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Supporting an Informed Selection of an Engineering Major

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Abstract

The following evidence based practice study investigates the impact of a First-Year Engineering discipline exploration course as it relates to retention, frequency of major change, and progress towards graduation. First-Year Engineering courses play a pivotal role in helping students not only determine which engineering discipline to choose but whether or not engineering is a major they want to continue to pursue. If students are able to make more informed decisions about the pathways in which to endeavor then there will likely be a quicker time to graduation and a less time and resources spent. However, not all First-Year Engineering courses and/or programs contain elements of major selection for students. This paper fills this gaps and describes how implementing a one-credit engineering orientation course can help students make timelier decisions regarding their intended major.

The study was conducted at a medium sized, Midwestern, public institution and compares two cohorts of students that experienced two different approaches to exploring engineering major selection, one starting in Fall of 2013 compared to the group stating in the Fall 2014. The original course, Fall 2013, involved a large lecture class with 200+ students, one instructor, and guest instructors from each department that lectured for 2 – 50 minute class periods on their discipline of engineering. The course was revised for Fall 2014 and involved 10 sections of 20-25 students that completed a hands on activity each week, 1 – 50 minute class period, related to each engineering discipline. Students rotated each week to a new engineering discipline session and after all departments had presented, students were able to select engineering disciplinary sessions of their interest for the remainder of the semester. For both cohorts, students were tracked longitudinally through their first-year, second-year, to the start of their third year to determine: (1) if they were retained in the STEM College and (2) the number of major changes during that time period. Results of these factors are analyzed statistically and discussed within the context of engineering major selection, retention, and time to graduation.

Background

In response to the national and global need for a more technically competent workforce, engineering educational initiatives include goals to increase the number of engineering graduates[1-2]. Studies have focused on opening pathways into engineering and study student motivation and self-efficacy[3]. It is believed that making an informed decision on engineering and engineering discipline helps to reduce the number of major changes and time to graduation[4-5]. Of concern is that the selection of an engineering major has been called "the uninformed choice"[6] yet it is a critical decision that has long term implications both professionally and personally. A prior study by Arcidiacono related to major selection found the decision to be related to a student's mathematical ability in particular[7]. It was also noted the vast long term monetary implications for such a decision, it has been documented that students who earn a degree in natural science earn significantly more than students who major in the humanities and social sciences. Finally, 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"[7].

Student ability and their expectation of future earning potential were reported as important factors in the selection of a college major; however, these perceptions may have errors that would influence major change[8]. Social Cognitive Career Theory is based on the idea that career development is 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.

The decision of the specific engineering discipline to study can be overwhelming, and students may not necessarily select the discipline that is the best fit for them on their first attempt. If a student finds themselves in a discipline that they do not feel is a suitable fit, their academic standing and retention within engineering may suffer. Therefore, in order to prevent students who did not find a discipline that was a best fit for them from migrating out of engineering, it is important to study the decision making of students and their discipline selection patterns. This is an essential first step towards understanding the perspectives of students as they select their intended major and potential career. While students tend to choose their disciplines for different reasons, their persistence in engineering is similar across all engineering disciplines. Student persistence in engineering is affected by both academic achievement as well as personal identity. Students who do not feel a strong connection between their self-identity and engineering as a career tend to be the most likely to leave engineering.[6,10] This helps explain the reason that high performing engineering students leave engineering as a major; they leave engineering if they do not feel a connection between themselves and what they perceive engineering to be like despite being successful in the major. However despite a lack of connection between their identity and engineering, some students may persist in engineering based upon factors such as the desire to earn an engineer's salary. Students with lower academic performance have been shown to persist in engineering if they identify with the engineering major or feel as if they were getting future usefulness or enjoyment from engineering.[6,10]

