AC 2012-5340: CRITICAL QUESTIONS TO WHICH ENGINEERING STUDENTS NEED ANSWERS

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Critical Questions to Which Engineering Students Need Answers

Abstract

There are many questions for which prospective or current engineering and computer science students are seeking or should be seeking answers. These critical questions cover many areas including: why a BS in engineering, why engineering, how is an engineering discipline chosen, how is an undergraduate degree in engineering financed, why pursue an engineering degree at a particular institution, how important is a mentor, how important is research, what important skills are required of an engineer, how important is graduate school, what is an MS thesis, why get a PhD, how is a company started, and what factors should be considered in choosing a job. Each of these areas includes many sub-questions.

A list of 136 questions was compiled to begin the project of providing answers to the critical engineering student questions. The answers to these questions will eventually be posted on the website of an engineering transfer student program sponsored by the National Science Foundation under an NSF-STEP grant. Since it will take some time to compile all of these answers, in this paper we sought to identify the most critical questions for these students as the starting point for providing the answers.

An assignment relative to these 136 questions was given to the students in two academic success programs. The students were asked to read through the 136 questions and then to select and to rank the top 20 questions critical to them. The rankings of the top twenty questions were then analyzed as a whole to determine the most critical and then by the various populations: by academic standing, by transfer or non-transfer status, by scholarship status, by gender, and by ethnicity. The results of this analysis are presented in the paper.

By reviewing the results of this study, educators who are working with engineering students are alerted to these critical questions and can bring up these issues in discussions with their students and help to provide answers. These actions are designed to help retention, to increase the interest of students in engineering, and to have more engineering graduates go on to graduate school. In this paper, the term “engineering” will also include computer science, a major within the Ira A. Fulton Schools of Engineering at Arizona State University.

I. Introduction

The retention of engineering and computer science students has been studied for over forty years. Retention is usually discussed along with recruitment in connection with the shortage of engineers being produced in the United States. In August 2011, Paul Otellini, the president and chief executive of Intel Corp and a member of the President’s Council on Jobs and

Competitiveness, wrote a letter to the Editor of The Washington Post that includes a good summary of the situation: “A chronic shortage of engineering students threatens America’s role as the world’s leading innovator and continues to impede our nation’s fragile economic recovery. Over the past 20 years, the percentage of engineers graduating in the United States has stagnated, while India and China surpass us with rapid progress.” Because of this situation, President Obama convened the Council on Jobs and Competitiveness. Otellini “co-leads a task force in this council to address the need for more American engineers – the people behind the inventions and advancements that improve our quality of life and our nation’s wealth and competitiveness.”¹

This task force is focused on “programs that will yield 10,000 more engineering graduates in the United States each year and begin to address the long-term threat of our nation’s growing skills crisis.” US-based companies are being asked to sponsor mentoring programs, internships and permanent job commitments for students in engineering. During the past two decades, the overall number of college graduations has increased about 50%, but the number of engineers that US colleges and universities send into the workforce annually has stayed the same at around 120,000. The increase requested is 8.33% in engineering degrees. “By contrast, roughly 1 million engineers a year graduate from universities in India and China. This education disparity threatens to slow our economic recovery, stunts our long-term competitiveness, and leaves technology firms in a skills crisis.”¹

It is well known that about 40% of students enrolled in science, technology, engineering and mathematics leave their major after the first year. Less than 50% of the students who start in these majors actually complete their degree. Although this percentage is about the same as the attrition for non-technical majors, the impact is not as crucial. These numbers point out that both recruitment and retention are critical activities to ensuring that we increase the number of engineering graduates.

There are well-known largely untapped resources for more engineers: women, underrepresented minorities, and community college transfers. In response to the need for more engineers, the Ira A. Fulton Schools of Engineering has three National Science Foundation (NSF) S-STEM academic scholarship programs for engineering and computer science students: one for lower division students (#0807134), one for upper division transfer students (#0728965) (primarily from local community colleges (CCs)), and one for upper division non-transfer students (#1060226), as well as graduate students. Transfer students from five non-metropolitan CCs are supported with scholarships from an NSF STEP program (#0856834). The emphasis for these programs is on women and underrepresented minority students. The goal for these students is to enrich their academic experience, graduate them, and have them go right on to graduate school full-time in engineering or computer science for a Master’s or PhD. These students are all US citizens or permanent residents.¹¹⁻¹⁴

II. Literature Review

Many studies and reports have been written on the retention of engineering students. Some studies focus on freshmen or lower division students since most attrition occurs there. There are three major themes found in retention literature related to student retention: teaching and learning styles, student preparation, and student attitudes.¹ Learning styles have been studied to compare engineering technology students with engineering students, who generally prefer global learning.² Other studies have considered how learning style based innovations can be used to improve the retention of female engineering students with an emphasis on spatial reasoning.³ Other have studied improving engineering student retention through “hands-on, team based, first-year design projects”⁴

