First-Year Student Persistence and Retention Influenced by Early Exposure to Engineering Practitioners Co-Teaching Entry-Level Courses: A Four-Year Indirect Assessment

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Abstract

The engineering education literature lacks long-term studies on persistence and retention impacts realized by teaching first-year engineering students about possible post-graduate career options via exposure to practicing engineers. At the University of North Texas (UNT), incoming mechanical and energy engineering (MEE) students (both freshman and transfers) participated in a mandatory two-course sequence which included a significant component that highlighted the everyday work of various practicing engineers. Classes were team-taught by faculty and local engineers from industry and government. Faculty shared their research activities and academic experience while practicing engineers discussed their industry work.

Indirect assessment of students' persistence and retention preferences was evaluated using an anonymous survey administered on the first day of class and then re-administered on the last day of class. A one-year pilot study spanning two semesters was conducted during the 2007 – 2008 academic year. In this pilot, students self-reported constant pre/post levels of interest in engineering, but they also reported a statistically significant decline in desire to remain in the MEE program. This outcome was unexpected. This apparent inconsistency is explained by the hypothesis that familiarizing first-year engineering students with the activities and duties they may encounter in their careers as practicing engineers encouraged and reinforced their commitment to their chosen engineering major – positive and unwavering persistence. However, this same exposure coupled with other experiences in their engineering curricula made students aware that their chosen major may not be the best match for their interests or abilities, and there may be a better choice within other available engineering majors – negative retention within the major. The term "soft weeding" was invoked to denote empowering students to make informed decisions about their chosen major through a low-risk introductory course before they pursue a program to which they are poorly matched. The goal of "soft weeding" is to allow students to correctly place themselves in the best-fit engineering major to avoid frustration and poor performance in later upper-division courses and eventual withdrawal.

Conclusions from the pilot study could have significant bearing on the design of introductory engineering courses for freshman and transfer students. The study could also inform administrative policy at engineering colleges; whether it is advantageous for students to choose a major early or instead complete common engineering core courses and declare a major after becoming better acquainted with the various available program options. Unfortunately, the pilot study only interrogated a single class of students over two semesters. With no comparison population available, this cohort could have held biases that make it difficult to extend the pilot study conclusions to the general engineering student population of any undergraduate program. We therefore report here the results of an extended four-year study, performed in identical fashion to the one-year pilot study. Pre/Post indirect assessments were given to four unique cohorts of students in entry-level 'Engineering Practice' courses between Fall 2007 and Spring 2011. The four-year study results are evaluated utilizing nonparametric statistical analysis compared to the reassessed pilot study to confirm and strengthen its validity by using a larger, more diverse student population less prone to the bias of a single class cohort.

Introduction

Undergraduate student interest in the fields of science, technology, engineering, and mathematics (STEM) has steadily declined over the past few decades with a cumulative loss of almost 40 percent.[1] This decline has prompted a massive response to investigate causes of decreasing retention as well as to introduce efforts to counteract losses.[2] Particular emphasis has been placed on augmenting first-year undergraduate experiences in STEM fields alongside traditional curricula to better acquaint students with their chosen fields early on. Strategies include attempts to expose students to practical experiences, providing foresight into what their future professional endeavors may involve.

Generally, first year courses have served to orient new students to college life with focus on teaching survival skills to encourage proper study habits and aid students in building their social and academic support structures. This approach is meant to improve retention by reinforcing study skills and honing “academic grit” needed to survive in higher education overall, but this approach does not address obstacles specific to a student’s individual chosen major.[3] Literature within engineering education calls for methods to redesign first year experiences that are tailored to this specific need as well as studies on how these redesigned experiences may affect retention rates within engineering programs. Current literature reports curricula that present initial math and science prerequisites in a more student-friendly fashion to reduce early attrition as well as programs that provide students with early exposure to design practice providing hands on experiences in engineering.[4-9] One study discusses a curriculum requiring each department to present on “their engineering”, allowing students a more educated view to base their career decisions.[10]

