Engineering Major Certainty: A Look at Major Discernment Initiatives Pre and Post

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This complete evidence based practice paper explores first-year engineering student's major discernment and the certainty level change with the introduction of formal course programming. The content of the course programming involved hands-on class sessions that exposed students to each of the engineering departments offered followed by sessions that allow students to select a department to learn about in greater depth through an alumni panel, lab tours, and a student panel. For each of these more in depth sessions, students select which they want to attend during class time as there were 5 sessions being offered at the same time slot representing the five departments for that institution. The purpose of this discernment module was to help First-Year Engineering students make an informed decision about their future study as an engineering major.

Students completed surveys multiple times throughout their first-year indicating their intended engineering major and how certain they felt about that decision. It was hypothesized that gaining this exposure formally would increase a student's self-reported certainty level with an engineering major by the end of the first-year. Statistical comparisons were made to certainty levels of students at the end of their first-year before this major discernment module was introduced (2016-2017 school year) and after (2017-2018 school year). There were 450-500 students for each school year considered.

Overall, the certainty level of students with their engineering major increased over the course of the school year with over 80% of students indicating an increased level of certainty after the discernment module was introduced. The percentage of students that changed majors during the first-year increased after implementing the major discernment module, with over 50% of students changing departments at some point during the first-year. The first-year to sophomore retention level increased by 5% after introducing the engineering major discernment module. The certainty levels for male students was higher than female students for all surveys; however, after the major discernment module was introduced the difference between male and female students was no longer significant. This indicates that this module likely had a positive influence for women in particular. Computer Science and Engineering students exhibit an initially higher certainty level than other engineering majors which we hypothesize to be related to prior high school courses taken in computer programming. Finally, certainty level in an engineering major was considered as it relates to academic preparedness and was found to be independent.

Background

The current study was conducted at a medium-sized, Midwestern, selective, private institution which offers 5 different engineering departments (with 9 degree programs). When students apply to the university they indicate an intended major, but are part of a common First-Year of Studies Program. If they indicate they are interested in any of the engineering disciplines they begin in the Introduction to Engineering Systems 2 semester course sequence and "declare" their engineering major during the second semester of their first-year. This declaration period is in March, but students can change up until August just prior to the start of sophomore year without any delay to degree completion. There are no administrative gates from the university; students can select their engineering major as long as they are in good academic standing (>=2.0 GPA). There is no application, GPA requirement, or caps placed on the number of students allowed in a given engineering program or department. The engineering program has first-year to sophomore retention that is over 80%, and sophomore to graduation rates above 90%.

The current study sought to understand the program experiences that were part of a two-semester course sequence, which includes a targeted module for the selection of an engineering major, shown in Figure 1.

The discernment module formally begins in week 6 of the semester with 8 seventy-five minute class sessions dedicated to understanding engineering majors, careers, and opportunities at the university and after graduation. During this module, students gain exposure to the engineering departments available at the university through a series of required events. In order to make room for this discernment module, other content of the course had to be adjusted accordingly. This was accomplished by reducing the length of the two group projects delivered during the semester and adjusting the project content to remove material that was not necessary for success in future engineering courses (as determined by student and faculty feedback).

First, all students were required to attend "Department Days" where 5 consecutive class sessions were used to introduce each of the 5 departments to all students (Aerospace and Mechanical Engineering, Chemical and Biomolecular Engineering, Civil and Environmental Engineering and Earth Sciences, Computer Science and Engineering, Electrical Engineering). This includes a description of the degrees offered, profiles of recent alumni, and hands-on activities related to that major. Next, students were required to attend a student panel, an alumni panel, and laboratory tours. In each case, students were required to attend these events for only one department (sessions for each department were offered in parallel so that each department met in a separate room), but they could attend additional department offerings based on their interests. Finally, students were required to attend 3 events outside of class time that would contribute to their major discernment. These included but were not limited to events put on by engineering student groups, departments, and the Career Center as well as individual meetings with faculty, alumni, or upper-class students. At the end of the module, students completed a reflective paper that outlined their experiences in engineering thus far and their expected major choice moving forward.