Engineering programs across the country have varying formats and matriculation processes ranging from: common course(s) for First-Year Engineering (FYE), direct admittance to an engineering discipline, or programs in which all students are initially undesignated[11]. Students enrolled in common FYE were more likely to persist to the third semester than direct admits or undesignated students[4-5] and were less likely to leave their institution by their 8th semester. Students in FYE were more likely to choose Mechanical Engineering or Civil Engineering and less likely to choose Electrical Engineering (FYE doesn't impact). Industrial Engineering is more likely to be selected by undesignated students. It was reported that students who take a semester or more to select their engineering major (even without a FYE course / program) are more likely to remain in their first major choice (41.9% vs. 37.9%), but a required FYE course / program helps even more (48.8% vs. 39.5%)[5]. A qualitative study was conducted in which students were interviewed and found that students select program on the basis of cost of attendance rather than the matriculation model. Further, required FYE courses do help students either affirm a prior choice of an engineering discipline or help students to select a major best suited to them[12].

This 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[13]. A primary objective of First-Year Engineering Programs is to provide students opportunities to learn about and explore the different engineering disciplines offered at their institution, and a prior study has reported that a course designed to offer those opportunities through an active learning approach (as opposed to a passive learning lecture environment) increased student certainty in the selection of their engineering discipline. And further, a higher percentage of students did change their intended engineering major during the First-Year Engineering using an active learning, partially flipped classroom model as opposed to a passive environment (33% vs. 22%)[14]. This is noteworthy because it increased major changes prior to the official program declaration / starting discipline specific course work so it does not slow the time to graduation. The current study builds on the hypothesis that changes that occur early during an "acceptable change period of a FYE Program" results in fewer major changes once beginning courses within that major and reducing the time to graduation for many students.

Introduction

A 1 credit hour course that is required for all incoming First-Year Engineering students was assessed before and after a course redesign. The goal of the course was to provide background to students on the engineering disciplinary options available to them; intended to make student selection of an engineering major "an informed choice." The institution studied is a medium sized university with an undergraduate population of approximately 13,000. Each year the First-Year Engineering Program enrolls 200-250 new students, with ~1,000 students in all engineering program across disciplines.

For many years, the approach to teaching students about the different engineering disciplines available at an Urban, Public University was a large enrollment, lecture format course. It was a passive learning environment that was administratively simple with a single section and one faculty instructor. The course is not atypical of an institution with a common First-Year Engineering Program in which students take common courses the first year and then select an engineering major at the end of that year. The course design did not consider more recently developed educational best practices and was unpopular with students as indicated in the baseline data collected. To address student concerns and promote informed decision making, a proposal for an educational innovation related to redesigning the course was submitted and accepted by the National Academy of Engineering Frontiers of Engineering Education Symposium in 2013. Working with other educators from across the country a new approach to teaching First-Year engineering students about the different engineering disciplines was developed and implemented in the fall of 2014.

The primary goal of the course remained constant throughout the redesign: to help educate students on the five different engineering disciplines (Civil, Chemical, Electrical, Industrial, and Mechanical) offered at the institution in support of informed major selection. The objective was to expose the students to each of those majors so that they initially select the best engineering major for themselves to promote educational and professional persistence (as well as to minimize major changes and time to graduation). The original course involved 1 large section of 200+ students with 1 course instructor, and each of the five engineering disciplines had 2 weeks to present information on their program. There were 2 weeks left at the end of the semester in which students also heard about internship and co-op opportunities available to them as well as a panel of professionals from different engineering disciplines.

The newly designed course involved using 5 instructors representing each of the disciplines of engineering (2 full time faculty and 3 industry professionals hired as adjunct faculty) over 10 sections of 20-25 students per section to engage in small group activities. Students attend a session for each discipline on a weekly rotating basis. Figure 1 is a graphical representation comparing the course structure of the original course (left) and the newly designed course (right).

