Examining Engineering Students' Major Selection

Developing Baseline Quantitative Results to Investigate Major Selection and Change

Jamie L. Paulson
College of Engineering
The Ohio State University
Columbus, OH, USA
Paulson.38@osu.edu

Rachel L. Kajfez, Krista M. Kecskemety
Department of Engineering Education
The Ohio State University
Columbus, OH, USA
Kajfez.2@osu.edu, Kecskemety.1@osu.edu

***Abstract*—Improving recruitment and retention are goals of many engineering programs. One factor that is tied strongly to recruitment and retention is a student's desire to study engineering in a specific engineering discipline. Some students switch between engineering majors during their undergraduate careers, which could increase their time to degree. Also, depending on the reasons students have for switching, the changes could also impact their motivation and personal commitment to engineering. Not all major changes are due to changes in student preference. Some changes may also result from external influences such as enrollment management. The research presented in this Work in Progress paper will be an initial step towards answering the question: *Why and how do students change engineering majors throughout their college career?* Through this research, we hope to gain added insights into how engineering students switch between majors so in the future we can seek a better understanding of why they switch.**

Keywords—major selection; major switching; enrollment management

I. Introduction

There have been many calls to improve the recruitment and retention of students in STEM fields within the nation [1-2]. In engineering, one factor that is tied strongly to recruitment and retention is a student's motivation to study engineering in a specific engineering discipline [3-5]. Despite their motivation to study a specific discipline, some students change their major within engineering throughout their college career and many times these changes are not to a more preferred major. Sometimes this change is due to outside influences such as competitive admission processes and the need for enrollment management strategies. As educators, we know that these outside influences are often unavoidable due to limited resources, but we do not necessarily know their long-term impact and how they directly affect students' major selection in engineering, STEM, and beyond. To effectively support their experiences, we need to better understand our students' switching patterns. Specifically, we need to know how they switch in order to effectively determine why they switch.

The work presented in this Research, Work in Progress paper will be an initial step towards answering the research question: *Why and how do students change engineering majors throughout their college career?* Specifically, we hope to gain added insights into the majors student move between during their undergraduate years by exploring patterns and trends in a Tableau visualization of a large dataset. While this type of information is typically reviewed by academic advisors and administrators, we believe it has value to all engineering educators. Specifically, it will help us better support our students by improving our understanding of how they are switching between majors. In the future, we will use this information to more strategically answer the why component of our research question through qualitative research (e.g., interviews, focus groups, document analysis, etc.).

II. Past Research

Attracting, retaining, and graduating sufficient numbers of engineers is a serious national concern [1-2]. However, many programs are also facing resource challenges necessitating enrollment management – the strategic, intentional efforts of institutions to actively influence and shape student enrollments. In the process, increasingly competitive admission processes have been created. Further complicating the problem is the fact that, despite a multitude of studies in engineering education and other fields, we still do not know how to predict which students will be successful in completing an engineering program. Before we can begin to analyze the information available in the Tableau data visualization, we must first understand the past research conducted related to this topic to identify what has not been completed that will help us improve success prediction.

A. The Literature

A tension exists between the recent calls to increase the number of engineers produced in the U.S. [1-2] and trends related to enrollment management [6]. While enrollment management is needed due to limits on space, faculty, and overall resources, we cannot help but wonder what the ramifications are for these limits on students' major selection and ultimately their retention in the field. As Karen Watson [7] said, "Action, uninformed by research, has led to mistakes, wasted resources, and inadequate foundations for future efforts." We take this concept further, believing that change which is not studied after its implementation can have the same consequences. Namely, we hypothesize that institutional and departmental actions related to enrollment management have affected student major selection and may be a source of problematic attrition. University-wide enrollment management has been examined in the literature and has found gender biases

in admissions [8]. It is possible that there are biases in major enrollment management as well, however, some of the factors leading to university admission bias, for example standardized testing biases, would not be a factor in major enrollment. This is something that should be investigated.

In engineering, problematic attrition is a term which has been used to describe post-degree attrition due to controllable factors that negatively students' experiences, driving them to exit the profession [9]. We suspect that one factor in this phenomena is the practice of enrollment management, which may cause a student to be denied access to their preferred engineering major despite their capability and interest.

