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Engineering Major Selection: An Examination of Initial Choice and Switching Throughout the First Year

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Abstract

This Work-in-Progress (WIP) research paper investigates the decisions of first-year engineering students as they select, and on occasion, switch their intended engineering major. This work provides useful initial insight into their decision making to better inform our practices for recruitment and retention of engineering students. In order to better understand the choices that first-year engineering students make concerning their intended major, this paper aims to examine how these students shift their intended engineering discipline throughout an academic year. This paper will discuss results from an examination of initial major choice and possible major switch during the first year of an engineering program. Three surveys were administered (at the beginning, middle, and end of academic year) which asked students about their perceptions of engineering, what major they were currently enrolled in, and their confidence in this major discipline selection. Results from these surveys showed several trends, including patterns related to students who switch majors throughout their first year. Examination of these trends may aid in knowledge of student interests, motivations, and ultimately decision-making in engineering major selection. Retention of first-year engineering students is of critical importance to the health of an engineering program, and a better understanding of students' disciplinary choices during their first year of study may allow educators and advisor to better address issues of attrition.

Introduction

First-year students who have selected engineering as their intended major are faced with a diversity of disciplinary options within the engineering field. The decision of the specific engineering discipline to study can be overwhelming (especially at institutions like ours that offer 14 engineering majors), and students may not necessarily select the discipline that is the best fit for them on their first attempt.[1] Student expectation of future earnings coupled with ability have been found to be critical determinates of college major; however, these perceptions may have errors that would influence major change.[2] 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.[3] 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. This idea of major and career selection relates to teaching and learning in the first year while we have not studied it directly.

This paper examines discipline selection and transfer for first-year engineering students. Through the use of a survey administered at three different points throughout at the first year (beginning, middle, and end), we were able to track students answers to two questions important to this work: 1) What was their current intended major, and 2) what was the student's confidence in this choice of discipline (using a Likert-type scale). These questions would allow us to track the students intended major throughout the first year and provide data as to how many students switched their intended major as well as which majors they were switching between.

Background

Before examining student retention within engineering as a major, we must first look at why students initially choose engineering and how prospective engineering students are different than first-year students in other majors. By examining these trends we can better understand the behaviors of the students surveyed for this study such as how these engineering students choose their majors within higher education.

A study by Zhang examined demographic and academic differences of engineering non-science and science related majors.[4] The results of this study showed that engineering majors were less likely to change their major than non-science majors but more likely to change than other science based majors. This is important because it showcases the common behavior of engineering students as compared to other students. A few of the other trends with engineering majors were that they were found to, on average, have better SAT math scores than other majors and a higher high school GPA than non-science majors.[4] A study by Arcidiacono reported that high ability students (which is linked to math achievement) have been found to shift to majors that result in more profitable professional pathways and lower ability students shift to "easier majors" with typically less profitable professional pathways.[5] We believe that the higher GPA of these engineering students may bias the discipline they eventually select as they may believe that they can handle a heavier course load than their peers.

One of the major factors that influences student choice of engineering as a major is their perspective related to engineering and their identity. Students enter engineering for many reasons, but according to work by Zahorian, the three that students rank as the most important factors were: personal academic interests, potential for societal contributions, and job prospects.[6] Between the engineering disciplines, other factors increase or decrease in their importance towards a student's discipline selection. One example of this is that electrical engineering majors have been shown to rank "perceived difficulty of major" as less important than other factors. The reasons students change disciplines may be related to how they rank these factors. If electrical engineering students believe "perceived difficulty of major" is not as important as other factors, there may be more students who end up transferring out of electrical engineering. Conversely, since they do not perceive the difficulty of major to be as important, these students may instead decide to stay in the major despite struggling under the difficulty of their classes. Additionally, they may just have a higher inherent interest in electrical engineering than other students in their disciplinary major.

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.[3,7] 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.[7]

The reasons that students choose engineering and the reasons that students persist in engineering are also closely linked. By surveying freshmen as they enter their first-year program, it was found that students who share similarities in future academic standing and engineering persistence answer survey questions similarly.[8] Of these students, those who withdrew from engineering in good academic standing tended to view their engineering, math, and science courses, as well as future engineering careers, more negatively than those who persisted. Those that left in good standing were also less confident in their engineering and math skills when they entered engineering as freshmen. We postulate that these students recognized that their interests or skills would be better developed in another major, and despite their academic achievement, decided to leave engineering to find a major they felt they fit into better. These two trends show that students who leave with low academic standing may have because of academic reasons whereas students who left engineering with good standing tended to leave because of their own identity and it's relation to engineering. In order to improve student persistence in engineering, one should be conscious of the student's perceptions of engineering and use their first-year courses to improve these perceptions. Other studies have shown that students leave engineering with high academic standing because they do not trust their own math/science abilities, they felt pressured by their parents to enter engineering, or they are simply not committed to attaining an engineering degree.[8] These reasons for leaving also tie into the students' perspectives of themselves within engineering, such as a student who was pressured into engineering. These factors make it so that a student cannot easily identify as an engineer.

