

# Student Demographics, Pathways, and Outcomes in Industrial Engineering\*

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Industrial Engineering (IE) is known for its high participation of women and welcoming culture. This multi-institution longitudinal study of student demographics and educational outcomes in IE affords more detailed insights into disciplinary dynamics by describing the demographics, trajectories, and outcomes of IE students into, out of, and through nine IE programs. This research presents a quantitative perspective of IE student pathways and outcomes disaggregated by race/ethnicity and gender. The study includes 10,994 IE first-time-in-college and transfer students in the USA. Framed using Astin's college impact model, student pathways vary by gender and race/ethnicity and are both an outcome of the environment and an important factor influencing the environment. The outcomes for all populations in IE are notably positive compared to other disciplines. Hispanic and Black engineering students chose IE at higher rates than Asian and White students, resulting in more racial/ethnic diversity than the engineering aggregate. Within each race/ethnicity, women in engineering chose IE at higher rates than men. Hispanic men and women achieved the highest graduation rates. Black, White, and Hispanic women in IE all graduated at higher rates than their male counterparts. More students of all groups except Black men switched or transferred into IE than left. This study complements prior qualitative work leading to a deeper understanding of IE, which is noted as attracting and retaining a diverse student population. Detailed descriptions of IE student pathways and educational outcomes can also guide other disciplines that seek to improve diversity and student success.

**Keywords:** industrial engineering; retention; choice; race/ethnicity; gender

## 1. Introduction

Industrial Engineering (sometimes referred to as industrial and systems engineering), is an engineering discipline which specializes in understanding how people, material, information, equipment, and energy work together in a complex system, by exerting and integrating mathematics and social science theory, with engineering approaches and analysis [1]. The Institute of Industrial Engineering, a professional association for practicing industrial engineers, states that, "Industrial engineering is about choices. Other engineering disciplines apply skills to very specific areas. IE gives practitioners the opportunity to work in a variety of businesses." [2]

Industrial Engineering is known for having a greater participation of women compared to other engineering disciplines. Some credit for this is given to the pioneering work of Lillian Gilbreth, often referred to as the "First Lady of Engineering" [3]. A 2015 survey estimated that 20.2% of all working IEs are female [4]. This is the highest percentage for

women of all engineering domains, with the next closest being Chemical Engineering at 14.7%. Among engineering BS degree recipients in 2013–2014, women comprise 31.6% of IE bachelor's graduates, high compared to the aggregate (19.5%) yet lower than Chemical Engineering graduates (36.3%) [5]. At the University of Oklahoma however, more than half of the IE undergraduates were women in 2001 [6].

Diversification of the engineering profession is considered a high priority for engineering educators [7], and a top priority for maintaining U.S. competitiveness and national security [8, 9]. Given the higher participation of women and the reported welcoming or "invited" nature of IE [10], examining the demographics and outcomes of the undergraduate IE population offers an opportunity to identify best practices for enhancing the participation of women and underrepresented racial/ethnic groups in the profession.

While there is a large and growing literature on the pathways of diverse populations in engineering,

the research presented here is distinguished in that it is longitudinal, multi-institution, discipline-specific, and disaggregated by race/ethnicity and gender. Connecting this study of IE to earlier qualitative research on IE leads to a deeper understanding of an engineering discipline noted for diversity, which may guide other disciplines looking to make gains in diversifying their student profile.

## 2. Literature review

The input-environment-outcome (I-E-O) college-impact model by Astin [11, 12] is used to frame this study. “Inputs” include student demographic characteristics, family background, and academic and social experiences that students bring to college. “Outcomes” include students’ characteristics, knowledge, skills, attitudes, values, beliefs, and behaviors as they exist after college (although some outcomes can be measured before graduation). The “Environment” is what colleges contribute to the observed outcomes—institutional characteristics, curricular structure, major, faculty make-up, as well as the ways students are involved or engaged with the environment.

From the perspective of research in higher education, inputs in the Astin model are generally taken as a precondition and immutable. Nevertheless, some studies control one or more inputs to understand the effect of others, such as Benton and colleagues [13], who study high-ability minority students, or Seymour and Hewitt [14], who interviewed students with SAT math scores above 650. Other researchers have focused more on the direct connection of inputs to outcomes, making important contributions that characterize the success of various populations and generate research questions that can be answered through qualitative research [15–25].

Studies that focus on the environment are less common, but are important because this is the part of the Astin model over which the institution and department have the most control. The co-construction of the environment by institutions, departments, faculty, and students is what ensures that “demography is not destiny”, as noted in a Pell Institute study regarding their hope for realizing the potential of students of low socioeconomic status [26].