By contrast, the study reported here provides a longitudinal perspective in assessing the effectiveness of a novel first year student experience: acquainting students with the careers of practicing engineers. Exposing first year undergraduates to engineering practitioners enables students to truly understand and evaluate what engineering is and what their lives may be like as professionals in engineering practice after graduation. For many students, this opportunity is often the first time they perform this self-assessment, and it allows them to make a more informed decision about their major. They may either reaffirm their dedication to their chosen field, or realize that they would prefer to change majors to pursue a different career path. The later outcome allows students to decide to switch majors early without wasting time and money pursuing a career path that will ultimately not bring them satisfaction.

Students choose engineering for a variety of reasons ranging from the intrinsic value of “accomplishing something difficult” to the altruistic opportunity to serve and help the community to the perceived fiscal benefit: the belief that an engineering degree will guarantee both stable employment and a higher standard of living. Other students choose engineering due to a misguided rational based on stereotypes or fantasies: they long to be *Star Trek’s* Mr. Scott – a technological miracle worker – or a celebrity like Bill Nye who trounces Creationists. Students who persist in engineering do not demonstrate the same lifestyle concerns as those who do not, supporting the supposition that some students do not understand what engineering practitioners do.[1] Furthermore, multiple studies show that high school students entering college have very little understanding of what practicing engineers do.[11-14]

A previous study, led by two of this paper's co-authors, was performed using a single cohort of freshman and transfer students enrolled in a two-semester introduction to engineering sequence. These courses were developed for mechanical and energy engineering (MEE) majors at the University of North Texas (UNT) and prominently included engineering practice as a component of the first year experience. A key course element was inviting practicing engineers to lecture on their experiences in the profession. Pre/Post surveys revealed that exposure to practicing engineers induced a statistically significant increase in student awareness of what practicing engineers do strongly correlated with a desire among students to remain within engineering. Here that study is continued and extended with a longitudinal perspective. Beginning with the pilot study and continuing every semester for four years (Fall 2008 - Spring 2011), data were consistently acquired via the identical entrance/exit survey method. The same hypothesis from the one-year pilot study will be tested by evaluating the more extensive four year data set: educating new engineering students about the responsibilities, activities, and projects they may encounter as practicing engineers will have an impact on students' desire to continue in engineering.[15]

Results found utilizing nonparametric analysis indicate that, on average, exposure to engineering practice and research does not statistically increase or decrease students' desire to remain in engineering, though it does significantly increase students' familiarity with faculty and research. Within some cohorts, there was a statistically significant decline in interest to remain in the specific MEE major. While this outcome may indicate that exposure to engineering practitioners does not increase retention, it may also infer that exposure serves as a deterrent from decreasing interest in engineering. In addition, early exposure to engineering practice enables students to make a truly educated decision about their future career path without need to navigate an engineering program for years only to fail and be forced to change majors and start another program entirely anew. This approach allows students to endure lesser trauma than having to change programs midway, and instead it provides a more positive academic experience for students to find their passion early on, even if it lies outside engineering. This academic self-selection process we call "soft weeding," as opposed to the more traditional "hard weeding" done when a student is forced out of a program due to academic hardship and underperformance in upper-division classes.

Methods

During the first year of UNT's MEE program, the department offered a consecutive two semester, one-hour seminar course coined MEE Practice I & II. Entering MEE freshman and new transfer students generally enrolled. While students were encouraged to take the courses sequentially, serial enrollment was not enforced. So in some cases, students took MEE Practice II years later than MEE Practice I. Each semester of MEE Practice I was a new group of students, while all but the first MEE Practice II course was mix of several cohorts. For purposes of data analysis, each semester is assumed to be populated by a separate, independent student cohort.

The first four weeks of each semester began with an interactive discussion on ethical codes of conduct expected of and adhered to by the engineering profession. Following this introduction to ethics, classes were team taught by faculty in concert with practicing engineers from local industry and government. Faculty shared their research experiences, while engineers from industry presented various projects and even ethical dilemmas they encountered in the workplace.