There is much work related to students' choice to study engineering [4,10-12]. Additionally, there is research showing the reasons and factors leading students to leave engineering [5,12,13]. Some research has focused on STEM fields but not engineering. Griffith [14] and Ferrare and Lee [15] examined women and underrepresented minority students switching into and out of STEM fields. One very interesting result from Griffith is that the major that students switch into could be strongly linked to courses students take during their first semester [15]. The key gap here is that we are missing the details of students switching between different engineering majors, and how this could be related to enrollment strategies within the engineering majors.

To fully understand the effects of enrollment management on problematic attrition, we must first understand how and why students change engineering majors. This research focuses on this issue through a long term mixed methods study.

B. *Our Past Work*

While there are many ways we could approach this topic, we have decided to frame our work around major switching. To begin, we started with data collected during the first year of an engineer's undergraduate education.

Over the 2014-2015 academic year, surveys were given three times to first-year engineering students about their intended major and their confidence in that decision. Analysis of these results has been completed and has shown that approximately 28% of the students change their intended major in that first year alone [16]. However, our previous research only investigated the first year and did not look at the additional years leading towards graduation. At our university, applying for an engineering major happens typically during the second year, after the completion of introductory major classes. Due to competitive admission criteria and general enrollment management practices in many of our disciplines, engineering students may be forced to delay entering their first choice major or may decide to switch disciplines due to factors other than interest. We suspect this has long term ramifications which have yet to be explored.

The remainder of this paper documents quantitative data available with respect to undergraduates' movement between majors throughout their academic career. The findings have provided a starting point for future qualitative data collection, which will provide rich data into students' motivations regarding major selection, as well as the impact of institutional and department practices such as enrollment management.

III. INITIAL FINDINGS

This work is based on a large dataset made accessible through interactive dashboards in Tableau, a data visualization software. The dataset represents six years of new freshman cohorts entering the College of Engineering at a large public research institution in the Midwest. Although the dataset does not include all students, such as students who transfer into the institution, change from non-engineering majors into the college, or move from regional campuses, the new first-year students included do represent a substantial population in the College of Engineering. The dataset includes information about a total of 9,670 engineering students who were admitted Autumn 2009 through Autumn 2014, including their program of enrollment each fall and any College of Engineering degrees earned. While there are competitive admission processes for the engineering majors at this institution, for the purposes of this project, we will focus on the discipline of enrollment, considering students in both 'pre-majors' with intentions to apply and students already admitted to the major.

We selected four points in time at which to examine students' enrollments: we compare their program of enrollment in their first autumn to that of their second autumn; their third autumn, by which time most students would have applied to a specific major; degrees earned from the college of engineering within four years; and degrees earned from the college of engineering within six years. Given the recent nature of the data, the number of the 9,670 students who has reached these four markers is smaller with each progression. All of the 9,670 students have data available for their second autumn, 8,075 have data available for their third autumn, 1,035 have earned degrees from the college of engineering within four years, and 878 have earned degrees from the college within six years.

In the following sections we highlight key trends and takeaways related to the data. Then, following each section, we will list key questions that remain after the data analysis. These questions will become the basis for our future work and future literature searches. Some of the questions that remain are questions that have been researched before either partially or fully. Therefore the future work will include a thorough literature review and analysis of how findings can be transferred to this student population and support the data found here or in the future work.

A. *Extent of Major Switching*

Our first questions concern the incidence of switching behaviors. To what extent do students switch between engineering majors and when do they switch? The first indication of students' uncertainty regarding engineering disciplines is the number of freshmen who choose to enter a program for exploring all of the engineering majors available in the college before moving into a specific program. Approximately 22% of all freshmen entering from Autumn 2009 - Autumn 2014 entered through this program, suggesting that a substantial portion of students have not yet committed to

a specific engineering discipline when they arrive at the university.

