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Investigating Performance in First-Year Engineering Programs as a Predictor of Future Academic Success

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Abstract

The first year of undergraduate study has the potential to be one of the most formative experiences for engineering students and will heavily influence a student's decision to persist in engineering. This study examined first-year engineering programs (FYEPs) to determine the extent to which academic performance in FYEPs can predict the degree of academic success in continuing undergraduate study for certain engineering disciplines. This study also examined how those influences varied across each major. Our results indicate a moderate positive correlation between academic performance in FYEPs and future academic performance along with time to enrollment into students' graduation majors. Students who earned higher letter grades in their FYEP had higher final grade point averages and faster enrollment times into their final majors than students who earned lower letter grades. The predictive power of performance in the FYEP varied by graduation major.

Keywords: First-Year Engineering Programs, success, MIDFIELD

Introduction

First-Year Engineering Programs (FYEPs) normally contain a common curriculum that is taken by first-year engineering students upon their matriculation into a college of engineering at certain universities. Since FYEPs are most engineering students' first exposure to the discipline, it has great potential to shape students' concepts of engineering and of their future coursework.

If FYEPs contain content that is suited to a particular set of majors, certain students could be underprepared for their continuing studies or have misinformed expectations of their major. This could lead to academic underperformance in their major or delayed enrollment times into their eventual graduation major. This study sought to address four research questions:

RQ1: Do students from some majors perform better academically in the engineering coursework of FYEPs than students from other majors?

RQ2: Is academic performance in the engineering coursework of FYEPs a predictor of future academic success in college?

RQ3: Does academic performance in the engineering coursework of an FYEP correlate with students' time to enrollment in their graduation majors?

RQ4: Does the institution attended affect the degree of academic success in the engineering coursework of an FYEP?

Minimal FYEP instruction in topics relevant to a particular major could be a possible contributor to any issue concerning varying levels of academic success across engineering disciplines. Answering these questions would provide insight into first-year engineering students' experiences and help guide future instruction within FYEPs.

Literature Review

Tinto's student model of departure [1] explores academic and social malintegration, as well as individual behavior, to explain why students fail to persist in higher education. Tinto proposes that grade performance and intellectual development form the basis of academic integration, which solidifies commitment to degree completion, while social integration is formed by peer-group interactions and faculty interactions, which strengthens institutional commitment. Students' failure to succeed academically or integrate into their identities through interactions with peers and faculty could be contributing factors to students' decisions to no longer persist in their disciplines.

In investigating the effects of FYEPs on the formation of academic and social integration in engineering students, prior research has found that the quality of academic instruction and social integration into the college of engineering has considerable impact on student considerations to continue in engineering. Failure to integrate socially into a specific engineering discipline can cause even high-achieving students to consider dropping out of engineering due to a lack of interest and feelings of neglect in their academic identities [2]. Seymour and Hewitt reported that there was little difference between the academic abilities of persisting engineering students and those who decide to drop out [3], indicating that other factors, such as academic and social integration, have greater influence on students' decisions to remain in engineering rather than academic ability alone.

First-year engineering programs also play a pivotal role in engineering students' self-efficacy and engineering identities, which have both been linked to continued persistence in engineering. A study by Pierrakos et. al showed that although engineering persistors and non-persistors have similar amounts of engineering exposure in the first year, persistors were more likely to have stronger identities in engineering and more social connections within the engineering community [4].

In relation to the previous research that has been conducted in this field, this work hopes to expand upon these findings by exploring the relationship between academic success in the first year and academic integration within certain engineering disciplines.

Data and Methodology

This study utilized data from MIDFIELD [5] (Multi-Institutional Database for Investigating Engineering Longitudinal Development) to determine if academic success in a student's First-Year Engineering Program (FYEP) is indicative of their future success in engineering. MIDFIELD is a national dataset containing the student-level records of 1.7 million undergraduate, degree-seeking students at 19 institutions in the U.S. from 1987 through 2018. The "fix9a" version of MIDFIELD used in this study was compiled on September 15th, 2022.

The target population of this study was students who completed a common first-year engineering sequence and matriculated to a degree granting major. Institutions with a FYEP model (FYP using the Chen et al. taxonomy [6]) were isolated by checking if the National Center for Education Statistics' Classification of Instructional Programs (CIP) [7] code for first-year engineering students was equal to 140102, indicating enrollment in an FYEP. This resulted in the utilization of data from three large, public institutions in the United States. These institutions are not geographically representative of the United States, with two being located in the southeast, and are all predominantly white institutions [8].