Where there is research on the environment and its effects, it most commonly addresses engineering in the aggregate rather than addressing disciplinary differences—where there is disaggregation, it most likely highlights race/ethnicity or gender, but not both simultaneously. [25, 27–30]. A few studies are noted for addressing the entire I-E-O model, addressing inputs, environment, and outcomes and connections among them. Ohland et al. [31] combined

longitudinal student records with data from the National Survey of Student Engagement to more thoroughly explore persistence and migration. Clark et al. [20] followed students at multiple universities into and through engineering, collecting students records, survey data, and ethnographic interviews, providing a rich story of the engineering environment.

Disciplinary cultures and practices have been shown to be a significant part of the environment. In *What Matters in College? Four Critical Years Revisited*, Astin [32] identifies a student’s major as being a highly influential environmental factor. He concludes that “engineering produces more significant effects on student outcomes than any other major field” [32 p. 371] Astin found that the choice of an engineering major was positively correlated with analytic skill development [32 p. 237] and job skills [32 p. 240], but was associated with lower satisfaction with the college experience, satisfaction with curriculum and instruction, and development of a diversity orientation [32 p. 306]. Related findings were reported in *Inside the Undergraduate Experience: The University of Washington’s Study of Learning* [33], in which the significant influence of major on learning a range of cognitive skills (from quantitative reasoning skills to writing competency) is illustrated. Other researchers have compared and contrasted engineering students and students of other majors [31, 34].

Different engineering disciplines have different cultures [35], yet few studies disaggregate by discipline and fewer still describe how environmental factors differ among the engineering disciplines. Using a nationally collected sample of 21 institutions representing 13 IE programs in the U.S., Knight et al. [36] compared the curriculum, instructional practices, and climate for engineering disciplines with higher gender diversity, including IE (29% female enrollment), to those with lower gender diversity, such as Electrical and Mechanical Engineering, but did not examine student pathways. A recent set of studies have sought to describe choice, persistence, and graduation outcomes for students in specific engineering disciplines disaggregating by race/ethnicity and gender [37–42]. Some of this research includes qualitative data and findings that substantially enhance the quantitative findings [41, 42]. By conducting a significant quantitative exploration at institutions where qualitative findings have already been published [41], this work adds to those earlier mixed-methods efforts. Further, while it is generally expected that the inputs (including racial/ethnic and gender composition) are determined by the students that attend a particular institution or by the population from which an institution recruits, by considering the

issue of disciplinary choice in different populations, this work gains insight into how the environment and aspects of disciplinary culture influence inputs, including who chooses to enroll or switch into that discipline. Overall, IE as a disciplinary domain relays a story exposing substantive aspects of student retention [6, 41, 43, 44].

### 2.1 Previous quantitative studies of Industrial Engineering student pathways

Research on the pathways and persistence of underrepresented students, including women, in IE is limited. However, studies confirm that women engineering students are more likely to choose IE than men. Humphreys and Freeland [45] tracked a group of 971 men and 261 women engineering students longitudinally at a single institution and disaggregated results by discipline and gender. Of the women in their study 10% chose IE compared to only 5% of the men. In another single institution study with 2,474 men and 613 women majoring in engineering, Stine [46] also found that women preferred IE, with 5% of the women and 2% of the men choosing IE. In a multi-institution study of large public universities, Brawner et al. [41] found that IE has the highest percentage of women for engineering disciplines at Semester three (38%) and six year graduation (37%). Finally, Litzler [47] reveals similar findings, studying the representation ratio of engineering disciplines in the Project to Assess Climate in Engineering (PACE) study. In this study, women are equally overrepresented in IE and Chemical Engineering compared to engineering as a whole [47]. Further, the only discipline with a higher representation ratio was Biological Engineering, which, as a discipline, is difficult to study because it is smaller and its high percentage of women is a more recent trend.

For all engineering disciplines combined, there is no gender gap in the college years in engineering persistence [13, 14, 48–51]. In a large multi-institution study, comparable rates of persistence or graduation were found for women and men of all races and ethnicities when the data were aggregated by discipline [52, 53]. For engineering, as a whole, multiple researchers have seen that women who left engineering were more likely to switch to non-engineering majors than to leave the institution [14, 52, 54].

The few longitudinal studies that include specific data on IE [45, 46] describe a single institution and have much smaller population sizes (71 and 30 respectively). Yet those studies have some findings in common with multi-institution studies with larger populations—that IE has a higher rate of persistence than other engineering majors [45, 46], and that men who leave engineering tend to leave

the institution, whereas women who leave are more likely to switch into non-engineering majors [45]. Other findings from those studies are jarringly different, in particular that women in IE were more likely than men not to graduate at all (17% vs. 12%) [46].

