AC 2009-432: EARLY EXPOSURE TO ENGINEERING PRACTITIONERS PROVIDES INFORMED CHOICES FOR STUDENTS CONTINUING ENGINEERING PROGRAMS

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Early Exposure to Engineering Practitioners Provides Informed Choices for Students Continuing Engineering Programs

Abstract

The engineering education literature calls for studies highlighting the impact of students' early exposure to post-graduate engineering careers. This paper provides data critical to assessing the effectiveness of a unique first-year experience concept: exposing new students to the careers of practicing engineers. We report on an initiative for incoming students to the mechanical and energy engineering (MEE) major at the University of North Texas (UNT). Our mandatory freshman course sequence, Mechanical and Energy Engineering Practice, includes exposure to practicing engineers as a significant component of the first-year experience by highlighting activities and responsibilities that engineers encounter after college as they join the profession. Classes are team-taught by the MEE faculty in concert with practicing engineers from local industries. Faculty share their careers as research engineers, whereas practicing engineers expose students to industry work. Through data collected from students enrolled in this course sequence, we test the hypothesis that educating new engineering students about the responsibilities, activities, and projects they may encounter as practicing engineers will have a positive impact on their intention to continue in engineering programs beyond the freshman year. We present results from a survey, which students took on the first day of class and then re-took on the last day in both Fall 2007 and Spring 2008. Interestingly, while students' self-reported level of interest in pursuing an engineering career remains positive and unchanged after exposure to engineering practitioners, students' reported desire to remain in the MEE department at the end of these classes declines. This drop is statistically significant. We argue that these low-risk, introductory-level, one-credit-hour courses function to familiarize students with the careers of practicing engineers while providing the exposure students need to decide whether the major and university they have selected is the correct long-term choice for them. At this early stage, they can choose to change programs for a better fit. We call this academic self-selection process "soft weeding," juxtaposed against "hard weeding" by which students are forced out of a program against their will after prolonged poor performance in several high-risk upper-division courses. Simultaneously, the courses positively reinforce and motivate students who find engineering careers a good match, helping them to persevere in their core pre-engineering courses.

Introduction

Many universities have bolstered efforts to recruit and retain students in science and engineering in response to federal reports citing a dearth of trained professionals in these fields.[1] Particular emphasis has been placed on enhancing the first-year experiences of science and engineering majors in an attempt to expose these students to practical experience alongside traditional pedagogical curricula.[2]

Conventional "first-year experience" courses focus on teaching college survival skills, providing campus orientation, and building camaraderie to support students as they embark on higher education. These activities are believed to improve student retention by reinforcing critical skill sets, knowledge, and networks for ensuing college years.[3] The engineering education literature calls for studies on how redesigned "first-year experience" courses affect retention rates and student success in engineering programs. Many reports on first-year programs describe integrated curricula to support students through math and science prerequisites that account for much of the early attrition.[4-8] Other reports illuminate programs that concentrate on design practice to give students "hands-on" experience and stimulate interest and retention.[6,7,9,10] This study fills a missing gap in the literature by assessing the effectiveness of a unique first-year experience concept: teaching new students about the careers of practicing engineers. Exposing first-year students to engineering practitioners is as critical as introducing problem solving skills or providing a design-and-build experience. It enables these students to picture, reflect upon, and make informed decisions about their potential future careers as practicing engineers. This thought process then maps onto choice of major. It can encourage students to stay or motivate them to switch to another program that better aligns with their long-term goals.

Many students choose engineering for pragmatic reasons, believing that completion of an engineering degree will guarantee stable employment prospects with higher starting salaries.[11] Unfortunately, students also elect to major in engineering by way of an "uninformed choice".[11] That is, they envision an engineering degree as the means to fulfill childhood fantasies. Studies indicate that high school students typically have a limited understanding of the activities and responsibilities undertaken by professional engineers.[12,13] Moreover, students who leave the science, technology, engineering, and math (STEM) disciplines express concerns about job prospects, remuneration, and lifestyle appeal associated with STEM careers not shared by students who persist.[11] This finding suggests exposing freshman to practicing engineers and helping students learn about the daily activities of the engineering profession may both inform them about career options and motivate them to persevere in engineering.