Engineers participating from industry were recruited via personal contacts made at conferences and career fairs, telephone calls to local firms' outreach departments, as well as being drawn from members of the College of Engineering's industrial advisory board. Respondents were generally positive towards the opportunity to share their experiences with students, and all expressed interest in returning in following years. The student-practitioner interaction was deemed mutual as both research and industry engineers could market their projects to the next generation of engineers and seed future recruitment opportunities.

To gauge the impact this early exposure to practicing engineers had on students' idea of what their chosen career might entail, an anonymous survey (Table 1) was developed to measure students' initial familiarity with engineering practice. The questions specifically interrogated students' intention to continue in engineering. Students enrolled in each offing of MEE Practice I and II took this survey on the first and last day of class. Differences in the survey responses before and after were used to gauge impact.

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

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 (GLOs) 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.

To provide quantitative analysis, nonparametric statistical analysis was utilized through the Mann Whitney U Test[16], which allows two populations to be compared without relying on assumptions such as having a fixed distribution. This approach is necessary as differences on a 1 to 4 ranking scale utilized are arbitrary and may vary from student to student.

A direct assessment of learning outcome achievement was also utilized through short essay take-home assignments. Students were required to respond to a prompt tying each speaker's presentation with a GLO. Examples include:

- 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?
- 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.

Each assignment was graded on a scale of 0 to 10, with students being provided a grading rubric before-hand. Zero to one point was awarded from submission with proper formatting, zero to three points were given for use of college-level writing, zero to three points were given based on how well the student responded to the prompt, and zero to three points were awarded depending on how well the student summarized the speaker.

In addition to the aforementioned survey questions, students were also asked reasons they chose the MEE program. In the pilot study, students were asked to comment on reasons in an open format. From that, a total of 13 lumped categories were identified, and afterward were asked in a checkbox format (Table 2).

Results & Discussion

Over the course of four years, on average, MEE Practice I demonstrated a statistically significant increase in awareness of practicing engineers in both industry and research correlating with a statistically significant increase in familiarity with MEE faculty and research (Figure 1). Similarly, MEE Practice II, over the same longitude, showed a significant increase in awareness of engineering research practice with an increased familiarity with MEE's research. Most cohorts (5 of 8) demonstrated a significant increase in understanding of engineering ethics (Figure 2). As would be expected, there is a statistically greater difference in the changes found in MEE Practice I than there are in Practice II as most of the students have already been exposed to a semester of information and are more familiarized with engineering practice in the second course than the first. Looking at an overall average (Figure 3) suggests that the courses successfully met the necessary GLO's needed by ABET (f) by increasing students' awareness of the engineering profession.

Table 2: Thirteen lumped categories identified as reasons for pursuing an MEE degree. Note: Questions 14, 15, and 16 were asked initially in the pilot study but were eliminated in the three following study years.

#	Reason
1	Interest/love in science/math/technology/logic/problem solving
2	Money/employment/job security/versatility of degree/relevance
3	Prior class or work experience
4	Perceived aptitude
5	Aspiration/career goal/desire for engineering degree
6	Desire to help society
7	Desire to help environment
8	Novelty of program
9	In lieu of other major/curiosity/"seems interesting"
10	Perceived need for engineers
11	Parent is engineer/family or mentor's influence
12	Challenge/test intelligence
13	Alternative energy prospects/energy research
14	Changing majors or transferring
15	Expressed displeasure after class
16	No comment*