### 2.2 Previous qualitative studies of the Industrial Engineering Environment

“Inviteful Engineering,” a term expressed by an IE student [10], epitomizes how some students have characterized the environment of IE in terms of approachability. Some suggest that the inviteful and hospitable nature of IE begins before students have fully committed to their educational pathway. Welcoming interactions created through effective informal and formal recruiting efforts, and enthusiastic agents leading outreach efforts are also known to influence students’ decisions, particularly those entering IE [55]. To the extent recruitment and outreach programs play a significant role in situating engineering programs as warm and inviting, the effort to recruit diverse engineering talent may be won or lost early in the process of exposing students to disciplinary choice. Whereas this may seem like a zero-sum matter, it is also possible that if the recruitment and outreach programs of all engineering disciplines were inviteful, the diversity of engineering as a whole would improve. This is the challenge posed by the National Academy of Engineering [7].

The inviteful nature students claim to experience in IE is said to be associated with three key factors: the presence of female faculty and the congeniality and availability of IE faculty and staff regardless of gender; high-quality IE faculty-student interactions; and a genuine expressed interest in the students in the program [43]. While faculty interactions appear to help attract students to the discipline, understanding the dynamics that prevent them from leaving the IE pathway is equally important and remains elusive. What is it then, which might help explain the interest factors that create “stickiness” [56] among students that either begin in or migrate to IE? Further, are there special attributes of the IE student population that will aid in this explanation?

In a recent study at Kansas State University, female IE students reported that the range of jobs available to them and job security were central in their decision to major in IE. In the same study, male IE students indicated that starting salaries and job variety were primary drivers of their decisions [57]. These findings are consistent with national survey results that job security and job opportunities were the career outcomes most important to women in engineering and that having many job opportunities was significantly more important to female engi-

neering students than to male engineering students [58]. Other research noted IE's breadth of career opportunity and connections to business [43] and the flexible nature of the degree [41] as keys to recruitment and retention for women in IE.

Until now, studies investigating students that choose, migrate into and out of, and ultimately graduate from IE have been limited to a single academic institution. Many of these studies were unable to examine critical aspects of their student populations such as race/ethnicity. Race/ethnicity is known to influence one's sense of belonging [21], which in turn can impact one's sense of identity and values [59]. In this work, we examine the research question "How do pathways and outcomes of students in IE vary by race/ethnicity and gender?" This paper represents a significant contribution to the existing discipline-focused body of work, by presenting a detailed gender, race/ethnicity, enrollment, and pathway description for over 10,000 students in IE.

### 3. Methods

Using a multi-institution database, this study presents descriptive quantitative findings for student demographics and outcomes for IE students, disaggregated by race/ethnicity and gender.

#### 3.1 Data source and limitations

The data source for this study is the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) [60]. Eleven U.S. institutions contribute data to the database, with nine located in the Southeastern U.S. The institutions are primarily large public institutions with above average enrollment of engineering students. Nine offer IE degrees and six are among the top twenty institutions in the U.S. in terms of IE degrees awarded [61]. IE graduates constituted eleven percent (818 of 7,678) of engineering bachelor's degrees awarded at the participating institutions in 2005 (a representative year for the time span of this study). In comparison, IE undergraduate degrees constitute only five percent of all undergraduate engineering degrees awarded across the United States in the same time period (3,891 of 77,428) [61].

The study includes only those students who self-identified as Asian, Black, Hispanic, or White. Even MIDFIELD does not have sufficient representation of other racial/ethnic groups to disaggregate by race, gender, and discipline simultaneously. International students are also excluded because institutions do not typically record their race/ethnicity information. In this study, this resulted in the elimination of eight percent (918 of 11,912) of the

IE students. Black students are overrepresented due to the inclusion of two Historically Black Colleges and Universities (HBCUs). There are fewer Hispanics among MIDFIELD IE students compared to the U.S. student population (4% vs. 16%) and more Black and White students (16.1% vs. 10.9%; 72.8% vs. 64.1%) [60, 61]. It is important to note that whereas "Hispanic" is an ethnicity (e.g. having an origin in a country formerly colonized by Spain) rather than a race and whereas standard U.S. census practice is to ask individuals to identify race separate from any Hispanic ethnicity, it is still common practice at universities for students to have the option to identify as "Hispanic" to the exclusion of identifying a race. This was the practice for most of the period when data in this study were collected from students. Further discussion of the specific ways that the different MIDFIELD partners collect race/ethnicity data is available elsewhere [52].