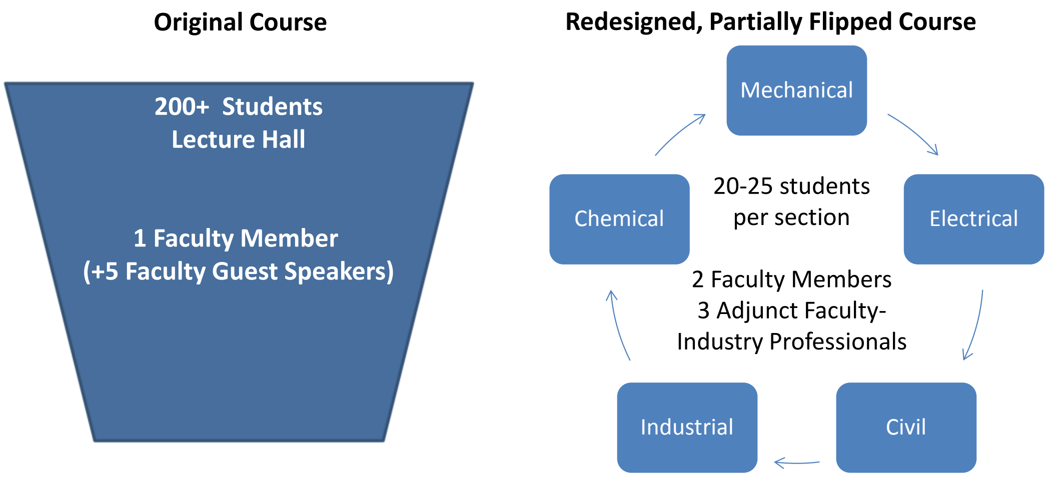

Figure 1. Comparison of Course Structures

The new course cut the time spent on the five disciplines in half such that each discipline had only 1 class session but the time was used to work on a hands-on activity related to that engineering discipline. In preparation for class each week, students were required to watch a short (5-10 minute) video on the engineering discipline they were focused on in class that week (flipped classroom). The students also participated in a resume workshop with professional practice staff leading sessions in a computer lab. Then the remainder of the semester was devoted to student choice, where students could select which class they wanted to attend depending on their engineering disciplinary interest (five sessions were going on in parallel in different rooms, students would go to the room of the session they wished to attend). These sessions were mostly lecture format; however, the class sizes were small to allow interactive discussion. Some of the disciplinary class sessions included meeting with engineering faculty, upper division students, off campus tour of an engineering facility, interviewing an engineering professional. On a weekly basis students were required to complete a survey and journal entry of their reaction to the prior week's session. There was also a "final exam" for the course which involved every student meeting with one of the five course instructors to discuss their selection of an engineering discipline for futures study (15 minute meeting). A week by week comparison of the original course to the redesigned course is shown in Table 1 the grey cells indicate the class sessions that are based on student choice.

Table 1. Week by Week Comparison between the Original and Newly Designed Courses

Week #	Original Course (2013)	Redesigned Course (2014)
1	Introductory Class Session	
2	Lecture on different engineering disciplines: Each of 5 disciplines (Civil, Chemical, Electrical, Industrial, and Mechanical) have 2 - 50 minute class periods	Hands-on Class Sessions on each of the 5 engineering disciplines (Civil, Chemical, Electrical, Industiral, and Mechanical) 1 - 50 minute class period
3		
4		
5		
6		
7		Resume Workshop and Co-op / Internship Discussion
8		Choose Which Discipline: Faculty representatives (academic requirements of a discipline)
9		Choose Which Discipline: Upper Division Students
10		Choose Which Local Engineering Company to Tour
11		Choose Which Discipline: Engineering Campus Lab Tours
12	Lecture on Co-Op / Internship Opportunities	Choose Which Discipline: Professional Society Panel of Student Members
13	Panel of Engineering Professionals from different disciplines	Choose an engineering professional to conduct an informational interview
14	N/A	Final Exam: Meet with an Engineering Course Instructor to Discuss Engineering Discipline Selection

An example of a hands-on session for Mechanical Engineering involved an egg drop activity where the students worked together to design a compartment to help an egg safely land from a 2 story drop. This activity is different than a high school physics experiment in that we had a high speed camera set up at the bottom and recorded the impact. We were able to look more closely at how effective the design / materials used were in helping to slow down the time of the impact and distribute the load. Figure 2 shows two images of student designs upon impact, the left shows the egg shattering, and on the right the protective cup deflecting.