It has also been shown that female engineering students tend to leave engineering with higher academic performance than male engineering students indicating that there are other reasons for their departure than just their performance.[9] Because of their high academic achievement (on average higher than their male counterparts), it can be determined that some female engineering students leave because of their satisfaction with engineering as a major and their own perception of their fit within engineering. Another explanation is that they are receiving grades below their expectations, despite scoring better than their male counterparts.[10] Students who leave engineering tended to leave engineering to major in computer science, business, or a physical science.[9] This is foreshadowed by the fact that students who eventually leave engineering tend to take more classes relating to physics, computer programming, computer science, and philosophy.[9]

Another important population of engineering students to consider is that of engineering transfer students. This includes transfer students who transfer both vertically from a two to a four year institution or laterally from a four year institution into a different four year institution. After transferring, transfer students are prone to experiencing an event referred to as GPA shock. GPA shock is where a student's GPA will fall significantly from what it was at their previous institution. It has been shown that students who transfer vertically are more prone to experiencing GPA shock compared to their peers that transferred laterally.[11] As has been seen in the other studies, students with low academic standing in engineering are prone to leaving engineering without proper perceptions of their major. In order to better help retention of transfer students, their own engineering perceptions need to be understood.

Above we identify some key topics related to major selections. Generally speaking, there is a wealth of information available about how students choose engineering as a major; however there is less information available about students' choices within engineering. We are interested in better understanding choices within engineering and have chosen to focus our work in that space. One factor that has been examined with engineering major choice and student persistence in that major is the matriculation path. Orr et al. found that 78% of students completed their degree in their first major choice in a direct matriculation program (students choose a major before their first-year).[12] Whereas the completion rate was higher with students who had a common first-year engineering program before selecting a major.[12] In this case, 89% completed the degree in the first major they chose after the first-year.[12] This has led to our interest to examine the choices being made during that common first-year engineering program. The patterns of students leaving and choosing engineering may attribute to the trends discovered within student discipline selection. However, in order to properly investigate trends in the discipline selections of engineering students, a survey was conducted. The following section will discuss how this survey was undertaken and how the data was analyzed in order to investigate these trends.

Methods

The data analyzed for this paper was taken from three surveys given to students in their first year of engineering. These students were asked a series of Likert-type (responses ranged from one to five: where one was very uncertain in engineering and five was very certain in engineering) questions in order to rank their opinions towards engineering as a major, their fit within engineering, and their fit within their own engineering discipline. This data was initially analyzed across three institutions and presented in a past ASEE paper that found that the first-year engineering experience tends to be a polarizing experience either increasing or decreasing students interest (and likely commitment) to engineering.[13] Further, that study found that the type of institution was an important factor to student major selection, and the authors postulate that those programs may attract a certain "type" of engineering student with different expectations or commitment levels.[13] The survey used in this work also included questions related to a student's choice of major. These questions are the focus for this work. The students were surveyed at the beginning of their first year, again at the middle of the first year (at the end of the first semester), and at the end of the first year. They were asked the same series of questions as well as what their discipline was at each point in time.

Participants

At our large, land-grant university, the first-year engineering program conducts courses for over 2,000 students each year. All engineering students are required to take a year of common first-year engineering coursework in one of the two tracks (Fundamentals of Engineering (FE) or Fundamentals of Engineering for Honors (FEH)) before they can apply to their major discipline. This follows an FYE matriculation category according to the work of Chen et al.[14] Additionally, students are able and encouraged to declare their intended major ("pre-major"). Each track teaches students problem solving, computer programming, technical graphics (visualization and

sketching), CAD, and design. This approach to the first year is common across engineering education.[15]

During the first course in the first-year engineering program, students are intentionally exposed to a variety of engineering majors through hands-on laboratory experiences that are contextualized to various majors. While the labs do not cover all 14 engineering majors available to the students, they do cover a majority of them to varying degrees. Electrical and Computer Engineering has the most lab experiences dedicated to them while not all first-year students (depending on track) would have lab experiences in the following majors: aviation, biomedical, chemical, engineering physics, food, agriculture and biological, and welding engineering. Students are also exposed to the various majors through their survey course which is a general introduction to the university and engineering if they decide to not declare a pre-major. Additionally, some students may be exposed to the different engineering disciplines through living-learning communities, student project teams, and other organizations. These types of exposures are beyond the first-year engineering program, but they may have a significant influence in students' major selection and their learning more broadly.