Only students who met specific criteria were included in the sample population. All data manipulation and quantitative analysis was completed using the R programming language [9]. The final sample includes 33,896 students who:

- completed a first-year engineering program,
- graduated from a degree-granting program in Mechanical, Electrical, Civil, Chemical, Industrial, Computer, or Aerospace Engineering,
- have six years of data available in MIDFIELD, and
- had no discrepancies between the student, term, and degrees tables in MIDFIELD.

The median starting year of students who graduated from Institutions A and B was 1995, and for students attending Institution C the median starting year was 2003. Given that this data is partly historical, this data may not accurately reflect the current enrollment trends in engineering.

The numbers of students disaggregated by gender and first-declared major is described in Table 1. Additional engineering majors were excluded from the sample due to their limited population size.

	Mechanical	Electrical	Civil	Chemical	Industrial	Computer	Aerospace	TOTAL
Male	7,205	5,284	4,100	2,632	2,572	3,429	2,532	27,754
Female	980	750	1,070	1,360	1,198	300	483	6,141
Unknown	0	0	0	0	0	0	1	1
TOTAL	8,185	6,034	5,170	3,992	3,770	3,729	3,016	**33,896**

Table 1 – MIDFIELD Sample Population by Engineering Major and Gender

Race and ethnicity data was also recorded. The sample is 77% White, 9% International, 6% Asian, 4% Black, 2% Hispanic/Latinx, 2% Other/Unknown, and less than 1% Native American. Of the students included in the sample, 86% were first-time college students, while 14% were transfer students.

The engineering coursework of the FYEP was identified by correlating the entries in the courses table in MIDFIELD with the first-year engineering course designation listed in the institution's course catalogue for the appropriate academic year. Final cumulative GPA was identified by using the cumulative GPA of the last recorded term for each student which was specified in the term table. Letter grades were grouped to the closest whole letter for analysis; for example, students who earned an A+, A, or A- were all included in the A category.

The term of enrollment in graduation major was identified by tracing backwards through time to find the last enrolled degree program of each student; this result was then correlated with the degree listed in the degrees table as a check for data consistency. The total terms enrolled in graduation major was calculated by taking the difference between total terms enrolled and total terms enrolled in the graduation major.

Analysis

To quantify the results of this study, the Chi-Squared Test of Independence was calculated to test the likelihood of a relationship between two or more categorical variables. However, with large samples such as this one, finding statistically significant values using a Chi-Square Test is not uncommon [10]; therefore, Cramer's V was also calculated to determine the strength of the correlation between the categorical fields. Cramer's V can range from values of 0 up to 1; a value of 0 indicates no association, while a value of 1 indicates perfect association. Within this range, values of 0.1 suggest a weak relationship, values of 0.3 suggest a medium relationship, and values of 0.5 or greater suggest a strong relationship [11].

Results and Discussion

To help guide analysis of the individual majors, each major was disaggregated by their FYEP letter grade and shown as a total percentage of students who earned A, B, and C letter grades. In Figure 1, the major with the highest number of students who earned an A in the FYEP is at the top (16% of CPE majors at Institution A), and the major with the least amount of students who earned an A is on the bottom (5% of IE majors at Institution A). Using the Chi-Squared Test of Independence and Cramer's V, major had little impact on performance in the FYEP (χ^2 = 737, df = 4, p ≈ 0) (V = 0.1254). Institution attended was observed to have a moderate correlation with the course grade earned (χ^2 = 2644, df = 4, p ≈ 0) (V = 0.2376).

