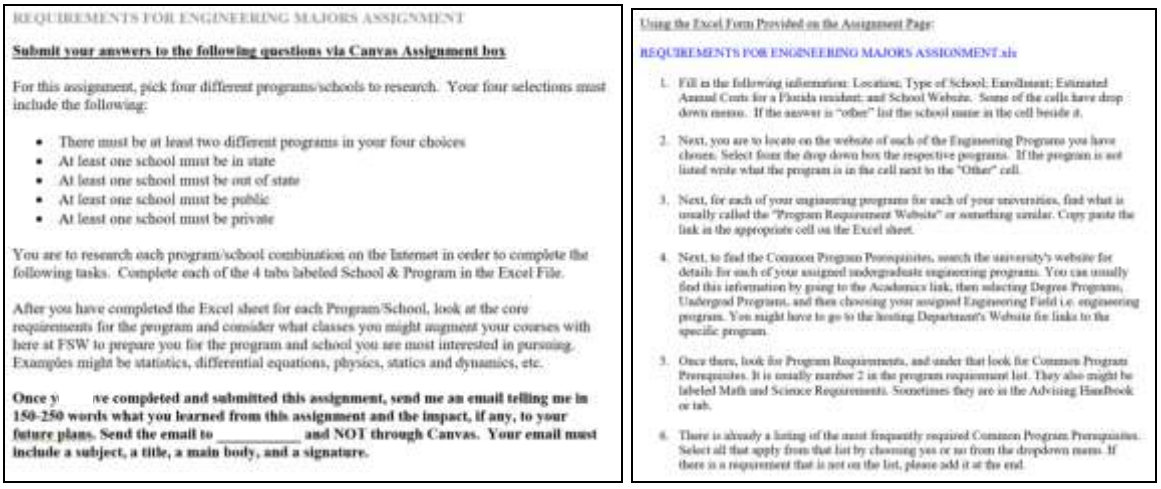
The Assignment

The students are given two weeks to complete the Requirements For Engineering Majors Assignment because it can be time-consuming for students to access and navigate university websites, especially if they are not used to doing so. The assignment itself is shown in Figure 1.

The assignment of the schools to research has varied semester to semester. One option is that each student is assigned either four (4) universities with one (1) engineering program to investigate or one (1) university with four (4) engineering programs to investigate. Figure 1 shows an alternative assignment option, requiring a combination of schools and programs. The authors also prepared an Excel template that was included in the assignment to help ensure that the results would be organized and that all information could be easily collected and graded. The Excel template was designed to have all the relevant information written in specific cells and for those questions that had pre-determined answers, drop down menus were provided. The students were to use the same template for all for components of the assignment.

We also note that the template contains common courses such and Calculus and Physics by their common state nomenclature. Our state has a statewide course numbering system [26] that applies to both the public community and state colleges as well as the public universities. As part of the introduction to the assignment, instructors often spend time in class discussing the statewide course numbering system and the advantages and disadvantages of the system to transferring students. Within the assignment, students were given tips on how they might find information on the website. Lessons learned from using the template include defining "enrollment" to mean specifically "undergraduate enrollment." Also, the "estimated annual cost" would have better been defined as "estimated annual cost without housing costs."

At the end of the assignment students were asked to reflect on what they learned, and email the instructor a summary of their reflection. The students were required to email the instructor outside of the school learning management system with the secondary goal of having the students practice sending professional correspondence.



REQUIREMENTS FOR ENGINEERING MAJORS ASSIGNMENT

Submit your answers to the following questions via Canvas Assignment box

For this assignment, pick four different programs/schools to research. Your four selections must include the following:

- There must be at least two different programs in your four choices
- At least one school must be in state
- At least one school must be out of state
- At least one school must be public
- At least one school must be private

You are to research each program/school combination on the Internet in order to complete the following tasks. Complete each of the 4 tabs labeled School & Program in the Excel File.

After you have completed the Excel sheet for each Program/School, look at the core requirements for the program and consider what classes you might augment your courses with here at FSW to prepare you for the program and school you are most interested in pursuing. Examples might be statistics, differential equations, physics, statics and dynamics, etc.