In this study, data critical to assessing the effectiveness of teaching new students about the careers of practicing engineers is presented and analyzed. A new course developed for mechanical and energy engineering (MEE) majors at the University of North Texas (UNT) includes exposure to engineering practice as a significant component of the first-year experience. Through survey data collected from students enrolled in this course sequence, the following hypothesis is tested: educating new engineering students about the responsibilities, activities, and projects they may encounter as practicing engineers will have an impact on retention rates.

The results indicate that knowing more about engineering practice and research does not affect students' inclination to remain in a STEM major. However, students do seem to be driven away from their current engineering program after acquiring exposure to engineering practitioners in related professional areas. This trend does not necessarily indicate the need to eliminate practice exposure from the first-year engineering curriculum to stimulate retention. Instead, early engineering practice exposure allows students to make informed decisions about their future career paths without navigating multi-year degree programs. Students who have made an "uninformed choice" or are not passionate about the particular engineering field they choose as freshmen are likely to eventually be forced out of that engineering degree program by prolonged poor performance. We feel that students experience less trauma and have a more positive overall academic experience after leaving a particular engineering program if they choose to change disciplines on their own before experiencing hardship in major-specific upper-division classes. We call this academic self-selection process "soft weeding."

Methods

The MEE Department offers a first-year experience course sequence taught over two consecutive semesters called MEE Practice I & II, which is offered in a series of 1-hour seminars. Entering freshmen generally enrolled in MEE Practice I in Fall 2007, and 88% subsequently returned in Spring 2008 for MEE Practice II. The semesters began with interactive ethics seminars taught by the instructor of record for the first 4 weeks to illuminate the underpinning principles and ethos adhered to by engineers in research, academia, and industry. Subsequent classes were team-taught by the MEE faculty in concert with five practicing engineers from local industry. Faculty members shared their careers as research engineers, and practicing engineers exposed students to projects encountered in the professional workplace.

Participating engineers from industry and government were recruited from local companies through three techniques: personal contacts made at university-sponsored conferences and career fairs; telephone calls to local firms' outreach coordinators; and members of the industrial advisory board of the College of Engineering. Practicing engineers generally responded favorably to requests to share their experiences with lower-division students, and they expressed positive feedback about interactions with the classes. All participants agreed to return for the following year's classes. The benefits of practitioner-student interactions are deemed mutual; students learn about the engineering workplace, and faculty and practicing engineers can market their research laboratories and companies to the next generation of engineers. One company representative responsible for human resources indicated that although his primary interest was recruiting graduating seniors, speaking to freshman uniquely enabled him to seed future positive recruitment opportunities and was thus welcomed.

Table 1: Students in MEE Practice I & II were asked to respond to these survey questions on the first day of class and again on the last day of class.

Question Number	Question
1	I am aware of what practicing engineers in industry do on a daily basis
2	I am aware of what research engineers at universities do on a daily basis.
3	Based on my current understanding of what practicing and research engineers do on a daily basis, I would enjoy engineering as a career.
4	It is my intention to continue as a mechanical & energy engineering major.
5	It is my intention to continue as a student within UNT's College of Engineering.
6	I understand how ethics guide the practice of engineering.
7	I am familiar with how the work engineers do impacts society.
8	I am familiar with the faculty of UNT's Mechanical & Energy Engineering Department.
9	I am familiar with the research conducted in UNT's Mechanical & Energy Engineering Department.

Students were asked to rate each of these questions according to the following scale:
1 = strongly disagree; 2 = disagree; 3 = agree; 4 = strongly agree

To gauge whether early exposure to engineering practice affects students' comprehension of what their chosen discipline or career entails, an anonymous survey was prepared (Table 1). This survey probed students' familiarity with engineering practice, asked them to gauge their familiarity with engineering careers, and allowed them to quantify their intention to continue as engineering students. Consenting students enrolled in MEE Practice I (Table 2 – top) and MEE Practice II (Table 2 – bottom) took this survey on the first day of class and then re-took the same survey on the last day. Differences in students' survey responses before and after the classes (Figures 1 and 2) were compared to gauge the impact of exposure to practice.

The surveys provided an indirect measure of how well MEE Practice I and II were meeting ABET outcome (f), "an understanding of professional and ethical responsibility," which was the featured course outcome. The major instructor-developed learning outcome associated with ABET criterion (f) was that "students will be exposed to industry and academic practitioners to enable appreciation of the jobs, tasks, and activities engineering professionals are responsible to conduct on a daily basis." General learning outcomes associated with this major learning outcome were that 1) students will determine whether engineering as a professional career suits their skills and interests; 2) students will recognize the difference among industry, research, and academic engineering jobs; and 3) students will be familiar with the MEE faculty, their areas of research, and the benefits of receiving training from these faculty members.