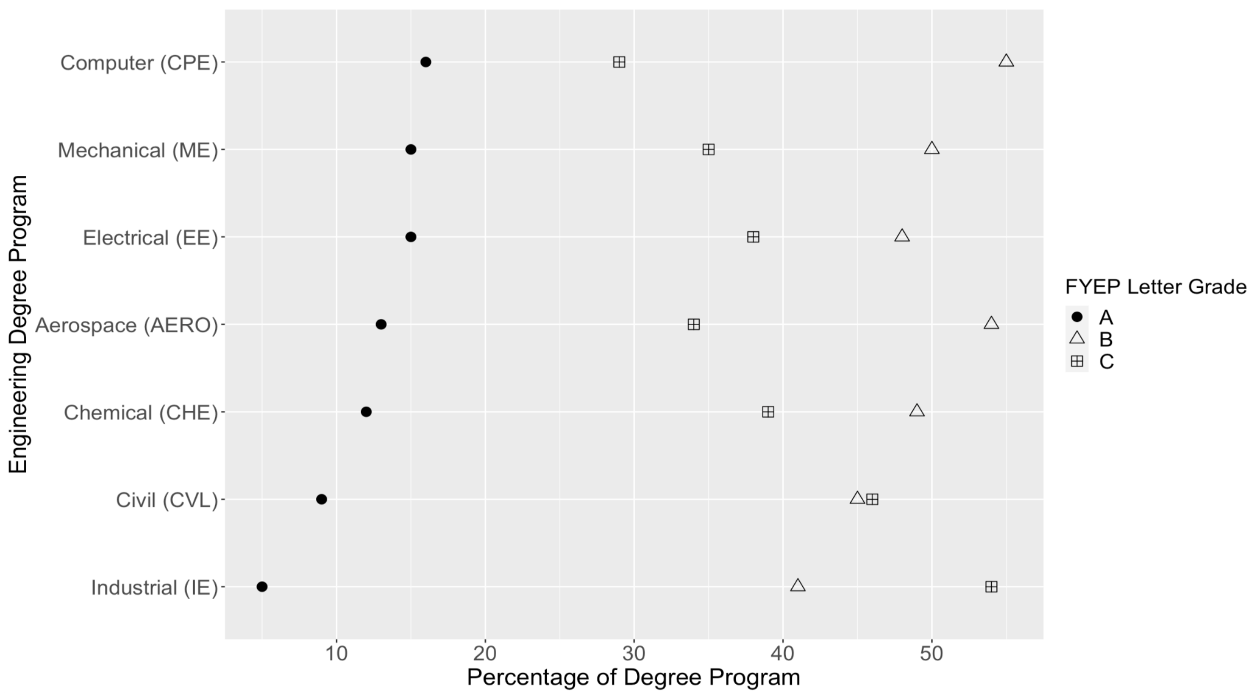

Figure 1 – Percentages of Engineering Majors Disaggregated by FYEP Letter Grade at Institution A

Figure 2 shows the final GPA categories of each major by the letter grade earned in the FYEP program. The majority of the students who earned an A in the engineering coursework of the FYEP graduated with a final GPA between 3.50-4.00; the majority of the students who earned a B graduated with a GPA of 3.00-3.49, and the majority of students who earned a C graduated with a 2.50-2.99 GPA. While these results are partly intuitive due to the fact that the letter grade earned has a direct impact on final cumulative GPA, comparing letter grade and GPA using the Chi-Squared Test of Independence (χ^2 = 5513, df = 6, p ≈ 0) and calculating Cramer's V (V = 0.3432) revealed that the results were moderately significant. The grade earned in the FYEP was the best predictor of future GPA for Aerospace Engineering majors (V = 0.3814) and the worst predictor for Computer Engineering majors (V = 0.2877) of the majors studied, but both suggest a moderate relationship. Institution was observed to have little effect on final GPA for all majors (V = 0.0506).

	Computer	**Mechanical**	**Electrical**	**Aerospace**	**Chemical**	**Civil**	**Industrial**
Cramer's V	0.2877	0.3453	0.3311	0.3814	0.3308	0.3491	0.3218

Table 2 – Cramer's V Suggesting the Relationship Between Final GPA and FYEP Letter Grade by Engineering Major at Institution A