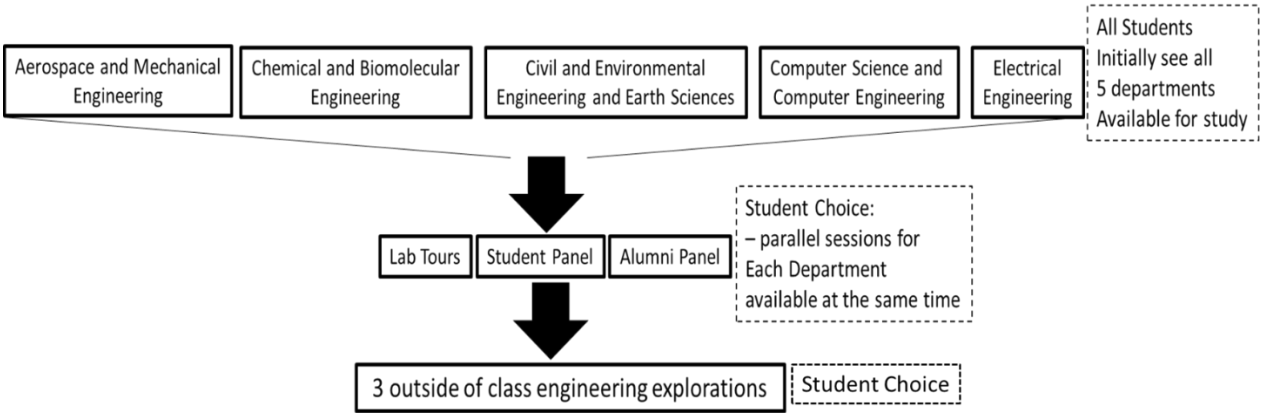

Figure 1. Model of Discernment Module

This program structure, with a requirement to initially see all departments followed by choice events, has also been implemented at another Midwestern university and yielded positive outcomes. Positive outcomes included: (1) a higher retention rate in engineering and the STEM College and (2) a decrease in the engineering major switches after the first-year[1-2]. Comparing the prior study to the current study site, there are significant institutional differences: an urban public vs. a selective private. In both contexts, the students enjoyed getting exposure to all departments but then having the flexibility to select activities based on the engineering discipline they were most interested in.

Research Questions:

1. Do First-Year engineering students that complete formal discernment activities indicate a higher level of understanding and confidence with their engineering major than those that do not?
2. What is the pathway for the students that are initially "undecided" engineering in terms of major selection after completing discernment activities?
3. What demographic groups are most likely to change engineering major after discernment activities? (intended major, gender, math preparation level, programming experience)

Literature Search:

A seminal work by Seymour, Hewitt, and Friend described the selection of an engineering major as an "uninformed choice"[3]. In the 2 decades since their work was published, there has been an increase in the number of First-Year Engineering Programs and the resources devoted to increase interest and retention as well as helping students to make a more informed engineering major selection. The content and structure of these programs varies widely by program and institution; however, typically cornerstone design projects, computing skills, and major discernment are central[4].

The selection of an engineering major is a critical decision that has long term implications both academically and professionally. A prior study on major selection by Arcidiacono reported that mathematical ability significantly impacted major selection. High ability students have been found to shift to majors that result in more profitable professional pathways, and lower ability students shift to "easier majors." This decision ultimately has financial implications, as students who earn a degree in natural sciences earn higher salaries than those with degrees in the humanities and social sciences.[5] Student aptitude combined with perceived future earning potential were reported as important factors in the selection of a college major; however, these perceptions may not reflect reality[5-6].