In order to create a representative data set for the disciplines, responses were only analyzed if the student answered all three of the surveys. This could be done as students were given an identifier that persisted throughout each survey. Through the identifiers, we were able to not only track the movements of the students as a group, but the identifiers allowed the students to be independently followed throughout each of these surveys. The responses were reviewed to ensure that the students' identities remained anonymous. In total, 2014 students were initially surveyed in order to gather data for this study. However, only students who answered all three surveys were used for analysis, and thus only 229 students were examined for this study (11%). While this may seem like a low response rate, the study design which required all 3 surveys to be completed and consent given for inclusion limited the participants and the sample size is large enough to be statistically relevant.

Analysis

Responses were initially sorted by discipline of the student at the beginning of the year. Following this, student responses to the Likert-type question regarding their level of certainty concerning this discipline selection were averaged, allowing an average certainty to be calculated for each discipline. The students' disciplines at each point in the year were also charted. This yielded data on the changing population of students in each discipline. Next, the students were sorted based on whether or not they changed their discipline by the middle or end of the year, allowing creation of a subset of the surveyed population to be examined – only those students who had decided to change their intended major during the first year. The disciplines of these students were graphed to show what disciplines the students were in at each point of the year. The students who changed their discipline were then broken down into their individual starting disciplines. Each of the disciplines was then charted based on what discipline the students moved into when transferring.

Results and Discussion

The following table, Table 1, shows the correlation of major ID with the engineering major that it corresponds to. The major ID's are used in the following figures. These majors represent all the engineering majors available to students at this institution.

Table 1: ID key for engineering majors offered.

ID	Discipline
AE	Aeronautical and Astronautical Engineering
A	Aviation
BME	Biomedical Engineering
ChE	Chemical Engineering
CE	Civil Engineering
CSE	Computer Science and Engineering
ECE	Electrical and Computer Engineering
EP	Engineering Physics
EE	Environmental Engineering
FAB	Food, Agricultural, and Biological Engineering
ISE	Industrial and Systems Engineering
MSE	Materials Science and Engineering
ME	Mechanical Engineering
WE	Welding Engineering

Figure 1, reveals the enrollment for each major at the start of the year, as well as illustrating the enrollment trends experienced by each major at the middle and end of the first year.

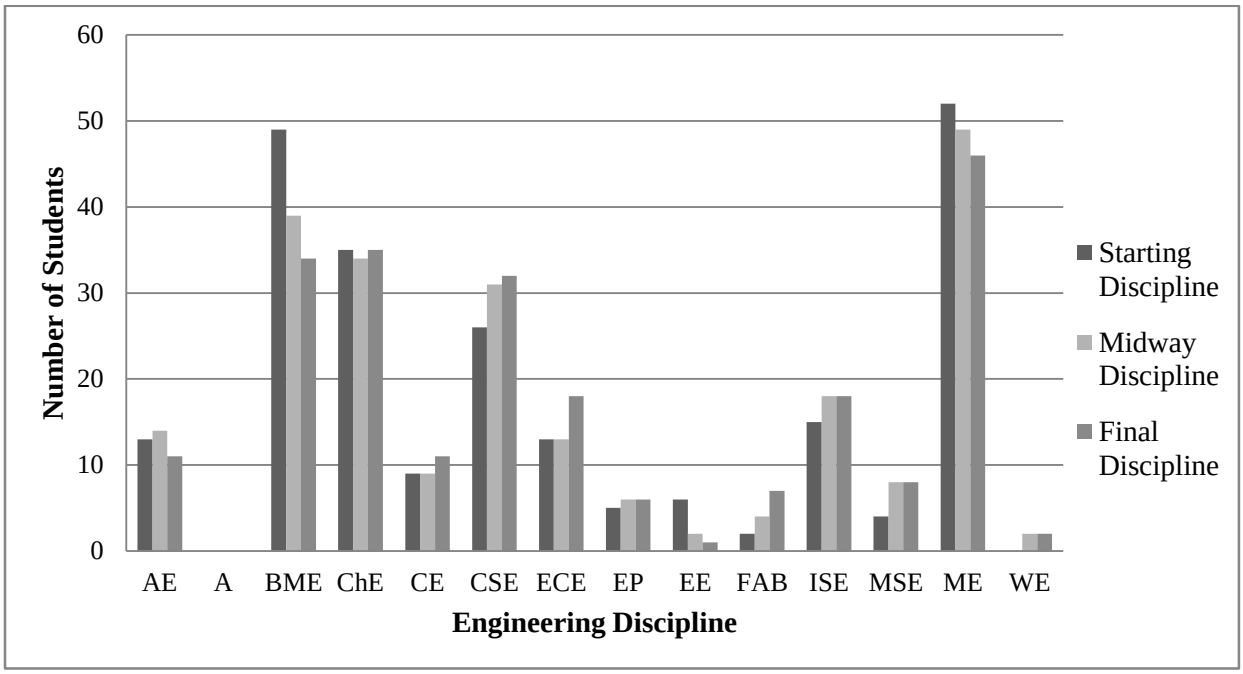

Figure 1: Distribution of students enrolled in various engineering disciplines throughout the first year.