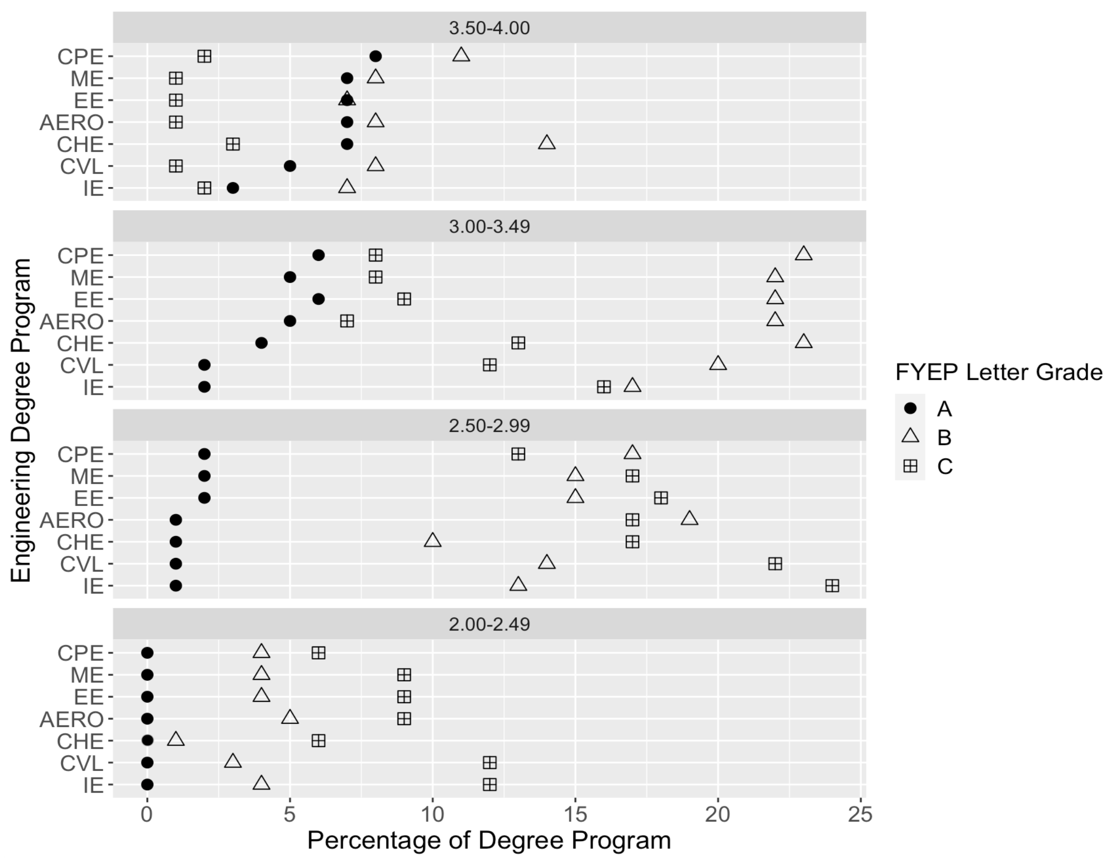

Figure 2 – Final Cumulative GPA Disaggregated by FYEP Letter Grade and Major at Institution A

As a final comparison between majors at a single institution, the cumulative percentage of students enrolled in their graduation major by term was calculated and disaggregated by the letter grade earned in the engineering coursework of the FYEP. At Institution A, students who earned an A in their FYEP engineering coursework enrolled in their majors by term 2.25, students who earned a B by term 2.59, and students who earned a C by term 2.82. Another notable observation is the difference of enrollment rate between the majors: among students who earned an A in their engineering coursework in their FYEP, CHE had the highest percentage of eventual graduates enrolled (96%) by the third semester, while CPE had the least (84%). The grade earned in the FYEP was the best predictor of enrollment time for CPE majors (χ^2 = 318, df = 4, p ≈ 0) (V = 0.3306) and the worst predictor of CVL enrollment times (χ^2 = 496, df = 4, p ≈ 0) (V = 0.2000).

	Computer	Mechanical	Electrical	Aerospace	Chemical	Civil	Industrial
Cramer's V	0.3306	0.2200	0.2630	0.3120	0.3060	0.2000	0.2362

Table 3 – Cramer's V Suggesting the Relationship Between Time to Enrollment in Graduation Major and FYEP Letter Grade by Engineering Major at Institution A

