"Not all those who wander are lost." Examining outcomes for migrating engineering students using ecosystem metrics

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***Abstract*— How successful are undergraduate students who begin in another major and migrate into engineering disciplines after matriculation? In this work in progress, we present quantitative data on outcomes for engineering migrators disaggregated by discipline, race/ethnicity, and sex. The study includes over 73,000 engineering students from nine U.S. universities, including first-time-in-college and transfer students who ever majored in the most common engineering disciplines: Chemical, Civil, Electrical, Industrial, and Mechanical Engineering. Adopting an ecosystem mindset, we have developed metrics including the graduation rate of migrators and "migration yield" to uncover dynamic information, not afforded by the conventional pipeline model, about the successes of students who migrate among the top five engineering disciplines. Our data show that the graduation rates of migrators are typically higher than those of starters for all engineering majors studied. Migration yield varies by race/ethnicity-sex as well as discipline. Migration yield for Chemical, Electrical, Industrial and Mechanical Engineering shows a sex-based effect, whereas Civil shows a race/ethnicity-based effect.**

Keywords—student migration, retention, underrepresentation

I. Introduction

Not all students graduate in the major in which they start. How successful are undergraduate students who begin in another major and migrate into engineering disciplines after matriculation? "Undergraduate migrators" are those who start in other engineering disciplines or in non-engineering majors, including students who do so at another institution before entering as transfers. This contrasts with metrics based on a more static pipeline metaphor that consider only limited options for how students navigate engineering education. In this work in progress, we adopt a perspective of an "ecosystem" [1] with its complicated interconnectedness. Little quantitative research has considered engineering student outcomes from an ecosystem perspective [2]. We present quantitative data on outcomes for engineering migrators disaggregated by discipline, race/ethnicity, and sex. Disaggregation by race/ethnicity and sex is relevant here because engineering students do not share monolithic experiences; and disaggregation allows us to measure whether and how such differences manifest within an engineering ecosystem.

Researching the trajectories of students who migrate to or among engineering disciplines is of interest for several reasons. Migration to another major after matriculation, for example, can lengthen time-to-graduation [3]. Reducing time to graduation is a pressing social issue, not only because students typically incur greater debt as they prolong their enrollments, but also because increasingly, performance-based-funding models require accountability for timely student graduation rates. Student advisors can benefit from a deeper understanding of how undergraduate migration from or to particular majors affects students individually. Disciplines losing migrators sustain an enrollment burden that does not lead to degree production. Programs that are acknowledged to be service departments (such as first-year engineering (FYE)) expect this sort of enrollment burden, but some departments may struggle to find the resources to support transient students. Disciplines attracting migrators are performing an important role for engineering colleges by providing a home for those who might otherwise leave engineering or never enter it. Only limited research examines migrators in engineering [4, 5].

II. Dataset and Metrics

We focus on the five most popular engineering majors including Mechanical (MCE), Civil (CVE), Electrical (ELE), Chemical (CHE), and Industrial (ISE). These five majors account for 70% of the engineering graduates in the U.S. in 2013 according to the American Society for Engineering Education (ASEE) Engineering Data Management System [6] and 75% of the engineering graduates in the dataset used in this work.

We use the "Multiple-Institution Database for Investigating Engineering Longitudinal Development" (MIDFIELD), which comprises whole population data of degree-seeking students at eleven institutions—including students of all disciplines, transfer students, part-time students, and students who first enroll at any time of year [see 7]. In this work, we only included the nine institutions that offered all five majors studied. Our study includes the 73,289 students who

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self-identified as Asian, Black, Hispanic or White, ever declared a major in one of these five engineering disciplines, and who have at least six years of data available. Population sizes are shown in Table 1. "Other" includes all other majors including those outside of engineering. Data from multiple years are pooled, but are studied longitudinally. A description of the racial/ethnic category choices used at MIDFIELD institutions is available [8].

TABLE I. STARTING DISCIPLINES OF MIDFIELD STUDENTS EVER ENROLLED IN CHE, CVE, ELE, ISE, AND MCE.