Short essay take-home assignments provided direct assessment of learning outcome achievement in these classes. For each speaker, students were asked to respond to a prompt that tied a speaker's presentation to one of the general learning outcomes for the course. Examples of prompts include the following:

- "Describe specific daily activities performed by practicing engineers in areas of interest to you."
- "Differentiate between levels of formal education required to obtain an engineering job in industry and academia. Are these education levels universal across different countries and cultures? Why are these different education levels required?"

Table 2: Gender and Ethnicity Data for Respondents [note: while the MEE department at UNT does include American Indians, these students were either not enrolled in the MEE Practice sequence, did not consent to the study, or chose not to self-report ethnicity in the surveys.]

MEE Practice I (MEEN 1110 Fall 2007)				
	Initial		**Final**	
Ethnicity	**Count**	**Percentage**	**Count**	**Percentage**
Asian	2	3.3	1	2.7
Black	6	9.8	3	8.1
White	40	65.6	23	62.2
Hispanic	9	14.8	5	13.5
Mixed	1	1.6	0	0.0
Unknown	3	4.9	5	13.5
SUM	61	100.0	37	100.0
Gender	**Count**	**Percentage**	**Count**	**Percentage**
Female	6	9.8	4	10.8
Male	53	86.9	30	81.1
Unknown	2	3.3	3	8.1
SUM	61	100.0	37	100.0

MEE Practice II (MEEN 1210 Spring 2008)				
	Initial		**Final**	
Ethnicity	**Count**	**Percentage**	**Count**	**Percentage**
Asian	1	2.4	1	2.9
Black	5	11.9	5	14.7
White	27	64.3	24	70.6
Hispanic	6	14.3	1	2.9
Unknown	3	7.1	3	8.8
SUM	42	100.0	34	100.0
Gender	**Count**	**Percentage**	**Count**	**Percentage**
Female	2	4.8	1	2.9
Male	39	92.9	32	94.1
Unknown	1	2.4	1	2.9
SUM	42	100.0	34	100.0

- "Identify and describe the variety of different engineering positions available to degreed engineers. Would you prefer to be a field engineer or a design engineer?"
- "Given the different successful methods to generate, record, and teach technical knowledge used throughout history, why must modern students earn college degrees to become practicing engineers?"
- "Describe the engineering job that is of most interest to you. Explain why this job is of interest."

Short essay assignments were graded on a scale of 0 to 10; students were given the grading rubric in advance, and they knew the grading scheme. Zero to one point was awarded for submitting assignments on time with proper headers, identifications, and word counts. Zero to three points were awarded for use of college-level writing; zero to three points were awarded on the basis of how well essays summarized what the speaker said; and zero to three points were awarded on the basis of how well students responded to the prompt. On writing skill, speaker summary, and addressing the prompt, number grades corresponded to the following subjective categories: 0 – nonexistent, 1 – inadequate, 2 – adequate, and 3 – exceptional. All grading was conducted by the instructor of record to minimize variability in the assessment of students' essays.