Once y ve completed and submitted this assignment, send me an email telling me in 150-250 words what you learned from this assignment and the impact, if any, to your future plans. Send the email to _____ and NOT through Canvas. Your email must include a subject, a title, a main body, and a signature.

Using the Excel Form Provided on the Assignment Page:

REQUIREMENTS FOR ENGINEERING MAJORS ASSIGNMENT.xls

1. Fill in the following information: Location; Type of School; Enrollment; Estimated Annual Costs for a Florida resident; and School Website. Some of the cells have drop down menus. If the answer is "other" list the school name in the cell beside it.
2. Next, you are to locate on the website of each of the Engineering Programs you have chosen. Select from the drop down box the respective programs. If the program is not listed write what the program is in the cell next to the "Other" cell.
3. Next, for each of your engineering programs for each of your universities, find what is usually called the "Program Requirement Website" or something similar. Copy paste the link in the appropriate cell on the Excel sheet.
4. Next, to find the Common Program Prerequisites, search the university's website for details for each of your assigned undergraduate engineering programs. You can usually find this information by going to the Academics link, then selecting Degree Programs, Undergrad Programs, and then choosing your assigned Engineering Field i.e. engineering program. You might have to go to the hosting Department's Website for links to the specific program.
5. Once there, look for Program Requirements, and under that look for Common Program Prerequisites. It is usually number 2 in the program requirement list. They also might be labeled Math and Science Requirements. Sometimes they are in the Advising Handbook or tab.
6. There is already a listing of the most frequently required Common Program Prerequisites. Select all that apply from that list by choosing yes or no from the dropdown menu. If there is a requirement that is not on the list, please add it at the end.

Figure 1. Requirements For Engineering Majors Assignment

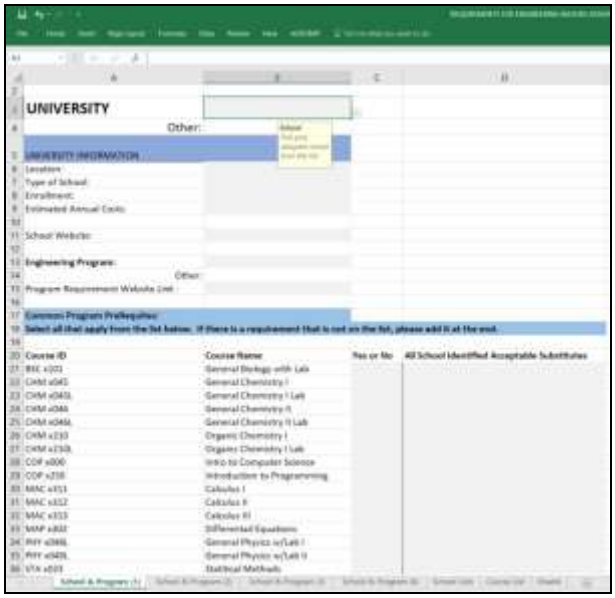


Figure 2. Requirements For Engineering Majors Assignment Excel Sheet

Methodology

In analyzing the impacts, we focused on the qualitative data gathered by the reflective summary portion of the assignment. The reflective summary portion simply required the student's to answer the open-ended requirement to discuss "what you learned from the assignment, and the impact, if any, on your future plans." To analyze the data, we used criteria-based content analysis.

First, results of the literature review were consolidated into six specific outcome categories. These categories are listed in Table 1: Criteria Categories. We then determined what key words and phrases were linked to each of these categories. These are also shown in Table 1. Next, the reflective summaries were color-coded based on keywords or phrases used by the students in their summaries. After the initial color doing was completed, the authors validated the others coding. Finally, a count of the different outcomes was made and tabulated as percentages. Many of the summaries contained more than one of the outcome criteria, so the percentages tabulated do not sum to 100%.