Other available datasets cannot support such a study. Data available from the American Society for Engineering Education [62] can be disaggregated by discipline, race/ethnicity, and gender, but are not longitudinal. Engineering Workforce Commission data [63] are typically aggregated and do not facilitate longitudinal studies. The Bureau of Labor Statistics [4] reports are aggregated and do not report populations smaller than 50,000, which eliminates many populations of interest in disciplinary studies. The National Science Board's Science and Engineering Indicators [64] use completion data from the Integrated Postsecondary Educational Data System (IPEDS) [65]. Where IPEDS data can be disaggregated by engineering discipline, the data are not longitudinal. Conversely, where IPEDS data are longitudinal, they cannot be disaggregated by engineering discipline. MIDFIELD comprises whole population data of degree-seeking students at 11 institutions—including students of all disciplines, transfer students, part-time students, and spring term admits [66].

Although MIDFIELD includes complete data from over 10% of engineering graduates in the U.S. in a given year, the selection of institutions is non-random, therefore the work presented here is descriptive, and may not be generalizable to national data. To address this limitation, a project to expand the MIDFIELD database to add a stratified random sample of U.S. institutions with engineering programs is underway [67].

#### 3.2 Student population

This study focuses on the 9,278 first-time-in-college (FTIC) and 1,716 transfer students who at some point majored in IE at one of the nine MIDFIELD partner institutions that offered IE degrees during the period of study and self-identified as Asian,

Black, Hispanic or White. This study includes only cohorts with six years of data between 1987 and 2011. A limited amount of data from the larger MIDFIELD dataset is provided for context in Table 1.

### 3.3 Approach

Students in multiple pathways are studied as follows: (1) FTIC students who matriculate directly into IE or who choose IE after completing the requirements of a first year engineering (FYE) program (where direct matriculation into specific engineering majors is not possible), (2) FTIC students who matriculate in other majors and migrate into IE, and (3) transfer students who make their way into IE.

To facilitate the comparison of the pathways of IE students at schools with FYE programs, and schools where students matriculate directly to specific engineering majors, the initial IE enrollment at FYE schools was imputed as has been done in similar studies [68]. This imputed enrollment is labeled Year 0. Students who started in FYE and immediately proceeded to an engineering discipline are counted as if they started in that discipline. Some students leave engineering or the institution before declaring a discipline. These students were allocated to specific majors at Year 0 in the same proportion as students of their race/ethnicity and gender chose each major after FYE (for analyses of how FYE affects students major choices, see [69–71]). Throughout this paper, “starters” refers to the total of FTIC students who matriculated directly into a major and those imputed to start in that major. “Transfers” refers to students who were designated as transfer students by the participating institutions. Transfer students are assigned as starting in a particular curricular semester, where for every 15 credits they transfer, their starting semester is increased by one.

In this paper, graduation is defined as having graduated by the sixth year from matriculation, following a standard of reporting by the Integrated Postsecondary Education Data System (IPEDS) [65]. The population at matriculation (Year 0) is needed for defining the persistence of the matricu-

lating cohort. The population at Year 4 marks the expected graduation date for most students and has been used as a measure of success by Seymour and Hewitt [14] and others. Finally, graduation, as defined above, is labeled Year 6. It is important to include the Year 6 outcome in addition to the Year 4 outcome, because differences in the graduation rate beyond Year 4 have been observed when the data are disaggregated by race/ethnicity and gender [72].

## 4. Results and discussion

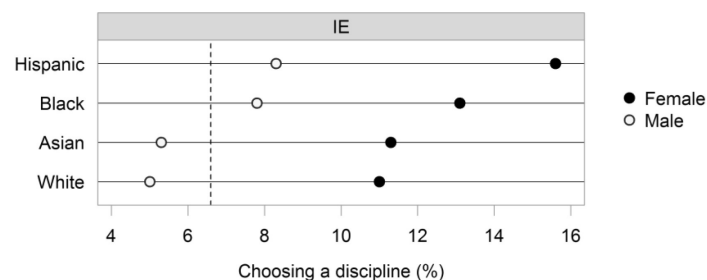
### 4.1 Choice

Focusing on those who chose IE when starting college, Table 1 shows the number of FTIC students in MIDFIELD starting in engineering (ENGR) and in IE by race/ethnicity and gender. Data are listed in decreasing order of engineering starters in each group.

The percentages of engineering starters who chose IE are also shown in Fig. 1. The rows indicate race/ethnicity and the data markers indicate percentages by gender. The vertical reference line shows the percentage of all the students who chose IE (Table 1, bottom row, “All Students”), 6.6%. Rows in Fig. 1 are ordered by decreasing median of percentages. In the graph, data markers to the right of the aggregate values indicate populations choosing a major at rates higher than average.