Race/Ethn & Sex	**CHE**	**CVE**	**ELE**	**ISE**	**MCE**	**Other**
Asian Female	252	128	209	145	103	326
Black Female	908	327	940	524	441	438
Hispanic Female	99	90	65	93	58	81
White Female	2344	1900	1106	1483	1588	2075
Asian Male	454	287	1463	294	773	776
Black Male	599	612	2291	518	1367	721
Hispanic Male	154	276	486	227	450	336
White Male	4918	7786	9979	2998	12308	7493

We combine two "starter" populations: those who matriculate directly in an engineering major, and those who matriculate in a first-year engineering program [9]. While first-year engineering students are definitively enrolled in engineering, they do not have a disciplinary identity at matriculation. Students who enter through other "undecided" pathways are similarly classified according to their first disciplinary affiliation. Thus the "Starters" population is more inclusive of students who enter through various pathways. In regard to "migration", the transition from a first-year engineering program is an expected part of the program, and thus is not counted as a change of major.

This study also includes transfer students who at some point enroll in one of the majors studied. Transfer students are also classified based on their first specific disciplinary affiliation. To calculate their six-year graduation rates, transfer students are assigned to an enrolled semester using each institution's definition and assigned a corresponding enrolled time. For example, a transfer student who enters a MIDFIELD institution with enough credits to be in the fifth semester of CVE in Fall 2009, is assigned an enrolled semester of "5" for Fall 2010 and a graduation time of 8 semesters if graduating in Spring 2011.

A. Graduation rate of migrators

This metric considers only the graduation rate of those who do migrate. Thus the number of students who graduate in a major other than where they started is divided by the number of migrators to that discipline (i.e. those ever enrolled who did not start in the discipline).

B. Migration Yield

"Migration yield" is the normalized gain of migrating students—the number of migrators a discipline attracts and graduates within six years (the gain) relative to the number of migrating students it could possibly attract. Migration yield is calculated using (1). Normalization is necessary to avoid having attrition bias the metric. This bias would disadvantage larger disciplines even if their six-year graduation rates were high.

$$\text{Migration Yield} = \text{Fraction of migrators attracted} \times \text{Fraction attracted that graduate} \quad (1)$$

$$= \frac{\text{Migrators attracted}}{\text{Pool of migrators who graduate}} \times \frac{\text{Migrators who graduate in this discipline}}{\text{Migrators attracted}}$$

A discipline's starting population is excluded from the potential migrator population, because a discipline cannot attract those students as migrators. Students who have not graduated by the sixth year of enrollment are also excluded, since we are focused on the population that graduates from the institution.

III. RESULTS

A. Graduation Rate of Migrators

Fig. 1 compares the graduation rates of migrators and starters disaggregated by discipline, race/ethnicity, and sex. Panels represent disciplines. The diagonal line represents equal graduation rates for migrators and starters. Most data markers are not on the parity line, revealing that migrators and starters have different stories. Most populations have data markers above the line, which means that migrators typically have higher graduation rates than the starting population. This points to their success and resilience highlighting the importance of including them in studies and emphasizing the positive nature of engineering-identity exploration [10] – that "not all those who wander are lost" [11]. The higher graduation rates of migrators are seen in all disciplines for Asian men, Asian women, White men, and White women. A notable exception to this is that Hispanic men and women in ISE do not have higher graduation rates for migrators. Although these data points are below the line, this is likely due to the starters' relatively high graduation rates (above 65%). The Hispanic men have migrator graduation rates of 66.9% compared to 68.3% for starters while Hispanic women have migrator graduation rates of 70.8% compared to 76.3% for starters, all high compared to other populations and disciplines.