Figure 2. An egg shattering on impact (left) A Protective Cup Deflecting on impact (right)

Other active learning activities included electronic snap circuits, structural builds, food processing, and case studies. This paper seeks to understand to what degree having an active, hands-on approach to exploring engineering major selection during the first year of engineering influences the number of subsequent major changes and progress towards graduation.

Data analysis of ENGR 1500 participants from Fall 2013 and Fall 2014

We conducted data analysis on both of the cohorts using Excel and Tableau. The analyses are subdivided into retention and major change. For each we show statistical comparisons between each of the two cohorts to determine the effectiveness of the new course. For the Fall 2013 and Fall 2014 cohorts there were 127 and 155 students, respectively, who were enrolled in the ENGR 1500 course and were First-Year Engineering students (with the exception of 1 student from the Fall 2014 cohort who started in Engineering Technology). The analyses below show a closer look at the retention rates of students within engineering after five (5) semesters, and which field of study they have chosen five (5) semesters after taking the engineering orientation ENGR 1500 course. For instance, the Fall 2013 cohort is examined after the Fall 2015 semester, and the Fall 2014 cohort is examined after the Fall 2016 semester.

STEM and Engineering Retention Rates

Data was investigated after five semesters to determine which students were still in the STEM College as well as which students were declared engineering students (i.e. First-Year Engineering or in any of the five engineering majors). Table 2 shows the total number of students in the ENGR 1500 course for each cohort along with the number of students in the STEM College (inclusive of engineering majors) and in engineering.

Table 2. Retention Rates by Cohort for ENGR 1500 participants after 5 Semesters

Fall 2013 Cohort	
Total Students	127
Still in STEM	82
Still in ENGR	74
STEM Retention Rate	64.57%
ENGR Retention Rate	58.27%

Fall 2014 Cohort	
Total Students	155
Still in STEM	107
Still in ENGR	96
STEM Retention Rate	69.03%
ENGR Retention Rate	61.94%

A simple z-score was calculated to determine if there were any significant differences between the two cohorts for 'ENGR Retention Rate.' Using Fall 2013 as population one and Fall 2014 as population two, the z-score comparing 58.27% and 61.94% is -0.63 which produces a *p-value* of .26, failing to reject that the two ratios are equivalent. Therefore we cannot infer that the new ENGR 1500 course retained more students at a statistically significant rate of alpha less than or equal to .05.

Even though the rate of increase of 3.67% is not significant, it is a positive trend to monitor in future semesters.

Major Change Pathway

After analyzing the retention rates, we look at student's major change pathways. We define a major change as when a student actively changes their declared major with an academic advisor or they are not enrolled in the University for at least one semester. Table 3 and 4 and Figure 2 show the evolution of student's major selection for each of the five semesters studied per cohort. During the first semester, either Fall 2013 or Fall 2014, most students were declared as a First-Year Engineering student. After which, students were able to actively pursue changing their major out of engineering at any point. However, most change of majors from First-Year Engineering to a specific engineering department, depicted as 'ENGR Dept' in the tables, were determined during their second semester and academically administered for the next fall semester (3rd semester overall). Therefore, we expect that most change of majors would take place during the 3rd semester, if the student declared a specific engineering department (Civil, Chemical, Electrical, Industrial, and Mechanical).