Due to national demand for qualified scientists and engineers in combination with the relatively low persistence rates, there has been a focus on retention of the students that initially indicate engineering. Prior studies have recommended focusing on efforts that would help to retain students. Ohland and associates suggest "identify programming that retains the students who come to college committed to an engineering major"[7]. The current study is focused on understanding the affective choices that first-year engineering students make with regards to their major. The exploration and selection of an engineering major is often a focal point of first-year engineering programs, and this experience has been found to be "polarizing," either affirming a student's plans to study engineering (or a specific discipline) or dissuading them all together[8]. Orr and associates conducted a large scale quantitative study based on data from the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD), reporting that students at institutions that were required to take an Introduction to Engineering Course were more likely to graduate with a degree in engineering than students at institutions that do not require an Introduction to Engineering Course[9]. Required First-Year Engineering courses do help students either affirm a prior choice of an engineering discipline or help students to select a major best suited to them, and also influences which engineering disciplines students are more likely to select[9-10].

Theory

Social Cognitive Career Theory (SCCT) recognizes career development as a process related to self-exploration and choice, but that there can be barriers that confound decision making. For example an individual's prior experiences and background (culture, gender, genetic endowment, sociostructural considerations, and disability or health status) impact the nature and range of their career possibilities considered. In theory, SCCT aims to describe the intersection of self-efficacy beliefs, outcome expectations, and goals[11]. Self-efficacy, defined by Bandura, is one's own belief about one's ability to

achieve a task[12]. This derives from four primary sources: performance outcomes, vicarious experiences, verbal persuasion, and physiological experiences. Self-efficacy is a task level theory; it is useful in class settings where students can perceive separate domains that they've experienced. Outcome expectations refer to the consequences and perceived outcomes of particular behaviors and actions. According to SCCT, one's engagement and persistence in an activity is partly determined by both their self-efficacy beliefs and outcome expectations. Lastly, personal goals, defined as an intention to engage in a certain activity or to attain a certain proficiency at an activity, are important to validate and confirm both self-efficacy beliefs and outcome expectations[11,13].

Methods

The current study primarily focused on quantitative methods from student surveys, collected at the end of the first-year engineering course sequence. Responses were collected from: (1) the spring 2017, before major discernment was integrated into the First-Year Engineering Program, and (2) the spring of 2018, after the discernment module was integrated into the curriculum. Table 1 shows there was over a 90% response rate for each administration, due to the time given in class to complete the survey (no incentive offered). The percentage of male and female respondents is proportional to the class representation which has 33-38% women during those administrations.

Table 1. Summary of Respondents

	Potential Respondents	Male Respondents	Female Respondents	Actual Respondents	Response Rate	Male Respondents	Female Respondents
Spring 2017	488	288	161	449	92.0%	64%	36%
Spring 2018	479	278	186	464	96.9%	60%	40%

In addition to the survey results, researchers collected and tracked student retention data. Due to very high institutional retention and the nature of major selection at the university, only retention within the College of Engineering was considered. The data were analyzed using the statistical software package, STATA. Descriptive statistical comparisons were made (frequency, percentage, mean, standard deviation) as well as unpaired t-tests for mean comparisons between the two administrations and by other factors such as intended engineering discipline, gender, math placement level, and prior programming experience.

Results / Discussion

Each of the three research questions is addressed relative to the statistical comparisons indicated in the methods section.

Question 1: *Do First-Year engineering students that complete formal discernment activities indicate a higher level of understanding and confidence with their engineering major than those that do not*?

Evidence supports

A survey question posed to students about the helpfulness of the program in exposure to different engineering disciplines shows evidence to support increased understanding. The survey prompt was: "How helpful were the Introduction to Engineering Courses in exposing you to the different engineering disciplines available for future study?" The mean student response difference increased from 2.39 (2017-before discernment) to 3.27 (2018 – after discernment) was highly statistically significant, based on an unpaired t-test comparing the mean response rate for students ($p<0.0001$). The summary of the percentage of students in each response category shows this shift in Figure 1.