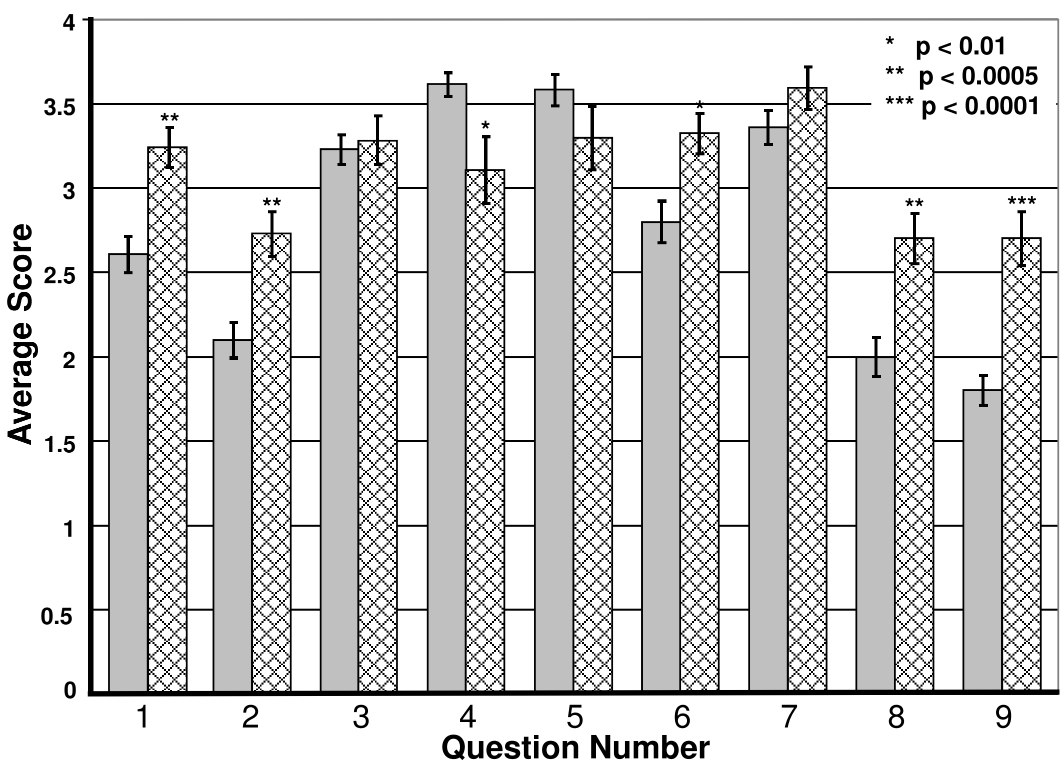

Figure 1: MEE Practice I (MEEN 1110 Fall 2007) differences between mean initial and mean final responses to survey questions. Gray bars indicate initial survey mean responses (n = 61). Hatched bars indicate final mean survey responses (n = 37). The probability of a result at least as extreme being observed in a random control group, p, is indicated at three levels.

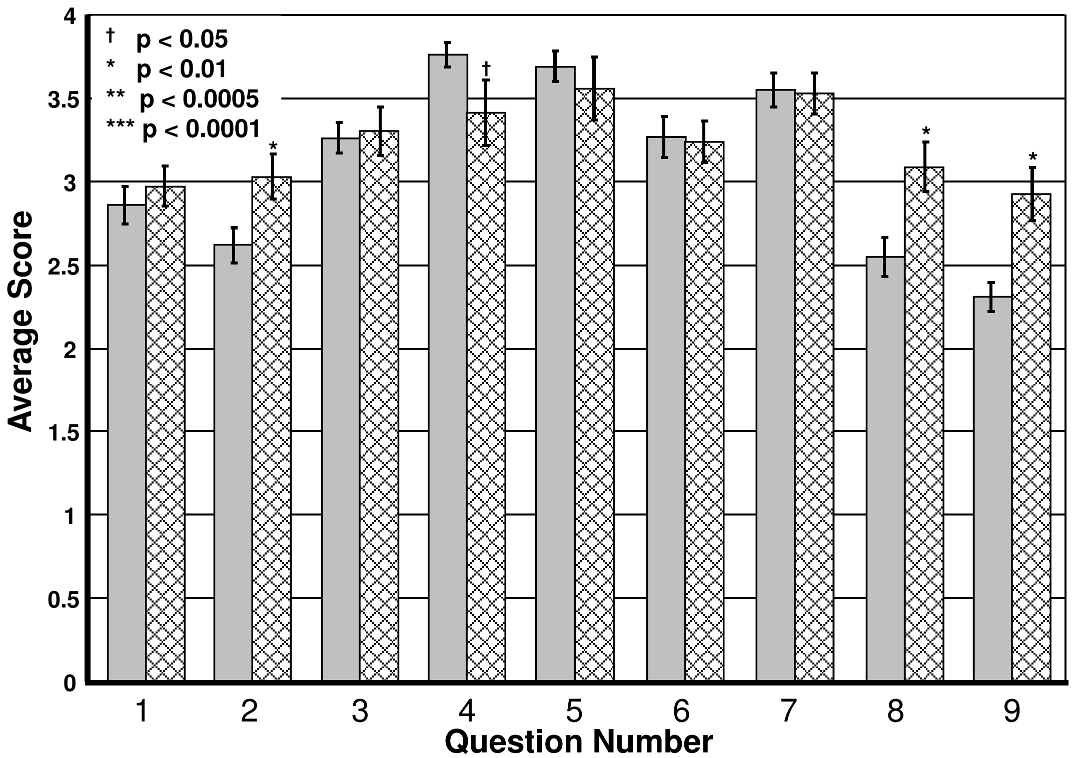

Figure 2: MEE Practice II (MEEN 1210 Spring 2008) differences between mean initial and mean final responses to survey questions. Gray bars indicate initial survey mean responses (n = 42). Hatched bars indicate final mean survey responses (n = 34). The probability of a result at least as extreme being observed in a random control group, p, is indicated at four levels.