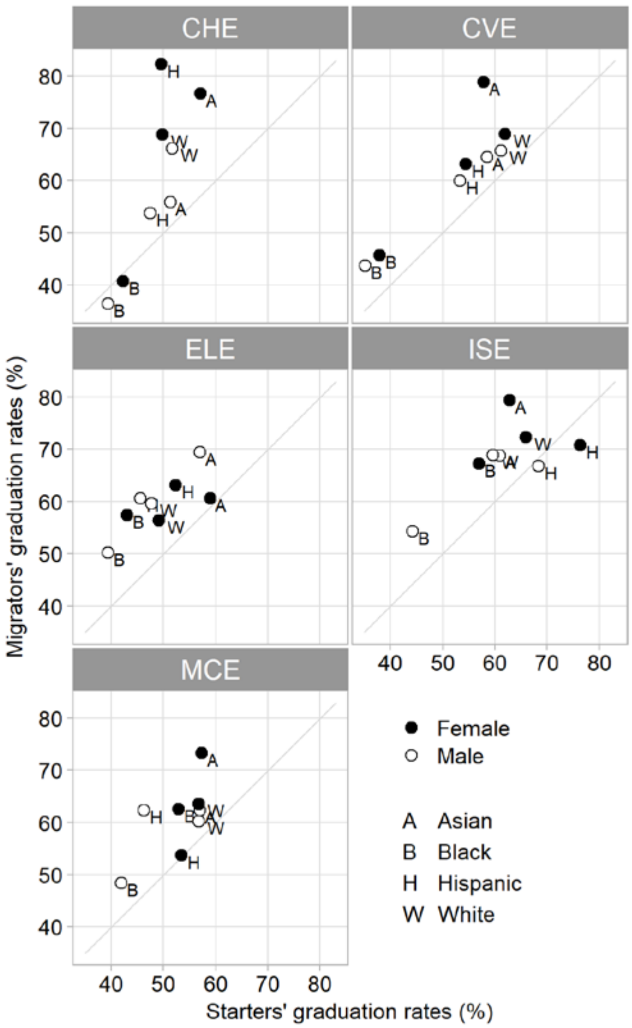

Fig. 1: Migrator graduation rates are generally higher than those of starters.

A different situation exists for Black men and women in CHE who have slightly lower graduation rates for migrators rates (36.5% and 40.8%, respectively) than starters (39.4% and 42.2%, respectively). The migrators' and starters' graduation rates are disturbingly low.

For CVE and ELE, Fig. 1 shows that the graduation rates of migrators and starters appear to be strongly related. This suggests that starters and migrators may share a similar set of conditions shaping their experiences in these disciplines. By contrast, the situation in CHE appears to be different for migrators and starters and for students from different subpopulations. There is significant variation in graduation rates for migrators of different subpopulations in CHE but little variation in the graduation rates of starters. Black and Hispanic students migrating into CHE have similar graduation rates as starters, whereas White and Asian students migrating into CHE have much higher graduation rates than starters. Sex-based effects vary among the disciplines, but are particularly small in the White population as is shown in Fig. 1 by the close proximity of the data markers labeled "W" for each discipline.

B. Migration Yield

The data markers in Fig. 2 represent the migration yield in a discipline for each race/ethnicity/sex group. Yield is read along the contour lines where markers lying on the same contour line have the same migration yield. The panels are ordered alphabetically left-to-right and top-to-bottom to match Fig. 1, and each figures shows the median migration yield (with a dotted curve) for that discipline. ISE has the highest migration yield and CHE the lowest.

There is significant variation in migration yield by discipline and by subpopulation within each discipline. Each panel has a different overall distribution of the eight dots representing the eight populations studied. The lowest migration yield is 2.9%; only 2.9% of Black male migrators are attracted to and graduate in CHE. In contrast, the highest migration yields are for Asian women in ISE (31.5%) and Asian men in ELE (29.5%), where about one-third of the available population is attracted and graduates, far more than any other population or discipline. Within each discipline, the range of migration yields for different populations vary from 10% in CVE to 24% in ELE.

Values on the same contour line represent achieving the same migration yield but often by different means. Consider, for example, Hispanic, White, and Black women in ISE who are all on the 25% contour. For Hispanic women, this 25% migration yield is a result of a high rate of attracting Hispanic women, but a lower rate of graduating them. For Black and White women, however, the situation is reversed—the 25% migration yield is a result of attracting a low rate of these students but graduating a higher fraction of those who are attracted.

Those populations that lie on the same vertical line share the same fraction of migrators attracted but different graduation rates. For example, in CHE, the fraction of male migrators attracted is low and fairly consistent for all race/ethnicities. However, White and Asian men graduate at higher rates than Black and Hispanic men suggesting that the graduation rates of migrators in CHE are marked by an achievement gap, suggesting the need for more discipline-specific research on educational inequities by race/ethnicity and its correlates. In MCE, White and Hispanic women migrators are attracted in about the same percentage but more than twice the number of White women migrators graduate compared to Hispanic women.

Populations that fall on the same horizontal line exhibit the same migrator graduation rate but different rates of attraction. For example, the migrator graduation rates of Asian, Black, and White men and women are similar in MCE. However, men are more attracted to MCE than women.