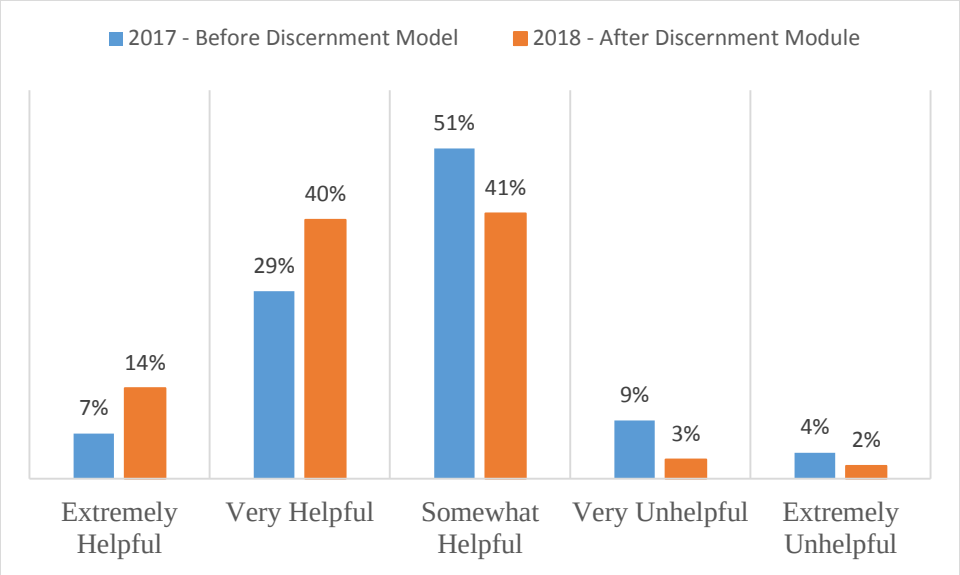

Figure 1. Helpfulness in Exposure to Different Engineering Disciplines

Comparing the student reported certainty level in an engineering discipline from the end of the school year 2017, before major discernment module, versus 2018, after the major discernment module, there is a higher percentage of "extremely certain" students which is directionally positive; however, this difference was not statistically significant to a 0.05 leve1. The self-reported responses are summarized in Table 2, the question to students was: "How certain do you feel about your intended engineering discipline?"

Table 2. Summary of End of Year Certainty Level

Certainty Level	Before Discernment Module Certainty Level 2017		After Discernment Module Certainty Level 2018	
	#	%	#	%
Extremely Uncertain	6	1%	7	2%
Very Uncertain	19	4%	16	3%
Somewhat Certain	86	19%	83	18%
Very Certain	200	45%	197	43%
Extremely Certain	134	30%	159	34%

Throughout a First-Year Engineering Course Sequence, it would be expected that the percentage of undecided engineering majors would decrease. After introducing the Engineering Discernment Module, which is primarily in the fall semester, there is a clearer decrease in the number of undecided students. Figure 2 shows a summary of the percentage of students that were still deciding at the beginning, middle, and end of the first year, and in 2018 after the discernment module there is a bigger reduction in undecided students at the end of the fall semester indicating an improved understanding and increased certainty level.