Student preparation has been studied from many angles. Classification systems have been developed for student characteristics affecting college enrollment and retention.⁵ The difference between rural and urban backgrounds have been shown to produce a difference in student performance and retention.⁶ Others have researched how to improve engineering retention using only incoming data.⁷

Student attitudes and perceptions can also influence retention.⁸ Additional research has looked at the retention of women, in particular, and tried to determine the effect of self-efficacy. Other studies have focused on increasing motivation for retention by increasing the interaction between students and between students and faculty. In another example, a research project at Oregon State University assessed freshmen student attitudes towards engineering, both as a student and as a chosen profession and the relationship between these perceptions. This study was prompted by the desire of that school to double the number of engineering graduates in five years.⁹

Papers on many of these subjects have also been written relative to upper division engineering students. Upper division students, in general, are two years older than freshman and they are closer to marriage, having children, trying to pay off a vehicle, beginning to think of a job, and are becoming confused with the many opportunities for specialization, to name a few of the differences.¹⁰

In this study, we look at both lower division and upper division engineering undergraduates, as well as some graduate students. We are exploring how we can help change engineering students' attitudes by providing answers to their questions. Having questions answered can be very important to a student, especially a first-generation student who does not have others close who know the answers.

III. Identifying Critical Questions

The authors have been working with engineering students for over 10 years through the NSF S-STEM Scholarship Programs. As a part of this program, an Academic Success Class is held and through this class the authors have been asked many questions. Some questions come through evaluations of the meeting in answer to the question. “Are there topics about which you want to know more?” Some questions come through emails from the student. Other questions come

through one-on-one dialogs with the students. Various methods have been used to help answer questions. In the past, the answers to all of the questions were typed out and given as a handout to the students at the next meeting. Later the answers to the questions were posted on the class Blackboard. Many of the same questions come up semester after semester.

There are many questions for which prospective or current engineering and computer science students are seeking or should be seeking answers. These critical questions cover many areas including: why a BS in engineering, why engineering, how is an engineering discipline chosen, how is an undergraduate degree in engineering financed, why pursue an engineering degree at a particular institution, how important is a mentor, how important is research, what important skills are required of an engineer, how important is graduate school, what is an MS thesis, why get a PhD, how is a company started, and what factors should be considered in choosing a job. Each of these areas includes many sub-questions.

To answer all of the pertinent questions will take some time, but we would like to start with those that are the most common to the various sets of students. A list of 136 questions was compiled to begin the project of providing answers to the critical engineering student questions. The answers to these questions will eventually be posted on the website of an engineering transfer student program sponsored by the National Science Foundation under an NSF-STEP grant 0856834. Since it will take some time to compile all of these answers, in this paper we sought to identify the most critical questions for these Academic Success students as the starting point for providing the answers.

An assignment relative to these 136 questions was given to the students in two academic success programs. The first class included 33 freshmen and sophomore engineering students who were recipients of an NSF S-STEM scholarship under grant 0807134. The second class included 113 students who were juniors, seniors, and graduate students in an academic success class where most of the students are scholarship holders of NSF S-STEM scholarships (grants 0728695 for transfer students and 1060226 for non-transfer and graduate students) or of NSF STEP grant 0856834 scholarships. Sixteen of the lower division students (48.5%) replied to the survey. Eighty-seven (77%) of the upper division and graduate students responded to the survey. All of these NSF programs have an emphasis on women and under-represented minority students. Over 60% of the scholarship students were female or underrepresented minority students. The scholarship students also all had unmet financial need, so financing graduate school is a real problem. The scholarship students all have 3.0 GPAs, but there are over 30 students who attend the class who do not have scholarships and may not have a 3.0 GPA nor unmet financial need. Most of the students are U.S. citizens or permanent residents.

The students were asked to read through the 136 questions and then to select and to rank the top 20 questions critical to them. The rankings of the top twenty questions were then analyzed as a whole to determine the most critical and then by the various populations: by academic standing, by transfer or non-transfer status, by scholarship status, by gender, and by ethnicity.

IV. Analysis and Discussion of Results

The students in the Academic Success Classes were instructed to select the most pertinent 20 questions to them out of 136 questions listed. The students were first asked for demographic data to allow an analysis by various classifications. There were 13 major categories of questions. The number in parentheses identifies how many questions were in that category.