The major distribution is largely consistent across the academic year, but there are a few key changes of note. For example, biomedical engineering started as the second most popular major with 49 students enrolled (three fewer than mechanical engineering) but by the end of the year had experienced the largest change in enrollment, losing 15 students and dropping to the third highest enrollment behind mechanical and chemical engineering. The movement of these biomedical engineering students was tracked by the surveys and details as to which disciplines these students moved to, as well as some possible reasons for their major selection realignment, are presented later in this section. Other disciplines demonstrating a clear enrollment change throughout the first year within this population were computer science and engineering, electrical and computer engineering, and food, agricultural, and biological engineering. Throughout the first year, these disciplines experienced the greatest net enrollment increase, each adding five or six students.

The following three graphs show the engineering discipline choices from only the subset of students who changed their major at some point during the first year. The first of this set of figures, Figure 2, shows the disciplines that this subset of students originated from (i.e. of those students who switched, what was their initial discipline choice). This figure shows that, as may be expected from the data presented in Figure 1, most of the discipline shifters originate from biomedical engineering and mechanical engineering, with 15 (30% of the original 49) and 13 (25% of the original 52) students respectively. It is likely that these numbers are greatest in these majors due to the highest initial enrollment and that mechanical engineering is sometimes viewed as a "default" major by undecided engineering students. While biomedical and mechanical engineering exhibited the largest number of students who opted to change their major at some point during the year, they were not alone as all but five of the engineering disciplines joined them as having at least one student who at some point switched out of their initial major selection.

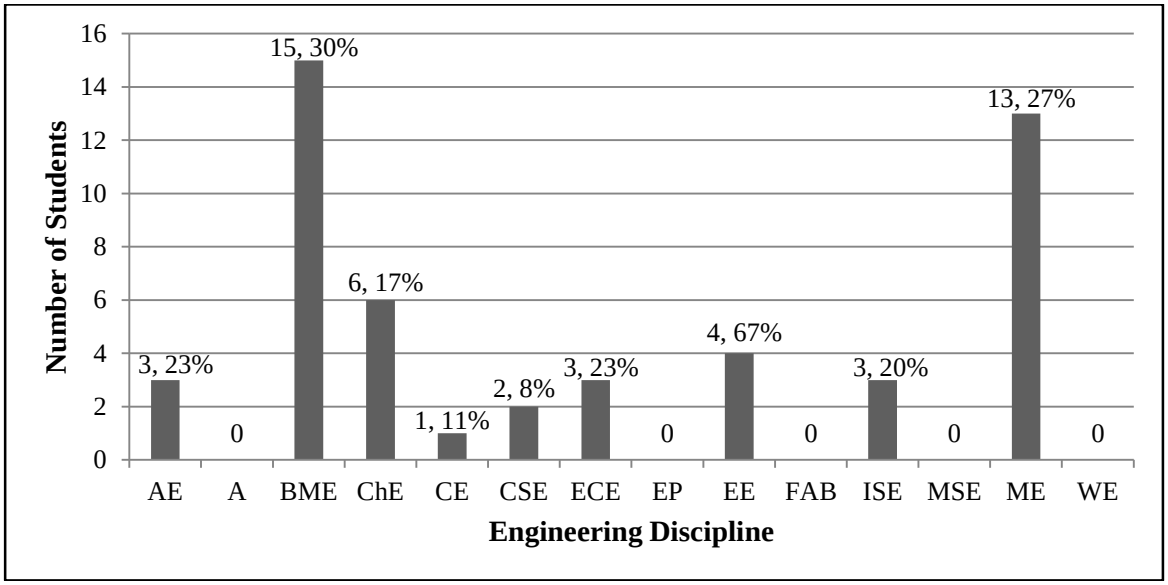

Figure 2: Initial major selections for students who switched disciplines at some point in the first year.

Figure 3 shows how the enrollment alignment and percentage of this subset of students (N=50) has changed from the beginning to the middle of the year (please note, these percentages are different than the percentages shown in Figure 2). While not all of these students have changed their discipline by the time of Figure 3, it begins to show the eventual trends of discipline growth and decline.