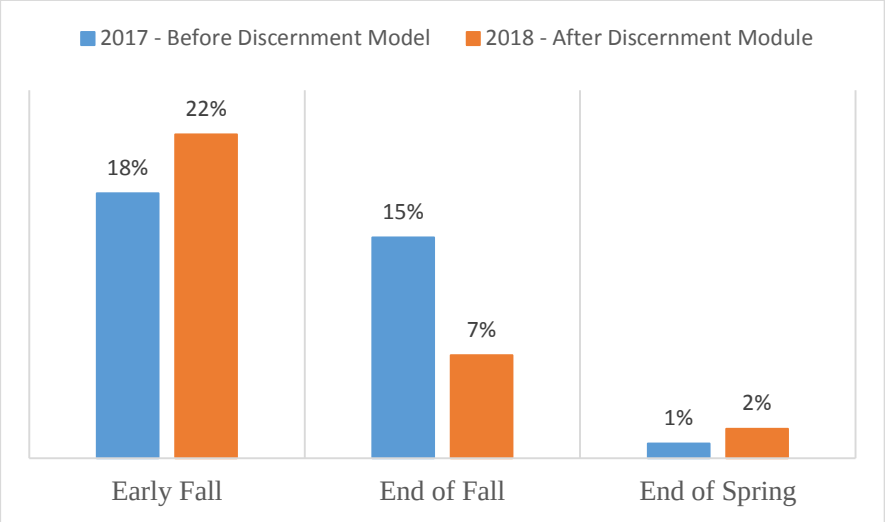

Figure 2. Percentage of Undecided Students throughout the First-Year

It should be noted that there is an increase in the starting number of "undecided" students in 2017-2018. This may be due to year to year variability or a result of student perception of the course. Because the students were aware that discernment would be part of the course structure, it is possible that more students used the class to explore major options and were therefore "undecided" at the start of the semester. There is a clear reduction in "undecided" students in both years with a more noticeable drop off when engineering discernment was explicitly included in the course. This reduction in undecided students can be attributed to many factors, including the course content and instruction. The reduction in students reporting "undecided" engineering majors in the fall semester cannot be attributed to students leaving the engineering course. In each academic year, fewer than 3 students have dropped during the fall semester. However, a number of students do leave engineering after the fall semester or after the spring semester. As Table 3 outlines below, less than 12% of students left the engineering curriculum after each semester offered. Due to the institutional structure, retention within the College of Engineering is the only concern during the first-year experience and is the most tracked metric.

Table 3. Summary of Drop Rate after each First-Year Engineering Course

	Before Discernment Module: 2016-2017			**After Discernment Module: 2017-2018**		
	# Received a Final Grade	**# Not Continuing**	**% of Class**	**# Received a Final Grade**	**# Not Continuing**	**% of Class**
End of Fall	497	52	10.5%	461	32	6.9%
End of Spring	463	48	10.4%	454	53	11.7%

*Only students enrolled full-time at the university as of the fall semester are included

Question 2: What is the pathway for the students that are initially "undecided" engineering in terms of major selection after completing discernment activities?

As noted previously, "undecided" students accounted for 93 and 111 first year students during the fall 2016 and fall 2017 semesters, respectively. Table 4, below, tracks the number of these undecided students that dropped out of the engineering curriculum between the fall survey and the start of their sophomore year.

Table 4. Engineering Drop Rate for Undecided Students

	Before Discernment Module: 2016-2017			After Discernment Module: 2017-2018		
	Undecided in Early Fall	**Number**	**Percent of Total**	**Undecided in Early Fall**	**Number**	**Percent of Total**
Dropped after Fall	93	17	18.3%	111	12	10.8%
Dropped after Spring		13	14.0%		14	12.6%
Total		30	32.3%		26	23.4%

In both course years, the "undecided" students drop out of the engineering curriculum at a slightly higher rate than the general course population (shown in Table 4). However, the drop rate is most noticeably higher before a discernment module was in place. The overall retention in the College of Engineering from starting First-Year Engineering to starting sophomore year increased from 81% to 85.5% after the introduction of the discernment module. It is possible that by adding the discernment module more students were able to find opportunities and interests within the College of Engineering and therefore decided to stay in the engineering curriculum. This was further explored by assessing which departments "undecided" students moved into as shown in Figure 3.