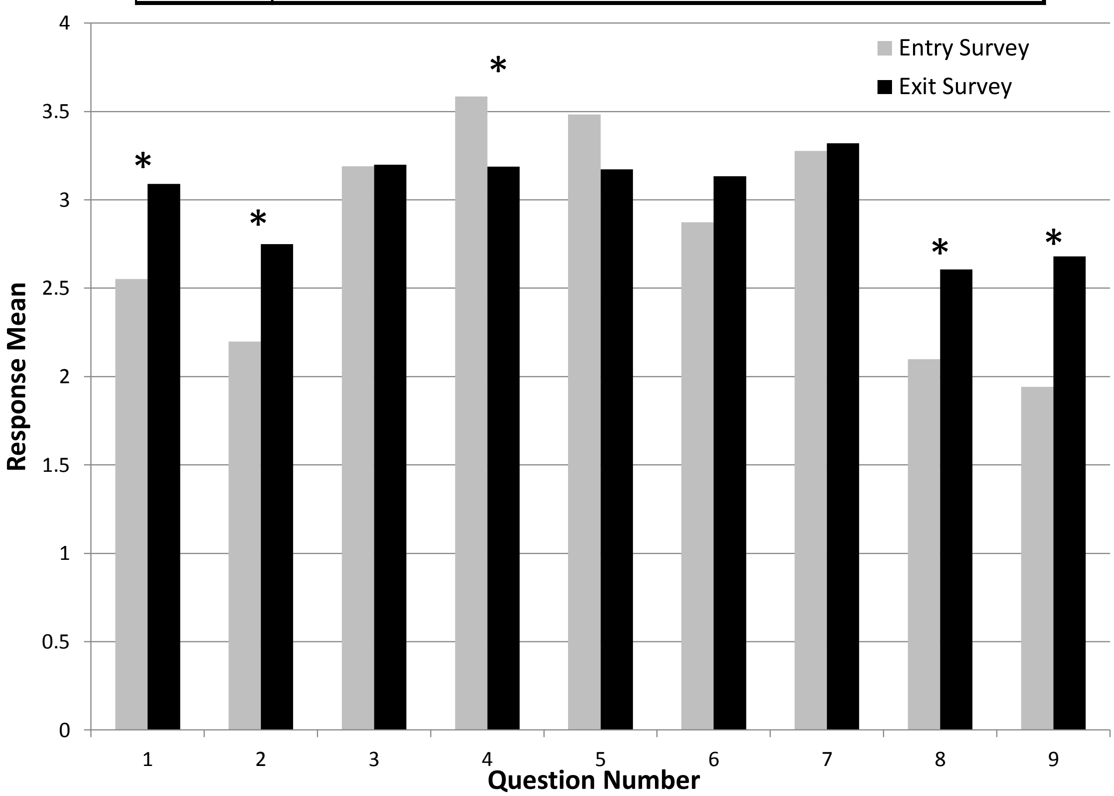

Figure 1: Averaged pre/post responses from all MEE Practice I courses (Fall Semesters). Note "*" signifies a statistically significant change ($p < 0.05$). Sample sizes vary per cohort and are found in Table 3.