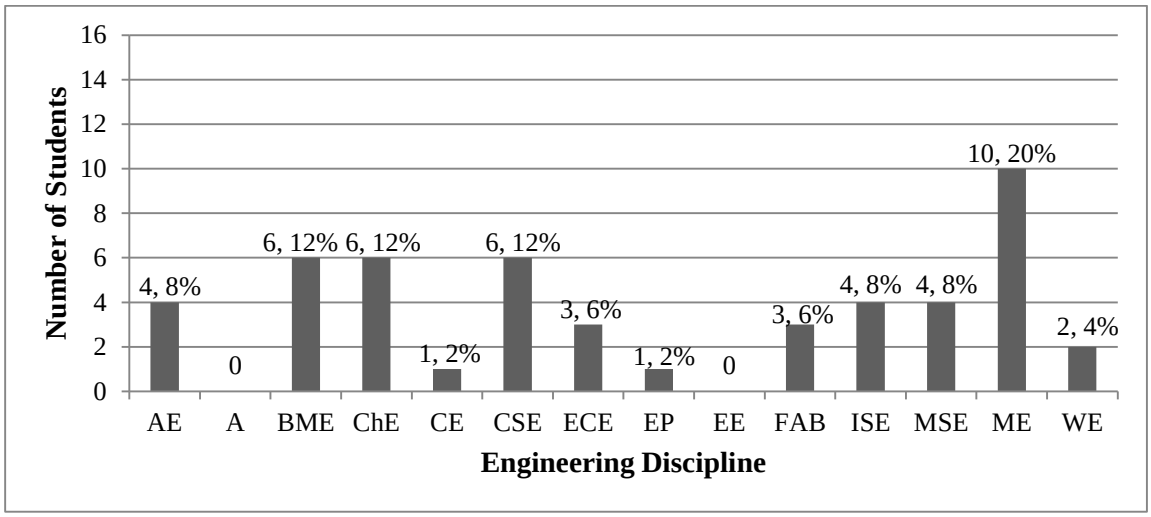

Figure 3: Discipline alignment at midpoint of first year for students who switched disciplines.

The final figure for this subset of students (N=50), Figure 4, shows the final discipline selections of all students who changed throughout the year. None of these students have remained within the discipline that they initially selected.

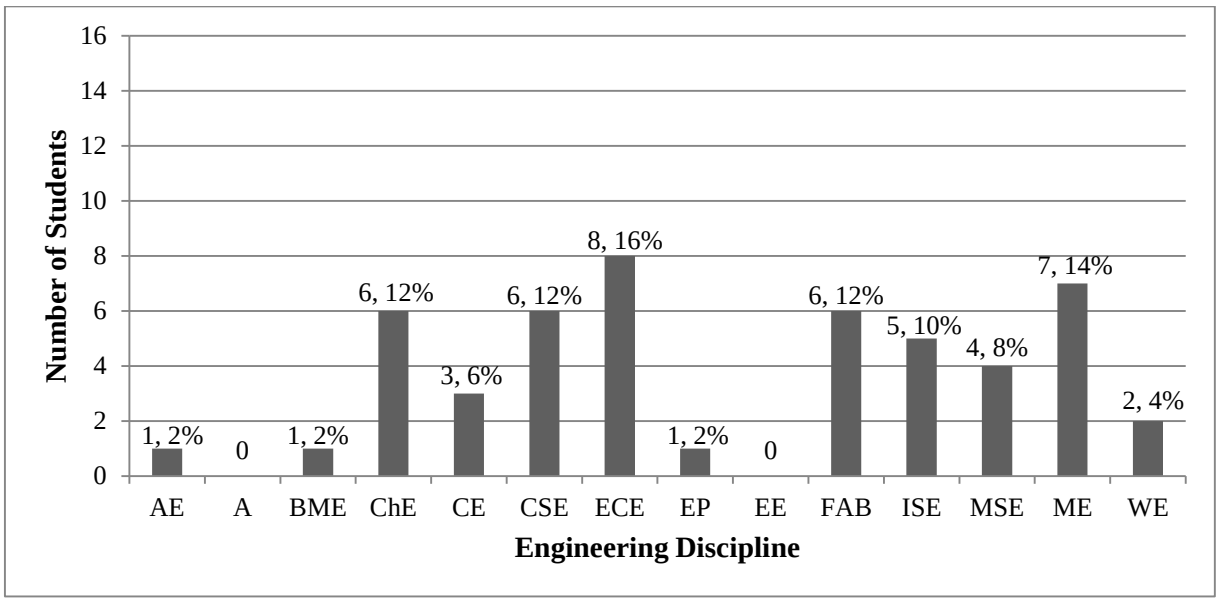

Figure 4: Discipline alignment at end of first year for students who switched disciplines.