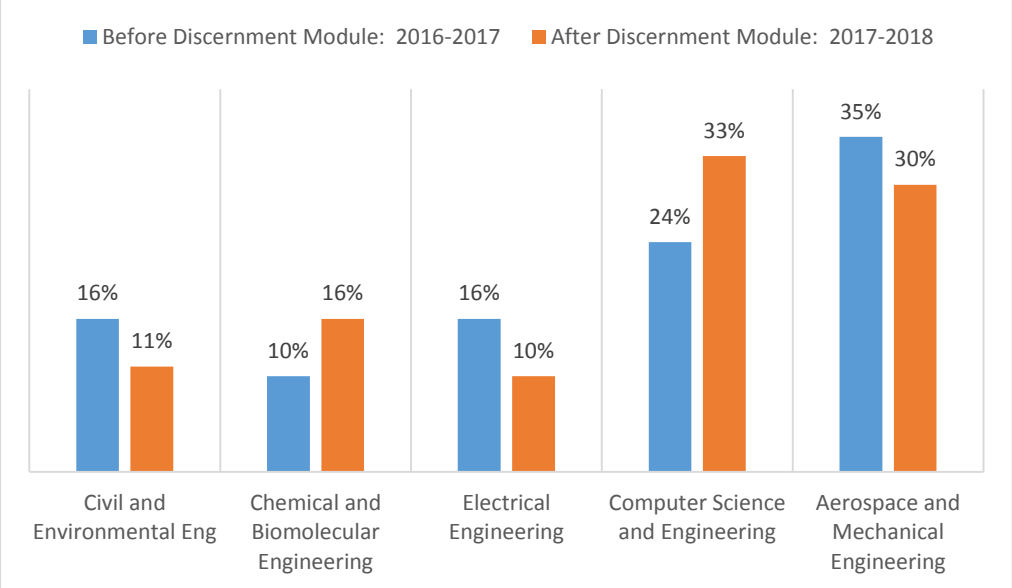

Figure 3. Ending Departments for students who started as "Undecided"

Students that were "undecided" entered the College of Engineering in similar rates to the departments' sizes. However, slight shifts in the selected departments were noted between the two course offerings. This is investigated more fully in the following sections as well.

Question 3: What demographic groups are most likely to change engineering major? (Intended major, Gender, high school math preparation level, prior programming experience)

There was a notable increase in the number of major changes documented during the First-Year of Engineering after introducing the discernment module during the 2017-2018 school year. Table 5 shows a 9% increase in the number of students that changed departments.

Table 5. Summary of Department Changes before and After Discernment Module

	Before Discernment Module		After Discernment Module	
	#	2016-2017	#	2017-2018
Changed Departments	217	42%	261	51%
Remained in Department	297	58%	253	49%

Question 3a: Intended Major

To understand the differences observed after the introduction of the discernment module, the researchers came up with the following potential rationales:

- Did students tend towards certain disciplines because they were more engaged with the departmental session for that discipline?

We don't believe that this is a primary reason, as the ratings for the Aerospace and Mechanical was the highest, as shown in Table 6, and yet it attracted a smaller percentage of students than it did before the discernment module. It is possible that by having the discernment modules in general opened up possibilities to more departments than students were not familiar with previously. Other studies have reported that undesignated engineering students in a required First-Year Engineering course are most likely to select Aero, Civil, Computer and Chemical when they do have to take a required course and Mechanical when they don't[16-17].

Table 6. Summary of Student Ratings of in Class Departmental Discernment Activities

Departmental Session	Average Rating (5 pt scale) 1=low / 5=high
Aerospace and Mechanical	4.07
Chemical and Biomolecular	3.33
Computer Science and Engr	3.26
Civil and Environmental	2.88
Electrical	3.31

- National trends for demand of CSE?

These numbers align with the national trend towards increased student enrollment and degrees awarded to Computer Science and Computer Engineering related fields, which showed a 10 fold increase from 2013 to 2017 according to the report from the American Society for Engineering Education[14-15].

As shown in Figure 4 computer science and engineering has the highest level of retention of students, and they also have the highest rate of attracting students from other majors and those that were "still deciding."