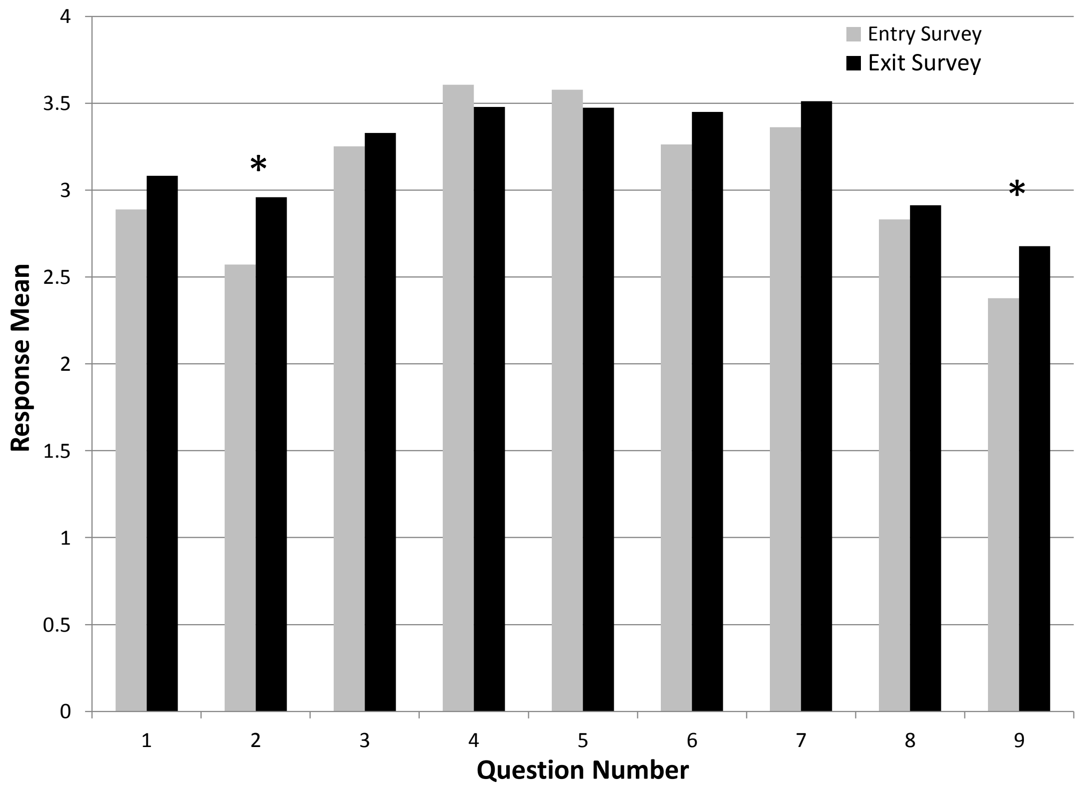

Figure 2: Averaged responses from all MEE Practice II courses (Spring Semesters). Note "*" signifies statistically significant change ($p < 0.05$). Sample sizes vary per cohort and are found in Table 3.

Direct assessment via students' essays confirmed that the courses successfully met the necessary GLO's needed by ABET (f) by increasing students' awareness of the engineering profession. Essays generally demonstrated that students could summarize what speakers said, and they could incorporate commentaries about the workplace onto the essay prompts. Since no direct assessments were given, differences in students learning and interests resulting from practitioner exposure could only be assessed through the entry/exit surveys. While all but one cohort maintained they would enjoy engineering, and all maintained that they would continue as a student in the UNT College of Engineering, there were a few classes that significantly declined in interest in continuing as a MEE major, specifically students participating in MEE Practice I. This finding could imply that upon learning more about mechanical and energy engineering practice, they realized other engineering professions might be more applicable to their passions. Other possible explanations could lie within the program itself. Data collection coincided with the first four years of the MEE program's existence. Thus, other external factors associated with the newness of the program (i.e., ongoing facility construction, rapid hiring of many new faculty, lack of program ABET accreditation) could have had an impact. Nonetheless, students did show consistent increase in awareness, implying they were indeed learning from the course. This observation allows elimination of lack of learning from a list of potential causes. Comparing the two separate courses and considering they are sequential, most students had become more acquainted with engineering practice in Practice II and thus, as expected, less statistical change is evident in Practice II. Most importantly, the results indicate that exposure to engineering practitioners does not decrease students' enthusiasm for engineering. On the hand, practitioner exposure does not increase student's interest either. However, it may instead maintain and reaffirm it.