Electrical and computer engineering and mechanical engineering attracted the most students shifting from other majors (8 and 7, respectively), with a number of other disciplines drawing only slightly fewer. These two disciplines accounted for 30% of the total of discipline alignment

students (15 out of 50). We suspect that this increase for electrical and computer engineering, as and similarly for computer science and engineering, may be due in part to the nature of the first-year program – computer programming is a fundamental concept taught in the first semester and applied in the second, and students gain significant experience with electronics both through labs and their design projects. These may be disciplines that some of our students are less familiar or comfortable with at the onset of their engineering education, and their subsequent experience throughout the first-year engineering program could facilitate the decision for some of these students to realign their major of choice. For those switching into mechanical engineering, a study by Kecskemety and Kajfez revealed that some of these students may feel that this discipline is the "jack of all trades" for engineering or that this major choice offered a great deal of options and versatility for their future career.[16]

Figure 4 also illustrates that biomedical engineering had the greatest net change in number of enrolled students, as only one student transferred into biomedical compared to the 15 that left. Further exploration of this trend is discussed later in this section.

The following graph, Figure 5, shows the enrollment total for each discipline at the end of the first-year engineering program. Each bar is split between the students who remained in their discipline from the start of the year and those that were new at the end of the year. This gives a clear indication of which disciplines had the largest increase in students due to students transferring into the discipline.

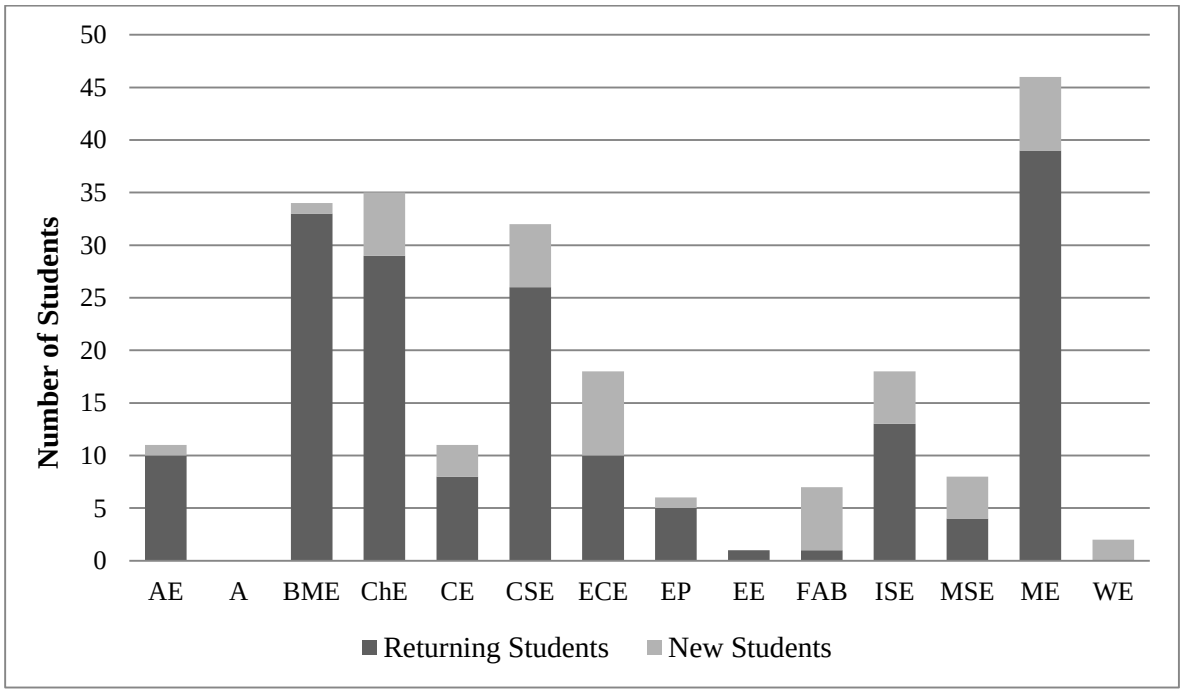

Figure 5: Final breakdown of returning vs "new" students for each discipline.

Figure 5 shows the interesting trend that food, agricultural, and biological engineering is made up of a majority of new students at the end of the first year (1 student who remained from the beginning of the year and 6 new students who transferred in throughout the year). Other majors with a large proportion of "new" students included materials science engineering (50%) and

electrical and computer engineering (44%). While no welding engineers were initially surveyed in this population, two students transferred into welding engineering making it a discipline made up of entirely transfer students. Environmental engineering found itself on the opposite end of this trend, as no students had transferred into this discipline throughout the first year. Other majors that had a low proportion of "new" students by the end of the year included biomedical engineering (3%), aeronautical and astronautical engineering (9%), and engineering physics (14%).