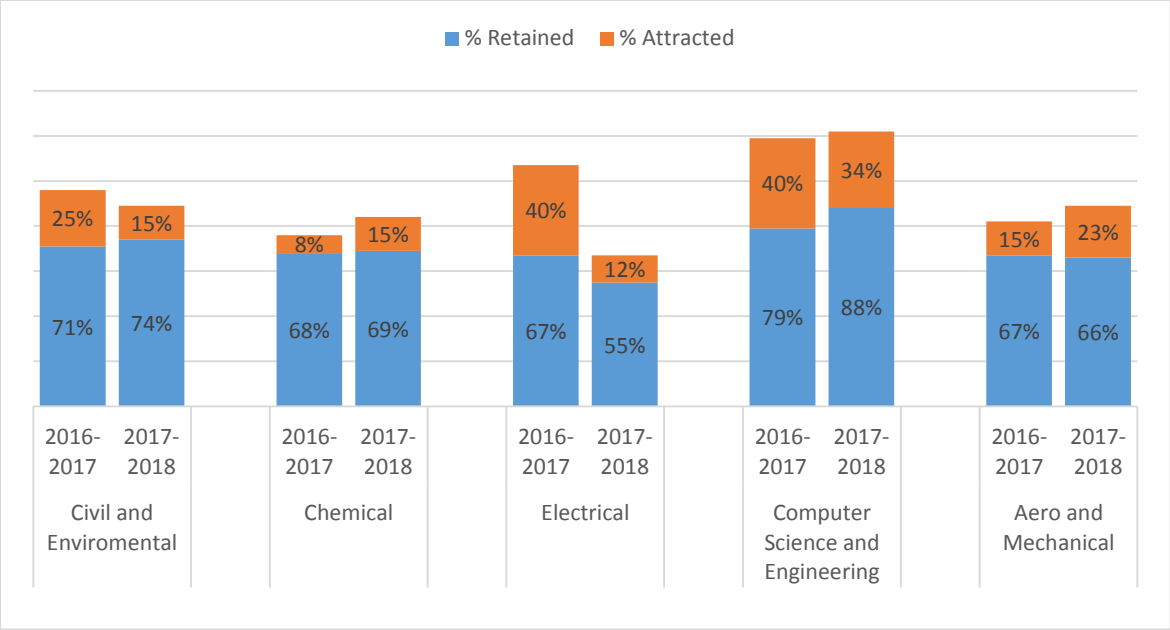

Figure 4. % of Students Attracted and Retained by Dept Before and After the Discernment Module

Question 3b. Gender

Comparing the two administration years: without discernment module 2016-2017 and with the discernment module 2017-2018 shows that women's certainty level improved with the introduction to the module. Without the module (2016-2017), the difference in certainty level between male and female students was statistically significant (worse for women as a lower number represents a higher certainty level). After the introduction of the discernment module (2017-2018) the certainty level for women improved and there was no longer a statistically significant difference.

Table 7. Gender Differences in Certainty Level

Time Period	Male: mean certainty value	Female: mean certainty value	Δ: mean certainty value	T value
End of 2017 (no discernment)	1.93	2.16	0.23	-2.60**
End of 2018 (discernment)	1.92	1.99	0.07	-0.76

Note: A higher value for certainty is less certain ** denotes p<0.01

Looking at the year when the discernment module was introduced, 2017-2018, there is a clear difference in the percentage of male vs. female students that indicated very low certainty levels but by the end of the year those the percentage of male and female students in low certainty levels were almost the same (4.5 vs. 4.7%). On the higher certainty levels, the women are still collectively below the men but they make larger gains throughout the year: women start out lower, make larger gains and are just slightly below male students.