Results

Between the beginning and the end of class in MEE Practice I (Fall 2007), students self-reported a statistically significant increase in awareness of what practicing and research engineers do on a daily basis (Figure 1, Questions 1 and 2); whereas in MEE Practice II (Spring 2008), students only reported a statistically significant increase in learning about the responsibilities of engineering researchers (Figure 2, Question 2). Students also reported a dramatic increase in familiarity with the MEE faculty and the research areas in which these professors are engaged in both the MEE Practice I and MEE Practice II (Figures 1 and 2, Questions 8 and 9). Furthermore, students reported an increased understanding of how ethics guides engineering in MEE Practice I but not in MEE Practice II (Figures 1 and 2, Question 6). This indirect assessment suggests that the course sequence successfully met the general learning outcomes within ABET criterion (f) by increasing students' awareness of the engineering profession and to the professors in the MEE Department as well as their ongoing research. Direct assessment of students' short essays agreed with these indirect results. Essays generally showed that students could summarize what speakers said and could map these commentaries about the engineering workplace onto the given essay prompts. Since no direct pre-/post-assessments were given, gains in student learning and changes in interests resulting from practitioner exposure could only be assessed through surveys.

Interestingly, while students' self-reported level of interest in pursuing an engineering career and remaining in the College of Engineering remained positive and statistically unchanged across both semesters (Figures 1 and 2, Questions 3 and 5), students reported a statistically significant drop in desire to remain in the MEE Department after both Fall and Spring semesters (Figures 1 and 2, Question 4). This result indicates that early exposure to engineering practice does not wane early enthusiasm for engineering. However, it suggests that upon learning of specific daily tasks undertaken by practitioners of mechanical and energy engineering, this cohort of students had a reduced desire to become professionals in this discipline. Practitioner exposure in MEE Practice I and II informed some students that they might prefer another STEM major over mechanical and energy engineering. Another possibility is that the style of teaching used in MEE Practice I and II was not palatable and drove students away. However, students self-reported a statistically significant increase in awareness of the courses' topical areas, and it is therefore unlikely that they chose to leave because they felt they weren't learning.

Table 3: Factors Influencing the Decision to Major in MEE in Fall 2007. Students were asked to write in the two top reasons influencing their decision to select MEE as their major. Commonly listed reasons are organized into predominant themes, and their frequencies are shown.

Fall 2007					
		Initial Responses		Final Responses	
Reason #	**Reason**	***Number***	***Percentage*** [†]	***Number***	***Percentage*** [†]
1	Interest/love in science/math/technology/logic/problem solving	31	34.8	14	31.1
2	Money/employment/job security/versatility of degree/relevance	11	12.4	4	8.9
3	Prior class or work experience	0	0.0	0	0.0
4	Perceived aptitude	5	5.6	0	0.0
5	Aspiration/career goal/desire for engineering degree	11	12.4	4	8.9
6	Desire to help society	6	6.7	6	13.3
7	Desire to help environment	1	1.1	2	4.4
8	Novelty of program	4	4.5	2	4.4
9	In lieu of other major/curiosity/"seems interesting"	4	4.5	0	0.0
10	Perceived need for engineers	5	5.6	0	0.0
11	Parent is engineer/family or mentor's influence	2	2.2	1	2.2
12	Challenge/test intelligence	3	3.4	1	2.2
13	Alternative energy prospects/energy research	6	6.7	4	8.9
14	Changing majors or transferring	N/A	N/A	5	11.1
15	Expressed displeasure after class	N/A	N/A	2	4.4
16	No comment [*]	33		29	
	Number of students responding	61		37	
	Possible "Factors Influencing Decision" responses	122		74	
	Sum of actual responses	89		45	
	Response rate	73.00%		60.80%	

[*] "No comment" refers to responses in which this open-ended question was left blank or students only listed one reason for their major choice.
[†] "No comment" responses were not included in the calculation of percentages of responses indicating factors influencing a decision to enter the MEE program.