**Table 1.** Percentage of Starters Who Chose IE by Gender and Race/Ethnicity

Race/Ethnicity-Gender	Starters in ENGR	Starters in IE	% IE
White Male	52948	2631	5.0
Black Male	5867	455	7.8
Asian Male	3645	194	5.3
Hispanic Male	1560	129	8.3
White Female	12451	1366	11.0
Black Female	3486	456	13.1
Asian Female	984	111	11.3
Hispanic Female	430	67	15.6
All Male	64020	3409	5.3
All Female	17351	2000	11.5
All Students	81371	5409	6.6



**Fig. 1.** Starters Choosing IE by Race/Ethnicity and Gender.

*IE attracted a small but diverse population at matriculation.* Only 6.6% of all engineering starters chose IE when they entered college. This is much lower than fields such as Electrical or Mechanical Engineering [68]. Disaggregating by race/ethnicity and gender, rates of choosing IE ranged widely from 5.0% to 15.6%. All the groups that chose IE at higher rates than average are underrepresented in engineering overall—women of all races/ethnicities and Hispanic and Black men. In this dataset, the numbers of Black men and women were comparable (455 and 456) because Black women chose IE at such a high rate. Hispanic women chose IE at an even higher rate, but fewer started in engineering. When studies aggregate all race/ethnicities and genders, these stories are lost. The diversity of those who chose IE resulted in a starting population that was less than 50% White male, compared to 65% for all of engineering in MIDFIELD.

*Women chose IE at higher rates than men for all race/ethnicities.* Hispanic women chose IE at the highest rates (15.6%), followed by Black women (13.1%). Overall, both Hispanic and Black students chose IE at higher rates than Asian and White students of the same gender. All women, as well as Black and Hispanic men, chose IE at rates greater than the average. This results in a population of students starting in IE that is quite different than engineering as a whole. At MIDFIELD institutions, 37% of IEs were female while only 21% of engineering students were female.

#### 4.2 Industrial engineering graduation success

Figure 2 shows the six-year graduation rates of IE starters. The short vertical reference lines indicate a group average: the percentage of a particular combination of race/ethnicity and gender that starts and graduates within six years in the same discipline aggregated across a family of disciplines (Aerospace, Agricultural/Biological/Biomedical, Chemical, Civil, Computer, Electrical, Industrial, and

Mechanical Engineering). These group averages ranged from a high of 41% for Asian males to a low of 30% for Black males. The average graduation rate in the starting engineering major was about 40%. Aggregated over all engineering majors, women did nearly as well or better than men in all racial/ethnic groups, and Black students and Hispanic males stand out as having low graduation rates in the starting major.

*Graduation rates were high for all students in IE.* Students who began their engineering career in IE are generally very successful at graduating in IE (Fig. 2). This was especially true for Hispanic women and men who graduated at the highest rates, well over 50%. For each race/ethnicity-gender group, IE graduation rates were higher than for the family of engineering disciplines. Black males had the lowest six-year graduation rates of all IE starters (33.8%), although this was still higher than the rate for engineering.

*Hispanic women and men excel in IE.* Hispanic women and men were especially successful in IE, with graduation rates of 62.7% and 52.7%, respectively. That is a noteworthy 24.5 points higher than other engineering disciplines for Hispanic women (62.7% vs. 38.2%) and 15.5 points higher for Hispanic men (52.7% vs. 37.2%). Hispanic students had the highest graduation rates in IE of all groups studied.

*Graduation rates in IE were generally higher for women than men.* In addition to choosing IE at a higher rate than their male counterparts, Black, White, and Hispanic women were more likely to graduate in six years in IE than their male counterparts. Asian students however, had comparable graduation rates (43.2% for women and 45.4% for men).

#### 4.3 Trajectories

Examining only the graduation rates of starters ignores the large fraction of students who started

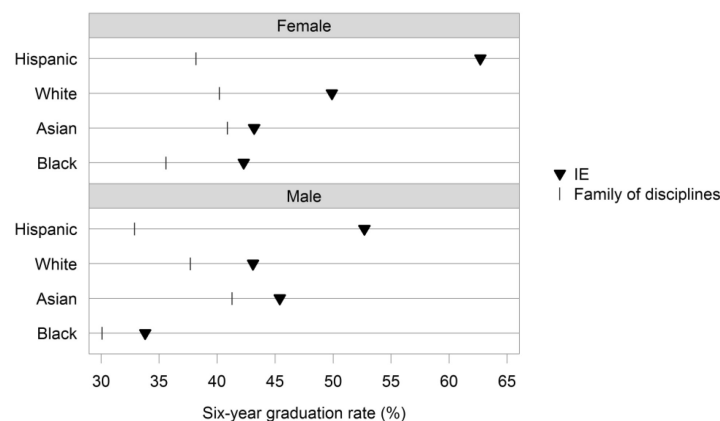


Fig. 2. Six-year Graduation Rate of IE Starters by Race/Ethnicity and Gender.