Excluding these students who entered undecided about an engineering discipline, approximately 16% of the engineering freshmen have moved into a different engineering major by their second autumn, a rate which increases to 30% by their third autumn. Of the 1,098 Autumn 2009 freshmen who entered in a specific engineering discipline, a total of approximately 61% have earned an engineering degree within six years - 44% in the same discipline in which they entered the college of engineering and 17% in a different engineering discipline. As mentioned earlier, approximately 1 in 5 engineering freshmen enter the university intending to further explore the engineering majors before committing to a single discipline. Among those students who enter with a declared discipline, approximately 1 in 3 will move to a different discipline by their third autumn, with half of these students switching by their second autumn and the other half by their third.

Key questions that remain:

- Why do students enter the freshman year in undeclared engineering? Is there something about this population and their previous knowledge of engineering that is unique?
- Why are students changing majors in their first year? In their second year?
- Is the timing of major switching correlated to different causes?

B. Sending & Receiving Majors

Our next questions concerned patterns of direction in students' moves between majors. Were there disciplines with distinct patterns of 'sending' or 'receiving' students? Operationally, we defined a 'sending' major as a program that retained less than 50% of the freshmen who initially entered in that discipline by the students' third autumn. By this criteria, 7 of the 14 engineering programs were 'sending' majors: aeronautical and astronautical engineering; aviation; biomedical engineering; engineering physics; environmental engineering; food, agricultural, and biological engineering; and mechanical engineering. We defined the 'receiving' majors as programs in which less than 50% of the students enrolled in the major during their third autumn had initially entered that discipline during their first autumn. By this definition, there were 6 'receiving' majors: civil engineering; engineering physics; food, agricultural, and biological engineering; industrial and systems engineering; materials and science engineering; and welding engineering. It should be noted that the two majors which appear in both lists, engineering physics and food, agricultural, and biological engineering, typically have lower enrollments and so the threshold of 50% may be reached with fewer students switching.

Key questions that remain:

- Why do students switch out of 'sending' majors?
- Why do students switch into 'receiving' majors?
- Are there misconceptions about majors?
- Do major admissions criteria and acceptance play a role in the 'sending' and 'receiving'?

C. Students Who Entered Engineering Undecided

We were also interested in which disciplines the students who entered as undecided within engineering switched. We identified the top 5 programs (mechanical engineering, civil engineering, industrial and systems and engineering, electrical and computer engineering, and chemical engineering) these undecided students had moved into by their second and third autumn, as well as engineering degrees they had earned within four and six years.

Key questions that remain:

- Why did these students select these majors? What information did they receive to make an informed decision?
- Were students considering these disciplines at the beginning of the first year?

D. Female & Underrepresented Minority Students

Finally, we have begun to explore the switching behaviors of female and underrepresented minority students, including Native American, Black or African American, and Hispanic students, to see if there were any trends which differed for these populations. We explored whether there were specific programs which seemed to attract or retain these students at higher rates and in which disciplines the students have successfully earned degrees.

By the students' third autumn, 34% of the female freshmen had left the college of engineering, as compared to 30% of male freshman. 31% of the female students were enrolled in one of three engineering disciplines in their third autumn: chemical engineering, industrial and systems engineering, and mechanical engineering. Of all the women who entered in a specific engineering discipline, more than half were retained to the same discipline by the students' third autumn in 7 of the 14 majors: chemical engineering, civil engineering, computer science and engineering, electrical and computer engineering, industrial and systems engineering, materials science engineering, and welding engineering. The 'receiving' majors for female students were: aviation; electrical and computer engineering; food, agricultural, and biological engineering; industrial and systems engineering; materials and science engineering; and welding engineering. Among the women who earned engineering degrees within four years, the greatest number of degrees were earned in chemical engineering, biomedical engineering, industrial systems and engineering, and mechanical engineering. The greatest number of engineering degrees earned by women within six years were in chemical engineering, mechanical engineering, and industrial and systems engineering.

By the students' third autumn, 39% of entering underrepresented minority students had left the college of engineering compared to 30% of non-underrepresented minority students leaving the college of engineering. Only 4 majors had retained more than half their entering underrepresented students: computer science and engineering, electrical engineering, industrial and systems engineering, and welding engineering. The 'receiving' majors for underrepresented students were: environmental engineering; food, agricultural, and biological engineering; industrial and

systems engineering; materials and science engineering; and welding engineering. 39% of the underrepresented students were enrolled in 1 of 5 majors in their third autumn: chemical engineering, computer science and engineering, electrical and computer engineering, industrial and systems engineering, and mechanical engineering.