Table 3. Fall 2013 ENGR 1500 Cohort Major Change Pathway

Observed Major	Major Fall 2013	Major Spring 2014	Major Fall 2014	Major Spring 2015	Major Fall 2015
1st-Year Engr	127	114	28	15	14 (11.02%)
ENGR Dept	0	0	66	68	60 (47.24%)
Engr Tech	0	2	4	5	4 (3.15%)
STEM (other)	0	1	2	5	5 (3.94%)
Non-STEM	0	1	4	7	10 (7.87%)
Not enrolled	0	9	23	27	34 (26.77%)
	127	127	127	127	127

Table 4. Fall 2014 ENGR 1500 Cohort Major Change Pathway

Observed Major	Major Fall 2014	Major Spring 2015	Major Fall 2015	Major Spring 2016	Major Fall 2016
1st-Year Engr	154	139	17	7	2 (1.29%)
ENGR Dept	0	1	95	97	94 (60.65%)
Engr Tech	1	2	3	4	6 (3.87%)
STEM (other)	0	3	5	3	5 (3.23%)
Non-STEM	0	3	9	11	13 (8.39%)
Not enrolled	0	7	26	33	35 (22.58%)
	155	155	155	155	155

The overall goal of the ENGR 1500 course is to help students make an informed selection of a major, within engineering or not, to reduce the time to degree. Therefore, the difference between percentages of students in engineering, or any other major, between cohorts cannot be looked at as a failure on the part of one cohort or the other. However, it is a goal of the course to help students make an informed selection of one of the five engineering disciplines at the University. So we look to compare the two cohorts in two manners: (1) The ENGR Dept rate declaration and (2) First-Year Engr rate. The first comparison helps to determine if the new course has statistically helped more students to declare an engineering major and the second comparison will determine if the new course helped students make a decision of any kind, either to enter into an engineering department or to leave entirely.

Again, a simple z-score was used to determine the differences between the two cohorts for each of the above listed differences. The first comparison, engineering department declaration, has the ENGR 1500 Fall 2013 cohort with 60 students, 47.24%, declaring an engineering major, and the ENGR 1500 Fall 2014 cohort with 94 students, 60.65% (as seen in the blue line in Figure 3). The z-score for the difference is -2.25, which gives a *p-value* of .013, and allows us to reject the hypothesis that the two rates are equal. Therefore, we declare that the new course is a better way for students to declare their engineering major.

The number of students not declaring any major outside of the initial starting point of First-Year Engineering is 14 (11.02%) and 2 (1.29%), for the Fall 2013 and Fall 2014 cohorts, respectively (as seen in the red line in Figure 2). The z-score for that difference is 3.52, which gives a *p-value* of less than .001. Therefore, the new course is better than the previous at helping students declare any major.