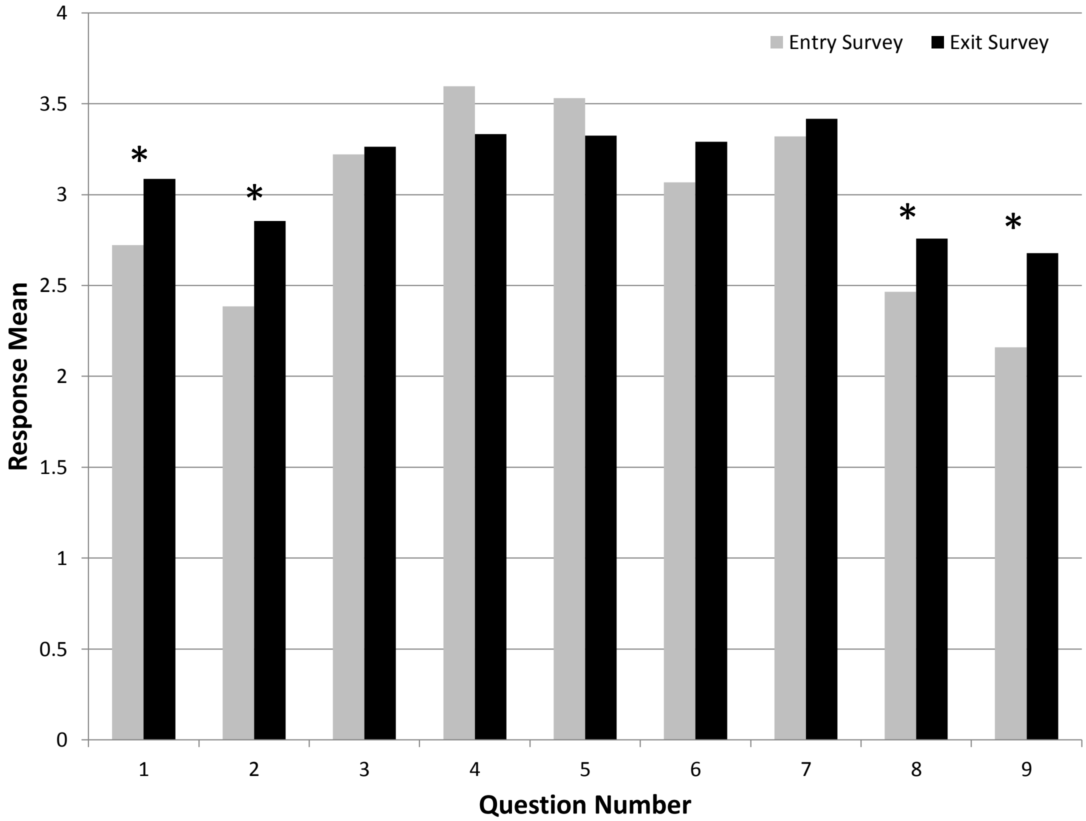

Figure 3: Cumulative pre/post response comparison over all 8 semesters to evaluate effectiveness of engineering exposure. Means are averages for each semester's initial and final response. Note "*" represents a statistically significant change ($p < 0.05$). Sample sizes vary per cohort and are found in Table 3.

Also important to note is that students' experiences were not isolated to this class. They were normal college students taking a variety of classes to satisfy their major requirements. Therefore, student decisions and demeanors towards engineering and the MEE program were also affected by other STEM classes they may have experienced, as well as other life experiences in general. Prior literature has shown that poorer performing students, tend to overestimate their predicted grades and are either unaware of or ignore possible deficits[14]. Consistent with this finding, exit surveys administered at the end of each semester coincided with the time when students may be suffering the most in other classes.

Likewise when entering a new semester, students may inaccurately overestimate their knowledge of potential topics such as ethics, leading to a decline when students realize a gap in their knowledge. Also, upper-division students would not necessarily gain the same amount of insight having already experienced engineering practice via internships and advanced course work, which would particularly affect cohorts in MEE Practice II as this could have been taken up to three years after its counterpart; or transfer students could have come in and taken both later in their career at UNT.

Table 3: Gender and ethnicity data for each entry and exit survey (Fall - MEE Practice I, Spring MEE Practice II).