Outcome	Title	Description
1	Self-Advising	Students are able to determine what the prerequisites are to obtain an engineering degree by learning to navigate the information provided on multiple engineering program websites; students create their own course schedule based on their new understanding of the requirements Keywords/phrases included: courses, pre-requisites, requirements, program websites, criteria
2	Student Motivations	Students discussed their motivation to either realistically consider an engineering degree, or their motivation to pursue alternative degrees Keywords/phrases included: doesn't change plans, confirmed plans, considering engineering, changing engineering field, changing degrees
3	Student Preparedness	Students discussed an understanding math and science requirements for an engineering degree; students discussed their preparedness in term of their math and/or science coursework Keywords/phrases included: math, science, understanding topics, chemistry requirements, science requirements, math topics, understanding math, wake-up call, reality
4	Financial Impacts	Students discussed financial implications of various schools, degrees, or programs Keywords/phrases included: financial, cost(s), differences between public and private, in-state, out-of-state, GI Bill, tuition, loan, expensive
5	Problem Solvers (ties in with entrepreneurs)	Students discussed being independent learners and problem solvers Keywords/phrases included: taught me, used resources, available resources, learned a lot
6	Appreciation of Engineering	Students discussed an appreciation of the various fields of engineering Keywords included: differences in fields, amount of work, engineering options, salary

Table 1. Criteria Categories

Results of the Assignment Analysis

As professors who regularly attempt to advise students on the best course for pursuing their desired educational goals, this assignment has proved to be extremely valuable. We found the best assignment method was to have student university and program assignments made anonymously and randomly, to ensure the trustworthiness of the results, and to force students to explore options they may not have previously considered. We also found specifically requiring students to pick schools that were both public and private, and in- and out- of state helped the students to explore other options as well.

The results of the criteria-based content analysis are summarized in Table 2: Content Analysis.

Outcome	Title	Term and response rate (ground, online)	Number of Responses		Percentage of Responses		Total Percentage Across Terms
			Ground	Online	Ground	Online	
1	Self-Advising	Fall 2016 (18,22)	11	17	61%	77%	**68%**
		Spring 2017 (21,20)	17	13	81%	65%	
		Fall 2017 (19,11)	14	8	74%	73%	
		Spring 2018 (12,19)	6	11	50%	58%	
2	Student Motivations	Fall 2016 (18,22)	7	11	39%	50%	**40%**
		Spring 2017 (21,20)	5	2	24%	10%	
		Fall 2017 (19,11)	12	2	63%	18%	
		Spring 2018 (12,19)	9	9	75%	47%	
3	Student Preparedness	Fall 2016 (18,22)	5	18	28%	82%	**52%**
		Spring 2017 (21,20)	6	10	29%	50%	
		Fall 2017 (19,11)	9	5	47%	45%	
		Spring 2018 (12,19)	4	17	33%	89%	
4	Financial Impacts	Fall 2016 (18,22)	4	3	22%	14%	**30%**
		Spring 2017 (21,20)	7	5	34%	25%	
		Fall 2017 (19,11)	11	3	58%	27%	
		Spring 2018 (12,19)	3	6	25%	32%	
5	Problem Solvers (ties in with entrepreneurs)	Fall 2016 (18,22)	1	2	6%	9%	**11%**
		Spring 2017 (21,20)	3	3	14%	15%	
		Fall 2017 (19,11)	2	1	11%	9%	
		Spring 2018 (12,19)	1	2	8%	11%	
6	Appreciation of Engineering	Fall 2016 (18,22)	5	6	28%	27%	**27%**
		Spring 2017 (21,20)	4	6	19%	30%	
		Fall 2017 (19,11)	6	6	32%	55%	
		Spring 2018 (12,19)	2	4	17%	21%	

Table 2. Content Analysis

Below are summaries of our findings by outcome and representative comments directly from the student reflective summaries in each outcome criteria.

Outcome 1: Self Advising. The outcome of this research is that predominately students were able to determine what the prerequisites are to obtain an engineering degree by learning to navigate to program websites. Those students who did not even know what a prerequisite was, were able to come away with new knowledge. Some of the students created their own course schedule based on their new understanding of the requirements, in effect self-advising. Some of the student reflections are shown below:

> *"I never really understood how credits worked either [sic] I have been guessing a lot of my college stuff."*

> *"Until this moment, I was under the impression that classes such as Chemistry would not be included in the required prerequisites for my desired engineering profession, Mechanical Engineering. I have since devised and launched a plan to add Chemistry 1 With Lab, to my course schedule for the 2018 Spring semester."*

"I am in shocked of how many math courses needs [sic] to be taken. Also this assignment made me think about my future and how I am going to approach the upcoming years. With the information that I've searched [sic] will help me create my own schedule with what classes I should take first and then what to take next."