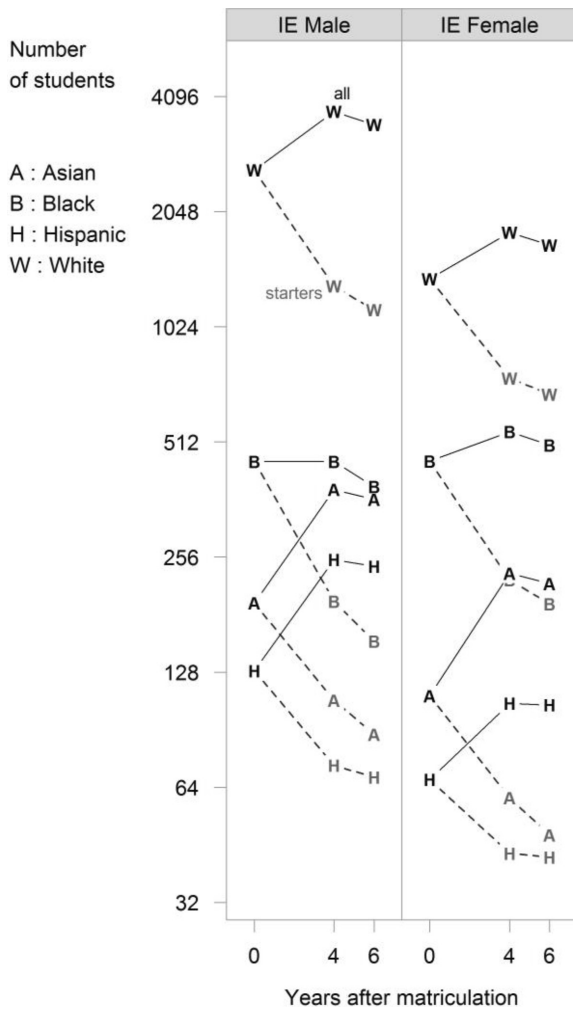


Fig. 3. Trajectories of IE Starters and All IE Students by Race/Ethnicity and Gender.

in other majors or at other institutions. Focusing on completion statistics also ignores the path students took, such as when students entered and left a major. Fig. 3 is a collection of time-series plots showing the number of students enrolled in IE at matriculation (0), enrolled or graduated four years later (4), and graduated by six years later (6), disaggregated by race/ethnicity and gender. The trajectories of the starters are represented by dashed lines and “all” students including transfers (from other institutions) and switchers (from the same institution, but started in other majors) are shown with solid lines. The vertical scale (numbers of students) is logarithmic, for ease of comparison between populations that differ by orders of magnitude. The horizontal scale (years from matriculation) is linear. The steeper the slope of the trajectory, the greater the fraction of students lost from a major.

Many students were attracted to IE once in college. IE lost many of its starters, but significant overall growth within IE was seen due to switchers from

other disciplines and transfers. There were actually more students who graduated in IE than started for all groups except Black men. The situation for Black men in IE was, however, better than for all other engineering disciplines studied in other work [73].

Hispanic students in IE tended to graduate if they were still enrolled after four years. The slopes of the Hispanic student trajectories in IE shown in Fig. 2 are shallower than those of other groups. This effect was particularly notable among Hispanic women in IE. This was anticipated by earlier research using MIDFIELD [72] in which Hispanic students who were enrolled in engineering for eight semesters (not necessarily consecutive) were very likely to graduate from engineering within six years. While that earlier study reported the pathways of Hispanic students in engineering in the aggregate, the success noted in Fig. 2 for Hispanics on the IE pathway has not been observed for Hispanic students in other disciplines.

#### 4.4 Stickiness

The presentation of trajectories in the previous section is useful and disaggregates student pathways, but is also complex, requiring 16 trajectories with three data points each to describe the enrollment and graduation behavior of each group. Here then, it is useful to employ another metric that can pool students from different pathways. The “major stickiness” is the number of students who graduated in a major divided by the number of students who ever declared that major [56], regardless of the path by which students entered the major. It includes starters, switchers, and transfer students. In Fig. 4, the rows indicate race/ethnicity, and the data markers show stickiness in the major as a percentage by gender. The vertical reference line indicates the aggregate stickiness of IE for all students in the panel.