As noted earlier, biomedical engineering experienced the greatest net change in students selecting this as their discipline of choice during the first year. Further examining the students whose initial major was biomedical engineering, the movement of these students into other disciplines is illustrated in Figure 6. A similar technique was used in a recent paper by Kecskemety and Kajfez that explored aeronautical and astronautical engineering major selection.[16] The three larger circles represent the number of students selecting biomedical engineering as their intended discipline throughout the academic year (from left, at the beginning, middle, and end of the year). The smaller circles indicate the movement of this population of students between biomedical engineering and other majors. This movement largely occurs in only one direction, with students selecting to move out of biomedical engineering and towards other disciplines.

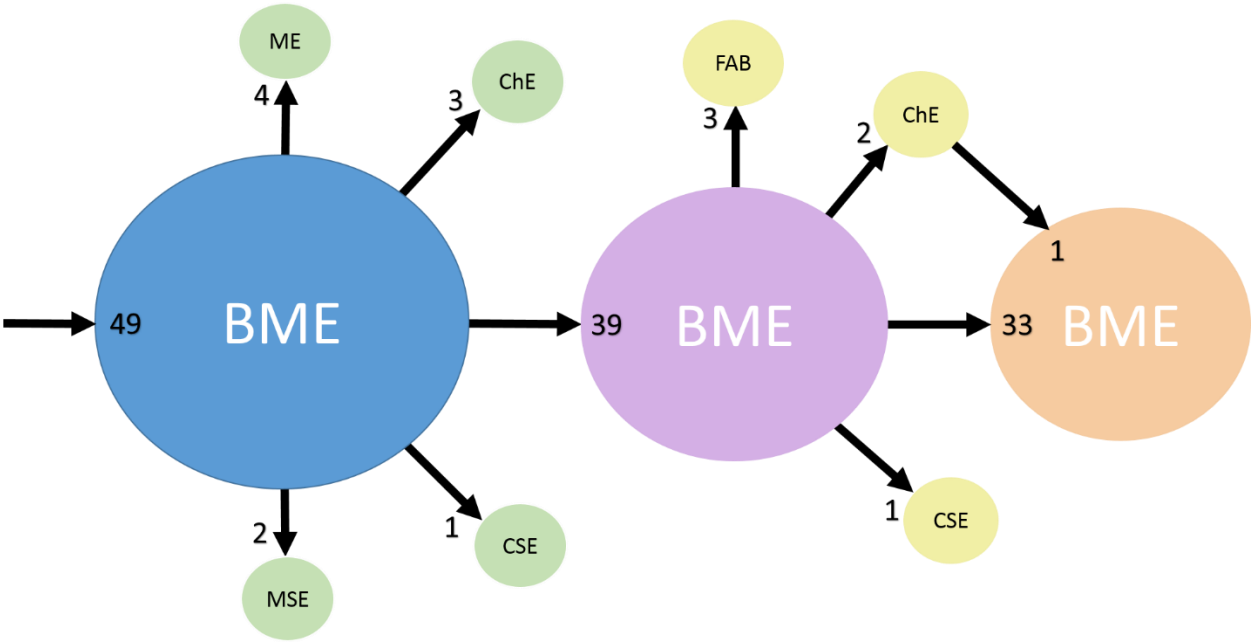

Figure 6: Tracking movement throughout the first year of an engineering program for students who initially selecting BME as their intended major.

In total, 15 students of the initial population of 49, or 31%, chose to move out of biomedical engineering during the course of the year with only one new student shifting to this discipline. This was unique among the major selections with a population greater than 15 students, as all five other disciplines had at least five new students shifting into those disciplines (Figure 5).

Only one other discipline of this size had a net decrease in students – mechanical engineering had nine fewer students at the end of the year vs. 15 fewer for biomedical engineering (Figure 1).

One possible explanation for the relative departure of students intending to major in biomedical engineering students may lie in the selectivity for this major at this institution. While other majors have admission criteria, biomedical engineering has by far the greatest restrictions. The department website indicates that only 75 students are admitted to the major each year, and that the average GPA of admitted students is greater than 3.5. While the population of majors selecting this discipline was only 34 by the end of the academic year for this study (from 229 out of the 2014 possible first-year students), the annual statistical report for the College of Engineering shows a total of 331 students had selected biomedical engineering as their pre-major.[17] This means that only 23% of these freshmen engineering students will go on to major in biomedical engineering, while the remaining 256 students will have to find a new discipline – within engineering or elsewhere. This report also revealed that biomedical engineering is one of only two majors where the number of pre-major students is greater than the number of students currently studying within that major (331 pre-major (first-year students) vs. 226 in major (second through fourth year students)).