Discussion

Importantly, the results reported here were influenced by the students' exposure not only to engineering practitioners in MEE Practice I and II but also to STEM classes underlying the MEE curriculum. Over both semesters, students' top cited reason for selecting mechanical and energy engineering as their major was "interest" (Tables 3 and 4). When asked to indicate the top two factors influencing them to major in mechanical and energy engineering, 25 to 35 percent of the respondents indicated A) an interest in math, science, technology, logic, and problem-solving; or B) a love for building things and "working with their hands." Notably, "Interest" as a determining reason for majoring in mechanical and energy engineering was cited more often at the beginning of MEE Practice I (34.8%) than at the end of MEE Practice II (25.5%). The measured reduction in "Interest" indicates that some students may initially have selected an engineering major as an "uninformed choice" founded on lack of awareness of the day-to-day responsibilities of engineers.[11] Furthermore, some students may have misjudged their "interest" or "love" of math and science based on high school experiences with less challenging courses in which they were able to succeed with little effort. Nonetheless, over the same academic year, students' desire to choose engineering as a career and to stay in the College of Engineering remained statistically unchanged. Cast against waning "interest", this result indicates that exposure to the activities of practicing engineers in entry-level courses does provide positive influence to offset student desire to leave engineering arising from difficulties with early STEM classes. In addition, exposure to practicing engineers helps ease students whose interests lay elsewhere into other STEM programs without driving them away from hard sciences, mathematics, and engineering.

Table 4: Factors Influencing the Decision to Major in MEE in Spring 2008. Students were asked to write in the two top reasons influencing their decision to select MEE as their major. Commonly listed reasons are organized into predominant themes, and their frequencies are shown.

Spring 2008					
		Initial Responses		Final Responses	
Reason #	**Reason**	***Number***	***Percentage*** †	***Number***	***Percentage*** †
1	Interest/love in science/math/technology/logic/problem solving	23	38.3	14	25.5
2	Money/employment/job security/versatility of degree/relevance	14	23.3	14	25.5
3	Prior class or work experience	3	5.0	1	1.8
4	Perceived aptitude	4	6.7	1	1.8
5	Aspiration/career goal/desire for engineering degree	0	0.0	1	1.8
6	Desire to help society	2	3.3	3	5.5
7	Desire to help environment	1	1.7	5	9.1
8	Novelty of program	1	1.7	2	3.6
9	In lieu of other major/curiosity/"seems interesting"	1	1.7	1	1.8
10	Perceived need for engineers	1	1.7	0	0.0
11	Parent is engineer/family or mentor's influence	3	5.0	3	5.5
12	Challenge/test intelligence	0	0.0	3	5.5
13	Alternative energy prospects/energy research	7	11.7	6	10.9
14	Changing majors or transferring	N/A	N/A	1	1.8
15	Expressed displeasure after class	N/A	N/A	0	0.0
16	No comment*	24		13	
	Number of students responding	42		34	
	Possible "Factors Influencing Decision" responses	84		68	
	Sum of actual responses	60		55	
	Response rate	71.40%		80.90%	

*"No comment" refers to responses in which this open-ended question was left blank or students only listed one reason for their major choice.

†"No comment" responses were not included in the calculation of percentages of responses indicating factors influencing a decision to enter the MEE program.

The second most common factor listed by students as influencing their decision to major in mechanical and energy engineering was employment potential. Inundated by messages emphasizing the U.S. need for scientists and engineers as well as the high pay scales in these careers, many students may perceive engineering to be a "safe" and lucrative major choice which will offer them ample job prospects, substantial salaries, and multiple advancement opportunities. After two semesters of exposure to STEM classes, "money and job security" as a motivating factor to remain in mechanical and energy engineering increased from 12.4% to 25.5%. By the end of the MEE Practice course sequence, "money and job security" became as strong a factor driving students to continue in MEE as "Interest." An image is evoked of students who stay in the program for the potential financial payoff despite growing disinterest in or frustration with their studies.

By taking a low-risk, introductory-level, 1-credit-hour course, students obtain the program exposure they need to decide whether the major and the university they have selected are the correct long-term choice for them. They can choose to change programs for a better fit. We call this academic self-selection process "soft weeding" juxtaposed against "hard weeding," by which students are forced out of a program against their will after prolonged poor performance in several high-risk upper-division courses. We feel that students experience less trauma and have a more positive overall academic experience after leaving a particular engineering program if they choose to change disciplines on their own before experiencing hardship in major-specific upper-division classes.