The most striking trend for underrepresented minority students, however, was the low number of degrees conferred. From the 3,404 total freshmen who entered in Autumn 2009, 2010, and 2011, only 63 underrepresented minority students had earned degrees within four years which is 20% of the initial underrepresented minority students who entered as freshman, but only 1.9% of the total student that entered as freshman between 2009-2011. The 20% degree competition is lower than the 29% of non-underrepresented minority students that earned a degree within 4 years. None of the underrepresented minority student degrees were in mechanical engineering, an unexpected absence given that this is the program with the highest enrollment of students in general. Among the underrepresented minority students who earned engineering degrees within four years, the greatest number of degrees were earned in industrial systems and engineering and chemical engineering. The greatest number of engineering degrees earned by underrepresented minority students within six years were in industrial and systems engineering.

Key questions that remain:

- Why are larger percentages of female and underrepresented minority students switching out of engineering after the first year?
- Why are female students attracted to chemical engineering, industrial and systems engineering, and mechanical engineering?
- Why have underrepresented minority students earned degrees in industrial systems and engineering, and chemical engineering, but not mechanical engineering?
- How can we use this information to increase enrollment and retention in these populations?

E. Students Switching to Non-Engineering Majors

Finally, we examined the patterns of students who switched into non-engineering majors. As the dataset did not include information about non-engineering degrees earned by the students, we used the major of enrollment in the students' fourth autumn as a proxy for students' eventual major. Grouping the major enrollment by college within the university produced the distribution shown in the first chart of Fig.1. To see how this compares to the general enrollment in the university, the Autumn 2015 undergraduate enrollment report [17] was used to generate the University Distribution in Fig. 1. The engineering students are slightly more likely to enroll in the College of the Arts and Sciences than the typical university population. Most of the other colleges remain the same, except the School of Architecture. This school is administratively part of the College of Engineering, and thus, it is not surprising that it might be a larger percentage of former engineering students than the general enrollment.

Examining female and underrepresented minority students also highlighted interesting trends. Compared to all former engineering students, former female engineering students were more likely to switch into the College of Education and Human Ecology and the School of Architecture, less likely to switch into the College of Business, and none switched into the College of Food, Agricultural and Environmental Sciences. Underrepresented minority students had similar distributions to all former engineering students. Additionally, first-generation students had a higher percentage switch into the College of Food, Agricultural, and Environmental Sciences.

Key questions that remain:

- Why are students switching out of engineering?
- Is GPA a factor in students switching out of engineering and which program they switch into?
- Are there any measures that can be used to predict this behavior?
- Do special degree programs that cross college lines (minors, collaborations with other colleges) help increase engineering retention?

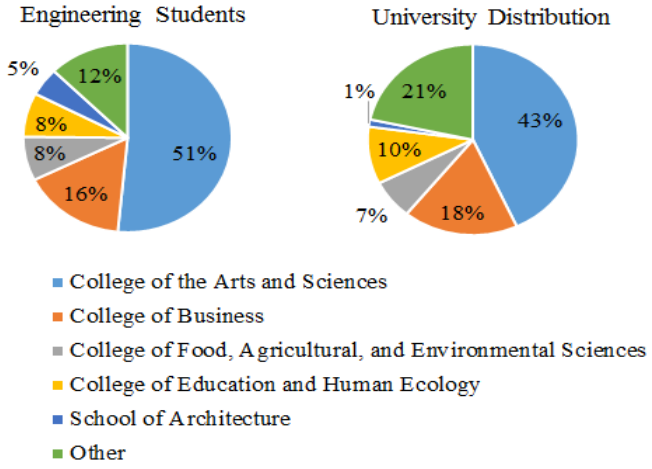

Fig. 1. Non-engineering enrollment: for students who started in engineering but had left by the fourth autumn, and total Autumn 2015 enrollment by college.