Finally, using the Likert-type survey questions concerning certainty for their major selection, Table 2 examines the certainty of selection between those choosing biomedical engineering vs. all other majors. While the certainty for students selecting biomedical engineering is higher in the pre-test (4.33 compared to 4.04), this difference is somewhat negligible by the post-test (4.32 compared to 4.38) as the certainty level for all majors rose throughout the year. It might be expected that, as students first intending to major in biomedical engineering switched out, this certainty score would increase – that the departing students would have been less certain of this choice to begin with, and that remaining students would have been further assured of their selection; however, this is not represented in the data. Despite the largest number of students leaving the major, the certainty level for students intending to study biomedical engineering stayed largely unchanged.

Table 2: Certainty response for biomedical engineering students vs the average of all other majors.

	Biomedical			**All Majors**		
		Certainty			Certainty	
	Number	Mean	Stdev.	Number	Mean	Stdev.
Pre-Test	N=49 21.40%	4.33	0.851	N=229	4.04	0.961
Mid-Test	N=39 17.03%	4.38	0.711	N=229	4.12	0.919
Post-Test	N=34 14.85%	4.32	0.727	N=229	4.28	0.888

Conclusion

First-year engineering students are faced with many disciplinary options related to their major which can be overwhelming. Additionally, students may not necessarily initially select the discipline that is the best fit for them when they start their first year. In order to ensure that students find the correct major, it is important to study their major decisions throughout their first year.

Based on our work, a significant percentage of students change their disciplinary choice throughout their first year (50 of 229, ~28%). The majors with the largest number of discipline changers are mechanical and biomedical engineering. We postulate that this is due to the large population of both mechanical and biomedical students at the university and the competitiveness of those majors. Based on our results, the largest gain in students were in computer science and engineering, electrical and computer engineering, and food, agricultural and biological engineering. We suspect that computer science and engineering and electrical and computer engineering gains are partially due to nature of first-year program (significant exposure via course/lab work with coding, electronics).

Our results are limited by the single year sample. This is just a snapshot of one class' movement based on self-reported data; the university's process for identifying students by major is reliable but in a small percentage of instances there may be students that intend to change major but are still classified under a different major. It would be interesting to study the results over multiple years for multiple groups of students. We have plans to conduct this type of analysis in the future looking at official major selection database information to limit the amount of self-reported data being used. Additionally, this study is limited because it does not include a qualitative perspective that may help us understand why students switch majors. In the future we can interview students to better understand the reasons for switching. We may be able to use the survey information to identify candidates for interviews. Another limitation is the sample and response rate. We only looked at 229 out of a possible 2014 possible student responses to ensure we could follow a student throughout their first year. If we expanded our analysis to all collected data, we may observe slightly different trends. Additionally, looking at the database information will allow us to access more student information. Finally, there is a possible limitation related to self-selection bias where those who completed all three surveys may be a slightly different population than those who did not. At this time, we do not have the data necessary to investigate this potential so it is a limitation to the transferability and generalizability of the results. We also recognize the limitation with self-reported data for those who may wish to switch out of engineering which is another reason to move to the database analysis approach.

This work is part of a larger study that we hope to continue into the future. Specifically, we are interested in continuing the study for another year and increasing the population size. We may include an incentive to increase response rate that would rely on the completion of all three surveys, and we hope to add a strong qualitative component such as interviews to better understand why students change their major selection. As stated above, we will also include an analysis that looks at student database information related to official major selections over the undergraduate careers. Additionally, the study could be expanded to better understand students' understanding of the major they have selected. We have begun such an analysis, but further work is needed to fully understand the students' views. For example, we could compare their views to those of more senior students or professionals working in the various majors.

It is hoped that the work presented here is a first step towards better understanding the decisions made by first-year engineering students as they face the task of selecting their intended major. Tracking student movement between majors and gaining insight as to their perceptions and

feelings about the different disciplines within engineering is a first step towards improving the recruitment, advising, and retention efforts made for these students.

This work, as well as future work in this area, may aid in the improvement to or creation of tools to better assist our first-year students as they navigate the many potential discipline options in engineering. Based on our work, we suggest that those teaching in the first year frequently discuss major selection and the different engineering majors with their students either formally or informally. Since it is not possible to include all possible majors in laboratory experiences, information about the majors may need to be addressed through other means such as assignments, student presentations, and guest-speakers. We know that students change their intended major so helping them navigate that process is essential for their success. This can be done in a variety of ways, but we suggest polling the students throughout the term and dedicating time in first-year courses to discuss the various majors highlighting similarities and differences to aid those considering switching. Another option may be connecting first-year students with more senior students so they can discuss major selection and switching. Through these types of practices, we hope to help students select the major that is the best fit.

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