1. BSE in Engineering (5)
2. Why Engineering? (8)
3. Choosing an Engineering Discipline (13)
4. Financing My BSE in Engineering (8)
5. Why Pursue a BSE in Engineering at ASU? (27)
6. Importance of a Mentor (6)
7. The Importance of Research: Figuring Out What I Want to Do (14)
8. Important Skills (24)
9. Importance of Graduate School (9)
10. The MS Thesis (6)
11. Getting a PhD (8)
12. Starting a Company (6)
13. Choosing a Job (2)

From the top 20 questions submitted by each of the 103 students, we determined the top five questions for each category. First, let us consider what the most important questions were by age group. See Table I.

Age	Category	Question	Sample Size
<21 Years	Why Engineering	Will there be a job for me when I graduate? Will it pay well? Will it be challenging or boring? Will it require traveling?	29 (64.4%)
	Getting a PhD	Why should I consider getting a PhD degree in engineering? What will it offer me over an MS in engineering? Advancement opportunities? Flexibility? Responsibilities? Salary?	24 (53.3%)
	Why Pursue a BS in Engineering at ASU?	How is my Engineering School viewed by industry?	22 (48.9%)
	Why Engineering?	What is the engineering work environment like?	20 (44.4%)
	Choosing a Job	How do I choose a job?	19 (42.2%)
>21 Years	Importance of Graduate School	How do I pay for Graduate School?	26 (44.8%)
	Important Skills	What professional organizations should I join? What do they offer?	24 (41.4%)
	Choosing a Job	How do I choose a job?	24 (41.4%)
	Choosing a Job	How should I weigh each of the following: engineering/technical responsibilities? Flexibility? Choosing what you work on? Flexible work hours? Working from home? Day Care? Work conditions? Work group dynamics? Opportunities for advancement? Location? Traveling? Benefits? Retirement plans? Bonuses? Salary?	24 (41.4%)
	Importance of a Mentor	How do I find a mentor?	23 (39.7%)

Table I. Top Five Questions by Age Group

Forty-five of the students were less than 21 years of age and 58 of the students were older than 21 years. These two groups had only one top five question in common: “How do I choose a job” from the 13th category of Choosing a Job. Interestingly, about the same percentage of each age group chose this question as one of their top twenty. Nineteen (42.2%) of the <21 years group selected this question and 24 (41.4%) of the >21 years group chose this question. It is not surprising to note that the students <21 years were concerned with the why of majoring in

engineering and had a major question about earning the BSE and the PhD in engineering. Their one question about choosing a job was their one match with the >21 years group. The older group, probably with more financial responsibilities, is most concerned with choosing a job, how to pay for graduate school, determining if belonging to a professional organization is worth it, and eager to know more about finding a mentor.

Another interesting way to analyze the results is to look at the critical questions by academic class.

Class	Category	Question	Sample Size
Freshman	Why Engineering?	Will there be a job for me when I graduate? Will it pay well? Will it be challenging/boring? Will it require travel??	9 (81.8%)
	Choosing A Job	How should I weigh each of the following: engineering/technical responsibilities? Etc.	6 (54.5%)
	Choosing An Engineering Discipline	What are typical salaries for someone possessing a BSE in engineering? How does this compare with other types of bachelor's degrees?	5 (45.5%)
	Why Pursue a BSE in Engineering at ASU	How is my engineering school viewed by industry?	5 (45.5%)
	Financing my BSE in Engineering	What scholarship opportunities exist if I pursue engineering?	5 (45.5%)
Sophomore	Importance of a Mentor	How do I find a mentor?	7 (70%)
	Why Engineering?	Will there be a job for me when I graduate? Will it pay well? Will it be challenging or boring? Will it require travel??	6 (60%)
	Why Engineering?	What is the engineering work environment like?	5 (50%)
	Why Pursue a BSE in Engineering at ASU?	How is my engineering school viewed by industry?	5 (50%)
	The Importance of Research	What exciting research efforts are being pursued at my engineering school?	5 (50%)
Junior	The Importance of Research	What is a research proposal? How do I write a research proposal?	21 (44.7%)
	Why Engineering?	What is the engineering work environment like?	19 (40.4%)
	Why Pursue a BSE in Engineering at ASU?	How is my engineering school viewed by industry?	19 (40.4%)
	Importance of Graduate School	How do I pay for graduate school?	19 (40.4%)
	Choosing a Job	How do I choose a job?	18 (38.3%)
Senior	Importance of Graduate School	How do I pay for graduate school?	14 (50%)
	Getting a PhD	Why should I consider getting a PhD degree in engineering? What will it offer me over an MS in engineering?	14 (50%)
	Choosing a Job	How do I choose a job?	14 (50%)
	Choosing a Job	How should I weigh each of the following: engineering/technical responsibilities? Etc.	14 (50%)
	The MS thesis	Should I pursue a master's thesis or take the comprehensive exam route?	12 (42.9%)
Graduate Student	Choosing a Job	How should I weigh each of the following: engineering/technical responsibilities? Etc.	5 (71.4%)
	Getting a PhD	Why should I consider getting a PhD degree in engineering? What will it offer me over an MS in engineering?	4 (57.1%)
	Why Pursue a BSE in engineering at ASU?	What unique support program does ASU offer that I might not be able to get elsewhere?	4 (57.1%)
	Important Skills	How does one develop leadership skills?	4 (57.1%)
	Getting a PhD	What is a PhD qualifying exam?	4 (57.1%)