	Fall 2007		Spring 2008			Fall 2009		Spring 2010	
Ethnicity	**Initial**	**Final**	**Initial**	**Final**	**Ethnicity**	**Initial**	**Final**	**Initial**	**Final**
Asian	3.3%	2.7%	2.4%	2.9%	*Asian*	7.4%	7.7%	10.8%	11.3%
Black	9.8%	8.1%	11.9%	14.7%	*Black*	5.9%	3.8%	3.1%	0.0%
White	65.0%	62.2%	64.3%	70.6%	*White*	66.2%	59.6%	67.7%	71.7%
Hispanic	14.8%	13.5%	14.3%	2.9%	*Hispanic*	13.2%	17.3%	9.2%	7.5%
Mixed	1.6%	0.0%	0.0%	0.0%	*Mixed*	4.4%	1.9%	3.1%	3.8%
Other	0.0%	0.0%	0.0%	0.0%	*Other*	2.9%	3.9%	0.0%	0.0%
Unknown	4.9%	13.5%	7.1%	8.8%	*Unknown*	0.0%	5.8%	6.1%	5.7%
TOTAL	61	37	42	34	TOTAL	68	52	65	5300.0%
Gender					**Gender**				
Female	9.8%	10.8%	4.8%	2.9%	*Female*	7.4%	7.7%	9.20%	7.5%
Male	86.9%	81.1%	92.9%	94.1%	*Male*	92.6%	88.5%	86%	88.7%
Unknown	3.3%	8.1%	2.4%	2.9%	*Unknown*	0.0%	3.8%	5%	3.8%
TOTAL	61	37	42	34	TOTAL	68	52	65	53
	Fall 2008		Spring 2009			Fall 2010		Spring 2011	
Ethnicity	**Initial**	**Final**	**Initial**	**Final**	**Ethnicity**	**Initial**	**Final**	**Initial**	**Final**
Asian	11.4%	14.9%	5.5%	6.5%	*Asian*	4.1%	6.3%	2.9%	5.3%
Black	5.7%	4.3%	9.1%	10.9%	*Black*	6.9%	7.8%	8.8%	8.8%
White	68.6%	68.1%	67.3%	65.2%	*White*	66.7%	65.6%	57.4%	56.1%
Hispanic	7.1%	4.3%	9.1%	13.0%	*Hispanic*	12.5%	11.0%	13.2%	14.0%
Mixed	2.9%	2.1%	1.8%	0.0%	*Mixed*	4.2%	3.1%	5.9%	1.8%
Other	0.0%	4.2%	3.6%	2.2%	*Other*	4.2%	3.1%	5.9%	8.7%
Unknown	4.3%	2.1%	3.6%	2.2%	*Unknown*	1.4%	3.1%	5.9%	5.3%
TOTAL	70	47	55	46	TOTAL	72	64	68	57
Gender					**Gender**				
Female	12.9%	14.9%	20.0%	26.1%	*Female*	16.7%	15.60%	14.7%	14.0%
Male	87.1%	80.9%	78.2%	71.7%	*Male*	83.3%	84.40%	80.9%	84.2%
Unknown	0.0%	4.2%	1.8%	2.2%	*Unknown*	0.0%	0.00%	4.4%	1.8%
TOTAL	70	47	55	46	TOTAL	72	64	68	57

Some students chose not to turn in class assignments, and thus already knew they would fail when taking the exit survey, possibly inducing negative attitudes affecting their answers. Students also vary in learning style and thus may not fit with the instructors chosen style. Also important, in the last academic year (Fall 2010 – Spring 2011), there was change in the course's instructor. While active efforts were made to deliver the class in the same manner as under the first instructor, a difference in content delivery style is unavoidable and may have affected data.

Students' reasons for entering the MEE program were very consistent between most cohorts, with the exception of the pilot study. That difference may be attributed to the open nature of the pilot studies question format compared to the checkbox format with 13 categories identified thereafter. Also a reason, "no comment" responses were not taken into account in percentage calculations in the pilot study. Consistently the primary reasons are either an interest in science, math, and technology or in the fiscal security and versatility provided by the degree.

Table 4: Percentage of each cohort associating with one of thirteen identified reasons for pursuing engineering. Note, within the pilot study, all "no comment" entries were ignored when calculating percentages. All cohort totals may be found in demographics.