IV. Future Research

During our presentation, we will display these initial findings in tabular and graphical displays. We will also discuss the remaining key questions we identified. It is our intention to use this data to inform future literature reviews related to these questions and develop our future research plans. These research plans will include gathering quantitative data on major admissions from student records, qualitative data through focus groups and interviews, and broader survey data about student perceptions. Also because some of the questions that have arisen from this work have been researched before, a thorough literature review on each topic will be performed as we continue to investigate the factors that influence engineering major enrollment and retention. We hope this future research will be useful to understand the impact of enrollment management strategies on overall retention and students' experiences within engineering.

REFERENCES

[1] President's Council of Advisors on Science and Technology. "Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics," 2012.

[2] National Research Council. "Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads." Washington, DC: National Academies Press, 2011.

[3] S. Parikh, H. Chen, K. Donaldson, S. Sheppard, "Does Major Matter? A Look at What Motivates Engineering Students in Different Majors." ASEE 2009.

[4] S. Zahorian, M. Elmore, and K.J. Temkin, "Factors that Influence Engineering Freshman to Choose Their Engineering Major." ASEE Annual Conference and Exposition, Atlanta, GA, 2013.

[5] H. M. Matusovich, R.A. Streveler, and R.L. Miller, "Why do students choose engineering? A qualitative, longitudinal investigation of students' motivational values," Journal of Engineering Education, vol. 99, no. 4: pp. 289-303, 2010.

[6] Enrollment Management Report, Practical Guidance in Recruitment, Admissions, Retention & Financial Aid. Jossey-Bass A Wiley Brand, www.enrollmentmanagementreport.com, 2015.

[7] K. Watson, "Change in Engineering Education: Where does Research Fit?," Journal of Engineering Education, vol. 98, no. 1: pp. 3-4, 2009.

[8] B.M. Holloway, T. Reed, P.K. Imbrie, and K. Reid, "Research-Informed Policy Change: A Retrospective on Engineering Admissions", Journal of Engineering Education, vol. 103, no. 2: pp. 247-301, 2014.

[9] J. Margolis and D. Kotys-Schwartz, "The post-graduation attrition of engineering students: An exploratory study on influential career choice factors," In ASME 2009 International Mechanical Engineering Congress and Exposition. American Society of Mechanical Engineers, pp. 449-462, January 2009.

[10] G. Lichtenstein, H. Loshbaugh, B. Claar, T. Bailey, and S. Sheppard, "Should I Stay Or Should I Go? Engineering Students' Persistence Is Based On Little Experience Or Data," Paper presented at the ASEE Annual Conference and Exposition, Honolulu, Hawaii, June 2007.

[11] P. Arcidiacono, V.J. Hotz, and S. Kang, "Modeling college major choices using elicited measures of expectations and counterfactuals," Journal of Econometrics, vol. 166, no 1: pp. 3-16, 2017.

[12] E. Seymour and N.M. Hewitt, "Talking about leaving: Why undergraduates leave the sciences." Boulder, CO: Westview, 2007.

[13] G. Zhang, B. Thorndyke, R. Carter T. Anderson, and M. Ohland, "A Comparison of Demographic Factors and Academic Performances between Students Graduated in Engineering and Other Discipline," Paper presented at the ASEE Annual Conference and Exposition, Nashville, TN, June 2003.

[14] A. Griffith, "Persistence of women and minorities in STEM field majors: Is it the school that matters?" Economics of Education Review, vol. 29: pp. 911-922, 2010.

[15] J. Ferrare and Y. Lee, "Should we still be talking about leaving? A comparative examination of social inequality in undergraduate patterns of switching majors," WCER Working Paper No. 2014-5.

[16] A. Theiss, J. Robertson, R. Kajfez, K. Kecskemety, and K Meyers, "Engineering Major Selection: An Examination of Initial Choice and Switching Throughout the First-year," ASEE Annual Conference and Exposition, New Orleans, LA, 2016.

[17] The Ohio State University Enrollment Services, "Highlights of Fifteenth Day Enrollment for the Autumn Term 2015", September, 2015.