Table II. Top Five Questions by Academic Class

Questions with color were chosen by more than one academic group

Even though some of the sample sizes are small, the percentage of students in each academic class is quite high on their top five questions, indicating that this is a question of importance to that academic group. Thus, the results appear consistent. The freshmen and sophomores share two questions in their top five. These two questions are in the Why Engineering? and Why an Engineering BSE at my school? Categories: “Will there be a good job for me when I graduate?” and “How is my engineering school viewed by industry?” Interestingly, this last question about the value industry places on their engineering program is also shared by juniors. Seniors and graduate students seem to have that question answered. The question “How should I weigh each of the following: engineering/technical responsibilities?” is shared by the freshmen, seniors, and graduate students.

Juniors share the question “How is my engineering school viewed by industry?” with both the freshmen and sophomores. In turn, juniors share one question just with sophomores from the Why Engineering category, “What is the engineering work environment like?” This last question is not of concern to seniors and graduate students, perhaps because they have held an industrial internship by that time and have a good idea of what engineering environments are like. Juniors share two questions just with seniors from the Importance of Graduate School category and the Choosing a Job category: “How do I pay for graduate school?” and “How do I choose a job?” Likewise, seniors and graduate students share two questions exclusively for these two groups from the Getting a PhD and Choosing a Job categories: “Why should I consider getting a PhD degree in engineering? What will it offer me over an MS in engineering?” and “How do I weigh the factors that go into choosing a job?” Interestingly, freshman also chose this last question on weighing job factors as one of their top five.

Questions unique to freshmen were concerned with typical engineering salaries and how they ranked with other fields and what scholarship opportunities exist if they pursue engineering. Unique questions for sophomores were their top choice of how to find a mentor and their fifth choice of wondering what exciting research efforts were being pursued at their school. Only the top choice question for juniors was not shared by another group. This question is from The Importance of Research category: “What is a research proposal? How do I write a research proposal?” The fifth choice question by seniors is the only question unique to them: “Should I pursue a master’s thesis or take the comprehensive exam route? What are the pros and cons of each?” Outside of the two top questions that graduate students share with seniors, graduate students have three top questions that are unique to them: “What unique support programs does my school offer that I might not be able to get elsewhere?”, “How does one develop leadership skills?”, and “What is a PhD qualifying exam?”

If we consider the top five choices for the seven student classifications that we have used in Tables I and II, we have narrowed down the 136 questions to a top 17 questions that are the concern of both young and old students and each academic class standing.

V. Summary and Conclusions

We narrowed the list of 136 questions to a possible top 17. We can further narrow these down to a critical 6 questions for a start to answering the questions of most concern to engineering students. The two most common critical questions among the classifications that we considered were: “How is our engineering school viewed by industry?” and “How do I choose a job?” The first question can usually be answered quite easily, while the second question is very difficult. There are four other critical questions which are quite common to these classifications. One of these four is the difficult follow-on question to the difficult one mentioned above: “How do you weigh all of the factors that come into play when choosing a job?” The other three critical questions are: “Will there be a good paying, challenging job for me when I graduate?” “How do I pay for graduate school?”, and “Why should I consider getting a PhD in engineering? What will it offer me over an MS in engineering?” are not that difficult to answer.

We will continue to address these questions in our Academic Success Class. The pressing questions for our students will change as we discuss them or give the students assignments on these categories. For example, the top question for juniors was “What is a research proposal? How do I write a research proposal?” This question was not a top five one for the freshmen and sophomores because they were required to write a proposal in their Success Class. Since this survey, the upper division students in the Academic Success Class have had a presentation on writing a research proposal and were given writing a research proposal as an assignment.

We will continue to work with our list of questions. We have already added questions that students suggested after they selected and ranked the questions critical to them. We will also begin posting answers or processes for our students that can lead to answers for these questions. See <https://mets.engineering.asu.edu> for the questions. We believe that if we address the main concerns of our engineering and computer science students, we will increase the probability that our students will graduate and go right on to graduate school in engineering.

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