	Fall 2007		*Spring 2008*		*Fall 2008*		*Spring 2009*	
Reason #	**Initial (%)**	**Final (%)**	**Initial (%)**	**Final (%)**	**Initial (%)**	**Final (%)**	**Initial (%)**	**Final (%)**
1	34.8	31.1	43.3	27.3	15.7	13.4	13.1	12
2	12.4	8.9	23.3	25.5	18.3	19.5	18.7	20.7
3	5.6	0	6.7	1.8	10.9	10.3	8.8	9.3
4	12.4	8.9	0	1.8	12.84	17.6	15	14.6
5	6.7	13.3	3.3	5.5	7.2	6.9	8.2	8.3
6	1.1	4.4	1.7	9.1	7.7	5.4	7.7	7
7	4.5	4.4	1.7	3.6	1.7	1.1	2	2
8	5.6	0	1.7	0	5.4	5	6	5.7
9	2.2	2.2	5	5.5	4	3.8	3.1	1.7
10	3.4	2.2	0	5.5	4.9	5.7	6	6.7
11	6.7	8.9	11.7	10.9	9.5	10.3	9.9	10.3
12	4.5	0	1.7	1.8	0.9	0	0.6	1
13					0.9	0.8	0.9	0.7
14		11.1		1.8				
15		4.4		0				
16								

Table 5: Percentage of each cohort associating with one of thirteen identified reasons for pursuing engineering. Note, within the pilot study, all no comments were ignored when calculating percentages. All cohort totals may be found in demographics.

	Fall 2009		*Spring 2010*		*Fall 2010*		*Spring 2011*	
Reason #	**Initial (%)**	**Final (%)**	**Initial (%)**	**Final (%)**	**Initial (%)**	**Final (%)**	**Initial (%)**	**Final (%)**
1	14.2	8.6	14.2	13.1	13.6	12.8	12.9	14.1
2	19.6	12.3	22.2	20.9	21.4	18.2	20.9	21.8
3	10.1	6.2	11.7	10	9.1	11.6	11.2	8.3
4	15.8	11.4	12.2	15.5	13.8	17.2	14	16.4
5	5.7	4.1	5.6	4.6	6.2	4.7	5.7	6.4
6	8.2	5.2	5.6	6.1	7.7	6.9	6.9	6.1
7	0.8	1.1	0.6	1.8	0.7	0.6	1.2	1.3
8	5.2	3	5.6	5.5	4.7	6.9	5	4.8
9	3.1	1.9	3.9	4.6	4.2	4.1	4.5	4.5
10	4.9	2.6	5.6	5.2	5.7	4.4	5.9	5.4
11	12.1	8.1	12.3	11.9	11.6	10.9	10	10.2
12	0.3	0.2	0.6	0.6	0.2	0.3	1	0.6
13	0.3	35.3	0.3	0.3	1	1.6	1	0
14								
15								
16								

Conclusion

With few exceptions, class cohorts generally self-reported increased awareness of what practicing engineers in industry do, as well as what research projects MEE faculty members were actively working on. With a few dramatic exceptions, every cohort also reported an improved understanding of the ethics involved in engineering. Thus, Practice I and Practice II provided students with a preview of possible career choices. This knowledge allows students to make a truly educated decision about what path they may take. It is reaffirming for students passionate about engineering, and it allows students worried that engineering may not be for them to switch programs without enduring the trauma of changing programs after investing 2 or 3 years and failing to complete an engineering program. As introduced in the pilot study, this soft weeding selection process is ideal for both the student and the University because it provides high quality, dedicated students, in both engineering and in fields where students enrolled in engineering program who chose to change majors switched into.

Follow up interviews with alumni are being conducted to further identify possible variables contributing to the identified trends, allowing more specific and detailed conclusions to be made. Future studies should include evaluations of the knowledge gap between what pre-college students perceive engineering to be and what engineering practice truly is. The effect of involvement within the MEE Department and retention as well as a comparison of retention rates between institutions that do and do not have exposure to engineering practice within their first year programs will be conducted. Also useful would be to identify students having left or leaving the program and interview them to specifically identify reasons for loss in retention.

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