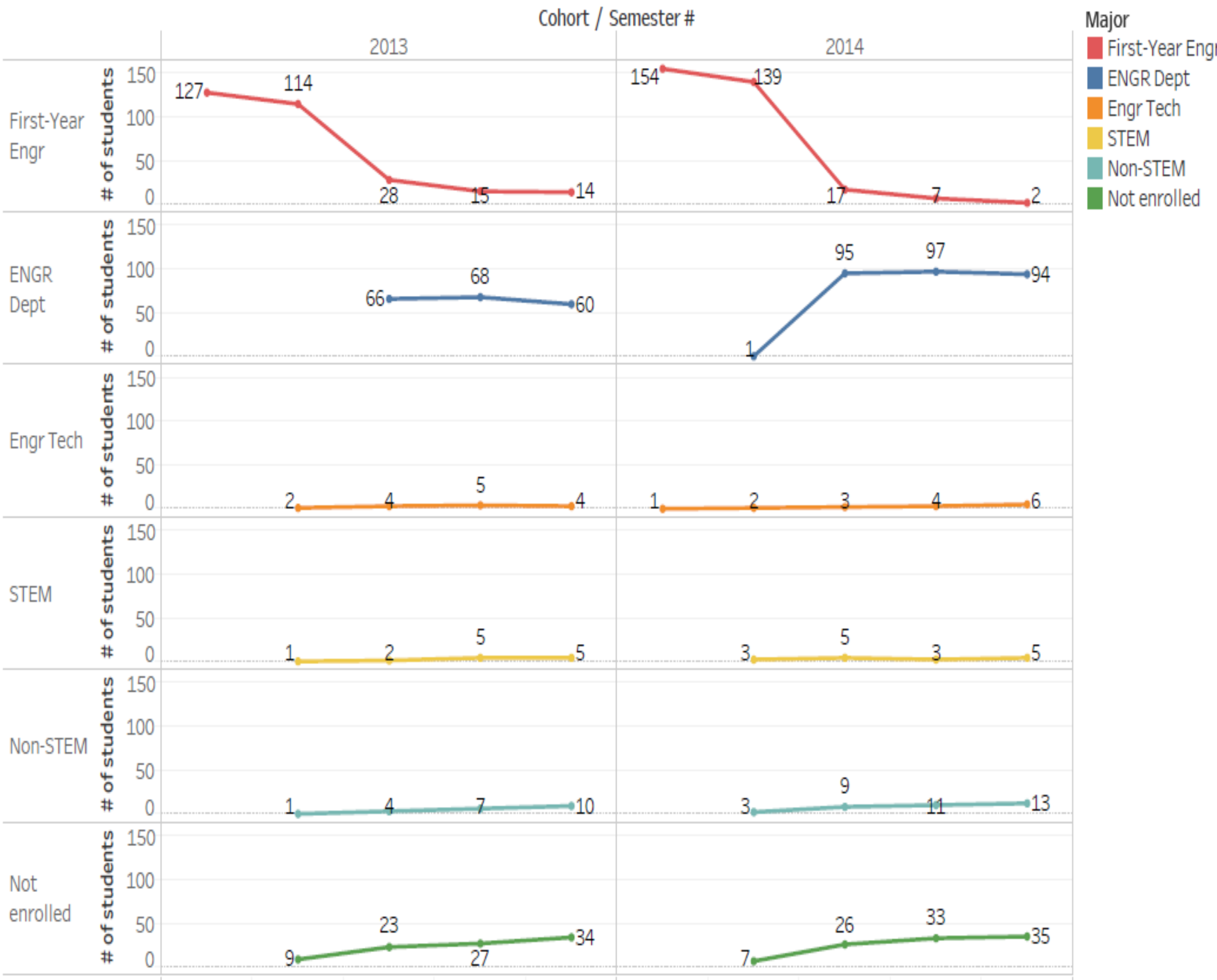

Figure 3. First-Year Engineering Student’s Major Change Pathway by Semester

Discussion and Conclusions

Overall, the results indicate a positive effect of the implementation of the new ENGR 1500 engineering orientation course. The new course has a higher retention rate in both engineering and STEM, as well as a higher rate of engineering major selection, and overall major selection after the first five semesters. These results can help to build a case for the importance of having an engineering orientation component tied to a first-year program. In particular, the current program is unique in that it gives a brief, hands-on experience with each of the engineering disciplines but then allows students to select which sessions they would like to attend based on their interests. We did not track how students moved between the free-choice parts, but anecdotally we know most students had enough information from the previous weeks to make an informed major selection by the free-choice weeks. Those free-choice weeks mostly confirmed and help students relate to their future majors.

Future work will want to be done to investigate the graduation rates of the two cohorts presented within this study. Additionally, adding more cohorts to the study will provide more clarity as to whether or not the new engineering orientation course is helping students select a major more quickly, and therefore reduce time to graduation. If so, there are policy implications to the requirements of such a first year engineering orientation course for universities with similar demographics.

Lastly, there are limitations to the results, as should be expected. First, there was not random assignment of the two cohorts; therefore, we cannot say the course was the only reason behind the results. For instance, students in the Fall 2014 cohort may have had higher standardized test results and were less likely to drop out of engineering or the university all together. Secondly, with the student major change being processed by the academic advisor and sent to a different unit within the university, there could have been potential delays in the reporting of the declaration of major, which would skew the results slightly.

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