Outcome 2: Student Motivations. The assignment had the benefit of addressing the student's motivation for achieving an engineering degree. There were approximately 10% of the students who has a result of the study, determined that engineering was not for them. The degree of course difficulty required dissuaded the students from pursuing the engineering degree, which was not surprising as many of our students were already focused on completing an associates of science degree and joining the workforce, while others are dual enrollment high school students who do not have any real expectations of seeking a degree in engineering. Some students were either inspired to realistically consider an engineering degree, which we expected as students taking the class as an elective were predispositioned to be interested in engineering, and as some of them were already planning and engineering degree as part of their program of study (or cynically, as students were telling us what they thought we wanted to hear). Some of the student reflections are shown below:

"This assignment remined [sic]me of the long road I have in front of me, and it motivated me to stay on track and be persistent."

"I now know much more of what is needed of [sic] me to succeed in this field if I still want to choose this path and now I'm rethinking my future major as a whole which I did not expect when starting this assignment."

Outcome 3: Student Preparedness. This outcome looks at whether or not the students had a thorough understanding of the prerequisite courses, particularly in math and science, required for an engineering degree. This was important as the success of engineering students is often tied to student preparedness. Our hope is that by making students aware that the courses they need to successfully transfer to an engineering program are much greater that the courses they need to earn an associates of arts degree and transfer to a university in general. Some of the student reflections are shown below:

"The assignment gave me a wakeup call, showing me that any degree may require a number of prerequisites and degree requirements before graduating."

"One of the thing that I learned from this assignment, is that no matter what type of engineering you're going to be, it required a lot of effort."

"I'm going to have to practice math more or I will struggle seeing [sic] that there is [sic] a plethora of math related [sic] classes."

Outcome 4: Financial Impacts. This outcome looked at student understanding of the costs associated with obtaining various degrees. Surprising to us, many did not know the different costs for different schools (private vs public, and out-of-state vs in-state). For our student population, financial implications can have a big impact on student retention. Some of the student reflections are shown below:

"If I would like to attend an out of state college or university it will cost more

than [sic]an in state[sic] university."

"One other thing that stood out for me while doing my research was the enormous price difference in out of state vs. in state [sic]tuition. I always knew that it was more expensive to go to school out of state, but i [sic] never realized exactly how much"

Outcome 5: Problem Solvers (ties in with entrepreneurs). This outcome looks at the student ability to problem solve, and ties in with the idea that entrepreneurial thinking is important to engineering. We that the format of the assignment helped students to be more independent learners and problem solvers, as seen below.

"For one this assignment has taught me to use my resources and dig to get information."

"I now know more than ever the paths that are available to me and I am going to take full advantage of that."

Outcome 6: Appreciation of Engineering. This outcome focuses on student appreciation of the different fields of engineering as well as an appreciation for what it takes to become an engineer. We feel the assignment helped with one of the other goals of the course – to have students leave with an appreciation of the various fields of engineering.

"Classes change drastically when looking though [sic] different engineering majors. A mechanical engineer has to take different classes compared a Bio-Med engineer. I would have thought that they would be somewhat similar since they are both engineering, but as I was looking at requirements for the programs. They were completely different."

Conclusions

While this research does not cover retention rates with our student population, nor does future research plan to do so, it would be interesting to discover if the students that were not deterred by the requirements of obtaining an engineering degree as a result of this assignment, did indeed continue on to pursue an engineering degree. A significant outcome of the study was that as a result of this assignment, students did discover that they did not want to pursue an engineering degree. This saved many students and possibly their families, time and money. Overall, the students become more aware of what it takes academically to obtain an engineering degree.

The implications of this work for the higher education community is two-fold. Primarily, students who are in secondary education should know what a pre-requisite is; the differences between a public and private higher-education institutions; the number of higher-education institutions offering various degrees of interest to them (in this case engineering); and enrollment ranges. Secondarily, this research is of value to the engineering community in that even though STEM activities and outreach have greatly increased, there is still a widespread lack of understanding as to the degree of math and science that is required to obtain an engineering degree.

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