Women stuck with IE more than men, particularly among Black students. Overall, females of all races/ethnicities tended to stick with their choice of IE more than their male counterparts. The greatest difference was for Black students, where Black females were much more likely to stick with IE than Black males (60.3% vs. 47.6%). Except for Black students, all others were at or above the average stickiness. The gender gap in stickiness for Black students was larger than the gender gap in the six-year graduation rate for Black students seen in Fig. 2. This implies that Black women who switched into IE must have been particularly successful to achieve this result.

Some transfer students had much higher stickiness than FTIC students in IE. Stickiness is disaggregated by FTIC and transfer students in Fig. 5. The high stickiness of transfer students is consistent with other work and likely due to their stronger commit-

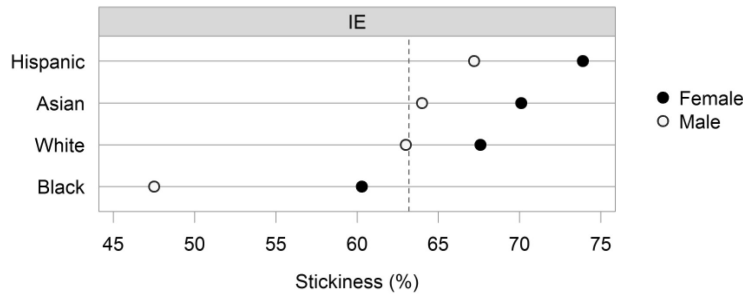


Fig. 4. Stickiness of Students Ever Majoring in IE by Race/Ethnicity and Gender.

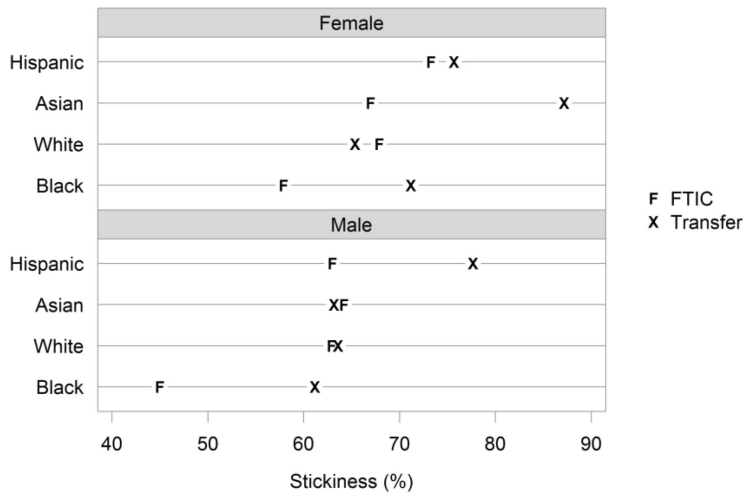


Fig. 5. Stickiness of FTIC and Transfer Students Who Ever Majored in IE by Race/Ethnicity and Gender.

ment to the major [56]. Within most groups, students who transferred into the MIDFIELD institution were “stickier” than those who started there (all achieving over 60% stickiness). This was especially true for Asian women, Black women, Hispanic men, and Black men. Differences in stickiness between FTIC and transfer students for Hispanic women, White women, Asian men, and White men were comparatively small.

In other work, Hispanic female transfer students were found to have extremely high stickiness in Electrical, Mechanical, Chemical, and Civil Engineering and engineering overall [68, 74]. The stickiness of Hispanic females in IE was the highest of any other group, but we did not find a large difference between FTIC and transfer students among Hispanic women.

### 5. Implications

As discussed earlier, the higher representation of women in IE compared to other engineering disciplines has attracted the attention of various researchers. Many of our findings from MIDFIELD related to women in IE did not appear to be gender exclusive. While the six-year graduation

rates for women were higher than expected, the six-year graduation rates for men were also higher than expected. As a result of students switching from other majors and transferring from other institutions, IE graduates included more women than enrolled in the discipline as first-time-in-college students; yet the same can be said of men. IE attracted more women than it lost. It also attracted more men than it lost. There is something different about IE, and qualitative researchers have described that difference in terms of the environment of IE, including how IE makes students feel welcome and gives them flexibility both in their academic program and in their careers.

In the context of Astin’s college impact model [32], the extent to which the pathways in and out of a discipline are gender and race/ethnicity specific is both an outcome of the environment and an important factor in determining the environment. By reference to the work of other scholars, we may suggest features of the environment that may contribute to the observed outcomes. In a study using Expectancy-Value Theory, Matusovich, Streveler, and Miller [28] found that in considering engineering as a career, it is critically important for the discipline of engineering to align with one’s sense



of self and values. The tighter that alignment, the better their model predicted persistence. This suggests that personal values can contribute to one's persistence in engineering. Foor & Walden [55] have suggested that as a discipline, IE is considered more socially interactive, engages people in higher levels of communication, is more office/business oriented, and is generally distant from traditional engineering technologies. Future research examining the alignment of these disciplinary characteristics with the values of students choosing and persisting in IE may help explain female and diverse students' interest in IE.