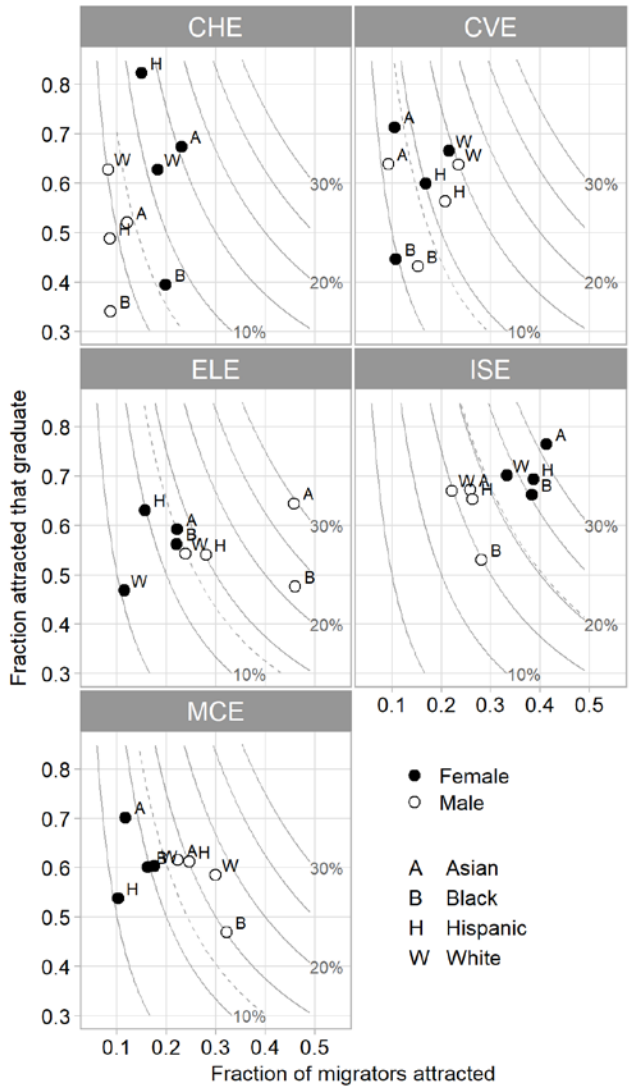

Fig. 2: Contour plot of migration yield as the product of the fraction of migrators attracted to a discipline (horizontal scale) and the fraction of those students graduating in the discipline (vertical scale).

For ISE, CHE, MCE, and to a lesser extent ELE, we see clusters by sex – the dots for women appear close together in Fig. 2 and those for men appear close together. In ISE and CHE, the migration yield of women of all races/ethnicities is higher than that of all men. In MCE and ELE, the opposite is true with the exception of Asian females, who exhibit a slightly higher migration yield than White men in ELE (13.1% compared to 12.9%). This might be related to enrollment trends—the disciplines that enroll a higher fraction of women (CHE and ISE) [6] have a higher migration yield of women, whereas the disciplines enrolling a lower fraction of women (MCE and ELE) have a lower migration yield of women. This sex-based grouping should be investigated further.

In Fig. 2, the pattern for migration yield for CVE is different. Rather than a sex-based grouping as seen in the other engineering disciplines studied, there appears to be a race/ethnicity-based grouping. The migration yield for White men and women is most tightly correlated.

IV. Discussion

Our findings suggest migrating engineering students are successful. Their graduation rates generally exceed those of students starting in these engineering disciplines. These students have experimented with various majors and eventually find their academic home. This suggests that these students are resilient and persistent. Less visible are the departmental patterns that sustain them or unwittingly abandon them. It is worth considering how departments bear a responsibility to support these students. What are the cultures of different engineering disciplines? This might consider how students' patterns within higher education can be understood using the frameworks of other types of migrants, or even refugees. Do students experience certain majors as safe-havens where they are welcomed? Who are the social agents that function to support and attract students, how do faculty demographics (e.g. role models) impact attractiveness of a discipline, and what other networks help students find their way? How do students find meaning, motivation, and a shared identity within the ecosystem of disciplinary cultures? Future qualitative research can build upon this study to contribute to our understandings of disciplinary variation.

Based on our findings, academic advisors of students failing to thrive in one engineering major should encourage them to consider other engineering majors. Also rather than considering migrators as problematic, engineering departments should welcome migrating students and embed structures to ensure their timely success to graduate. As our data show, many undergraduate migrators are indeed successful.

V. Conclusions

This study of over 70,000 engineering students from nine U.S. universities in the five most common disciplines showed that migrators, undergraduate engineering students who begin in another major and migrate into engineering disciplines after matriculation, are successful. This quantitative data on outcomes for engineering migrators was disaggregated by discipline, race/ethnicity, and sex. With these ecosystem metrics, we uncovered dynamic information about the successes of students who migrate among the top five engineering disciplines not afforded by the conventional pipeline model. We showed that migrator graduation rates are higher than starters for most populations studied. Migration yield varies by discipline, is different for women and men, and varies by race/ethnicity in meaningful ways.

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