One caveat of the data collection technique used in this study is its reliance on the ability of students to accurately self-appraise their level of knowledge. Prior studies have indicated that students, especially poorer performing students, generally overestimate their predicted grade in a course, and unskilled students may be unaware of their skill deficits.[14] Thus, the stagnation in self-reported learning with respect to the daily responsibilities of industry engineers (Question 1) and ethical principles guiding engineering (Question 6) demonstrated in MEE Practice II may be more indicative of students' inability to properly gauge their knowledge than a lack of additional learning of these subjects during the second semester. It is also important to note the overlap in enrollment over the two semesters, with 88% of students taking MEE Practice II in Spring 2008 having just completed MEE Practice I in Fall 2007. Students overestimating their expertise about engineering careers and ethics may report inaccurately high scores on the initial surveys, leaving little room for gain on the exit survey. This tendency may be especially heightened just after they complete a course covering these learning objectives as would occur in the case of administering the MEE II Practice entry survey to students who just completed MEE Practice I in the previous term. To eliminate self-reporting bias, future studies will include direct pre-/post-assessments to measure student knowledge of engineering ethics, industry careers, and research careers. These data will then be cross-referenced against scores arising from student self-appraisals.

Importantly, in Fall 2007, 10 students out of 61 enrolled chose not to turn in class assignments and therefore knew they were receiving failing grades in the class when they took the exit survey. Comments written on surveys believed to be from these students suggested respondents used the survey to berate the instructor or express frustration with the university, the college, the department, the course, or a combination of these items. The exit surveys in question reported "1 – strongly disagree" for all questions. Despite the negative skew these extreme responses put into the results, it was decided not to remove these surveys from the data pool. In addition, many students enrolled in MEE Practice I & II were also co-enrolled in the freshman-level math and science courses, prerequisites to the MEE program. Many students knew they had failed these classes and would be suspended from the university when they took the MEE Practice I & II exit surveys. Being hard-weeded out of the MEE program, these students may have wished to continue in mechanical and energy engineering but could no longer do so; hence, the disparity in responses between Questions 3 and 4.

Conclusions

Survey data from MEE Practice I & II at UNT indicate that the course sequence provides students with a realistic perception of the careers of practicing and research engineers while familiarizing them with ethics and simultaneously reaffirming their commitment to complete engineering degrees. Further demonstration of these course benefits are encapsulated in comments drawn from student assignments in which they reacted to industry presenters (Table 5). For many students, the courses serve as a positive, introductory experience that cements relationships with future peers and colleagues. At the same time, this course facilitates early self-selection of students out of the MEE major via a low-risk academic environment. We have introduced the term "soft weeding" to distinguish this informed self-selection from the "hard weeding" that students may experience as they struggle academically through required major-specific coursework.

Future work includes longitudinal analysis of the impact of MEE Practice I & II on retention rates within the MEE Department and propensity of students to engage in academic auxiliary programs, including undergraduate research, professional societies, and career internships. The influence of MEE Practice I & II on retention rates in mechanical engineering will ultimately be compared to similar departments at peer institutions that have no "first-year experience" program. Additionally, the department's alumni survey will inquire about retrospective impact of early practitioner exposure to determine the value of these interactions in the context of the entire B.S. degree program.

Table 5: Student Comments Reflecting on Speaker Presentations about Engineering Careers.

[The speaker] made an interesting observation regarding his duties as an engineer; *in a day's work, he spends only a small fraction of his time performing engineering related tasks.*
A typical day in the life of an engineer is not typical at all.
Overall, the presentation provided me with a renewed sense of purpose and direction.
I am happy to say that [the speaker] truly inspired me to be an engineer. I am excited about the future outlook of my career.
With all of these facts, [the speaker] successfully made me desire to be an engineer even more than I did before I enrolled at UNT.
Being an engineer requires a lot of time and work. [The speaker] put that concept into full perspective.
Everyone I spoke to about the presentation said that it is what they needed to confirm that they wanted to get into engineering.
[The speaker's] description of his employer made me want to be in his shoes at this point in his career. His job is one that involves a lot of work, but is enjoyable and productive at the same time.
[The speaker's] presentation in his experiences as a professional engineer provided valuable insight into the day-to-day reality.

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