Work by Holland [75] might also provide insight into the particular values of some engineering students that resonate with IE. The Holland codes include the dimensions Realistic, Investigative, Artistic, Social, Enterprising, and Conventional. Certain combinations of Holland codes have been found to be more prevalent among engineers; specifically, they possess higher scores on the Realistic, Investigating, and Enterprising dimensions. Thus, students with these scores are often encouraged to consider engineering as a career. Alternatively, students with higher scores on the Realistic, Social, and Enterprising dimensions are encouraged to consider a career in business. Based on the similarity of this coding and suggested career destinations, engineering students who discover that engineering study does not meet their social needs, might be expected to switch to business, and indeed, business is the most likely destination for students leaving engineering but remaining at the university [52]. Considering these insights, the more social and business-related aspects of IE might provide an outlet for students within engineering, who value a more personal and engaging environment.

Why is IE popular as a switching destination but not as popular as an initial choice? Some of this may have to do with job placement starting salary differences, reputation, and familiarity with the discipline. Although it has been suggested that grades are an important factor in major selection and migration [76], earlier work using MIDFIELD found that students choosing IE initially have similar grades to students starting in other disciplines [52]. Literature about IE includes mixed messages, which could influence student choice. There also exists the "imaginary engineering" label discussed by Foor & Walden [55] which forebodes that some students will receive messages from peers and others that discourage them from starting in IE. However, as the positive messages emerge from IE students describing their experience as "inviteful" [55] and "passion" oriented [6, 41], they may encourage other students to switch to IE, particularly those who do not feel like they fit in other engineering majors.

Finally, the high observed graduation rates of IE students in this study resonate with the findings of the Purdue-Gallup study [77], which identified three important college student support elements: (1) having at least one professor who was excited about student learning, (2) feeling that professors cared about the student as a person, and (3) having a mentor who encouraged the student to pursue goals and dreams. According to this study, graduates who had experienced all three supports in college reported 2.3 times the engagement at work and 1.9 times the general well-being of graduates who did not have those experiences. Industrial Engineering students have described their professors as having passion and enthusiasm for the subject, and they have described their department as a "family". IE students "love" their major, their faculty, and the other students in their major [41], which may speak to students' individual values, as well as inform perspectives on observed persistence in the major.

## 6. Conclusions

The purpose of this study was to explain how pathways and outcomes of students in IE vary by ethnicity/race and gender. This study provides evidence that IE attracts and retains a more diverse student population in terms of race/ethnicity as well as gender, when compared to engineering as a whole. Data disaggregation reveals two important detailed findings. First, Hispanic and Black engineering students chose IE at higher rates than Asian and White students, and second, that men and women of all races/ethnicities were more successful in IE than other engineering disciplines, when measured by higher graduation rates. Further, while improved outcomes were observed for both women and men in IE compared to other engineering disciplines, this research revealed that IE fosters particularly positive outcomes for women at the nine institutions studied. In particular, for the examined MIDFIELD institutions, women were more than twice as likely to start in IE as men, with large differences observed for all racial/ethnic groups. Likewise, among IE starters, Hispanic, Black, and White women were notably more likely to graduate than their male colleagues, and women that ever majored in IE were at least five percentage points more likely than men to graduate in IE, with the difference larger than 12 percentage points among Black students.

Additional interesting aspects of IE student outcomes were also discovered, with the stickiness of Hispanic females in IE being the highest of any group studied. Among transfer students, Hispanic males, Asian females, and Black students were much more likely to "stick" with IE than their FTIC

counterparts. Moreover, for Hispanic females in IE, the 62.7% six-year graduation rate of starters was particularly notable. Opportunities for future research could explore whether there may be cultural norms associated with Hispanic students that are particularly aligned with those of IE programs.

Using performance metrics of student diversity, retention, and graduation outcomes, the IE student population examined here suggests that IE is doing something right; something that other disciplines might benefit from. More qualitative work is needed to deepen the understanding of how these outcomes result from the IE environment (as described in Astin's Model), as well as how aspects of race/ethnicity and gender identity/values drive disciplinary choice and persistence (i.e. Expectancy Value Theory). Future quantitative work will develop direct comparisons between IE and other engineering disciplines to uncover its unique attributes associated with student outcomes.

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