Table 8. Gains in Certainty Level by Gender for 2017-2018

Time Period	Uncertain (Extremely or Very)		Somewhat Certain		Certain (Extremely or Very)	
	Female	Male	Female	Male	Female	Male
Fall	10.4%	8.0%	41.0%	37.3%	48.5%	54.7%
End of Spring	4.5%	4.7%	17.9%	16.0%	77.6%	79.2%
% Change	-6.0%	-3.3%	-23.1%	-21.2%	29.1%	24.5%

Question 3c. Math Preparation Level

High School Math preparation level is not correlated with engineering certainty level. The difference in engineering certainty was not statistically significant if someone was on track for math or ahead of schedule. The following tables from 2017-2018 show that the engineering certainty level for students in Calculus 1 in the fall / Calculus II in the spring (on track) as compared to a more advanced placement level was not statistically significant. A summary of certainty levels by math preparation level is shown in Table 9.

Table 9. Certainty Level by Math Preparation

Math Level	Time Point of Survey	Survey Response				
		Extremely Certain	Very Certain	Somewhat Certain	Very Uncertain	Extremely Uncertain
On track for math	Start of Year	11.20%	37.80%	36.40%	10.20%	4.20%
	End of Year	28.70%	46.50%	19.70%	3.60%	1.60%
Ahead 1 semester for math	Start of Year	16.80%	29.90%	41.10%	8.40%	3.70%
	End of Year	31.60%	43.20%	20.10%	3.90%	1.30%
Ahead 2 semesters for math	Start of Year	18.80%	31.60%	38.40%	9.00%	2.30%
	End of Year	36.10%	43.60%	15.50%	3.90%	1.00%

Question 3d. Prior Programming Experience

37% of incoming engineering students in for 2017-2018 had prior computer programming experience, and it was found to be a statistically significant factor in engineering certainty level. Based on unpaired t-test, students with prior programming experience were also more certain about engineering ($p<0.0001$). This prior high school experience increases engineering certainty level as would be indicated by Social Cognitive Career Theory (performance outcome)[13]. The more notable concern is that women were much less likely to have computer programming experience before coming to college (only 36% of those with prior programming experience) – which has also been reported in other studies[18]. And although we do not have data by minority status we would suspect that they also be less likely to have this experience[18]. On a national level the number of women and minority students in the growing field of computer science and engineering is also lower[15]. Table 10 compares student certainty level with and without programming experience.

Table 10. Certainty Level and Programming Experience

Programming Experience	Mean Certainty Level	T-test
Students WITH Prior Programming Experience (170 students)	1.71	-4.4670***
Students WITHOUT Prior Programming Experience (292)	2.09	

Conclusions:

In all, this study shows that students make considerable gains in their certainty towards engineering major selection with or without a dedicated discernment model. However, major certainty is more significant when students are exposed more intentionally to all of the engineering options available to them. Students completing the discernment module indicated higher levels of understanding and certainty in engineering. Further study is needed to determine if this increased certainty is carried throughout the engineering curriculum and into students' career choices.

In addition, the implemented discernment model could have contributed to significant certainty gains for some specific groups within the initial constituency. Women reported greater gains in engineering certainty when a discernment module is present. It is possible that gender differences in retention or major placement could be reduced through the carefully construction of major choice course material. Also, the number of "undecided" students was reduced more significantly in the fall semester when a discernment module was present. Undecided students are often the most likely to leave engineering; therefore, explicit major discernment could be a meaningful strategy in increasing retention of these students.

Finally, although students' academic preparation, as determined by college math placement, did not show a correlation to their engineering certainty, programming experience did. This matches well with Social Cognitive Career Theory in that students with more significant exposure to engineering and engineering concepts in high school are more likely to enter the engineering curriculum. Like many studies before, this indicates the importance of secondary education in the college engineering program enrollment. However, this study indicates that exposure to pre-requisite topics does not play as significant of a role in students' engineering certainty as having a meaningful engineering experience before entering college.

Future works will continue to follow the students in these cohorts to determine how first-year experiences play a role in persistence in engineering while at the university and into first careers. In addition, this study will be repeated with additional cohorts to better understand year-to-year variability in student perception, major choices, and certainty levels.

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