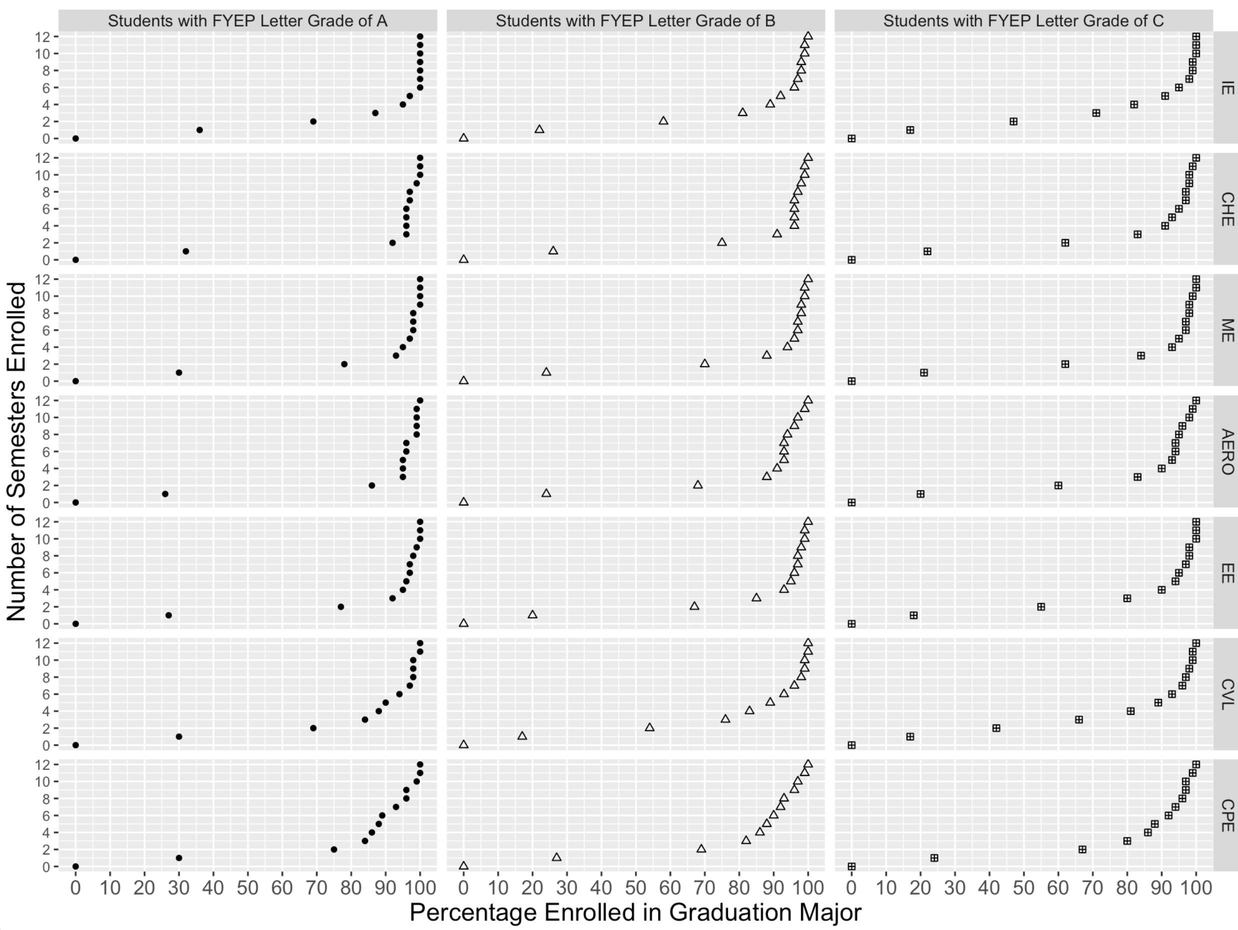

Figure 3 – Cumulative Percentage of Students Enrolled in their Graduation Major by Semester

Comparisons were also made between specific majors at the institutions studied to see if GPA changed significantly while controlling for degree program and letter grade earned in the engineering coursework of the FYEP. Analysis showed a large difference in the percentage of students in each major graduating with a certain GPA range based on the institution attended. For example, over 50% of CPEs who earned an A in their FYEP graduated with a 3.50-4.00 at Institution A, but <35% of CPEs who earned an A in their FYEP at Institution C graduated with the same GPA. This trend can be observed in Figure 4. Using the Chi-Squared Test of Independence (χ^2 = 376, df = 6, p ≈ 0), CPE performance was found to be moderately predicted by FYEP letter grade (V = 0.2877). Despite large gaps seeming to appear within the percentages of CPE students, institution actually has very little impact on final GPA (V = 0.0653).

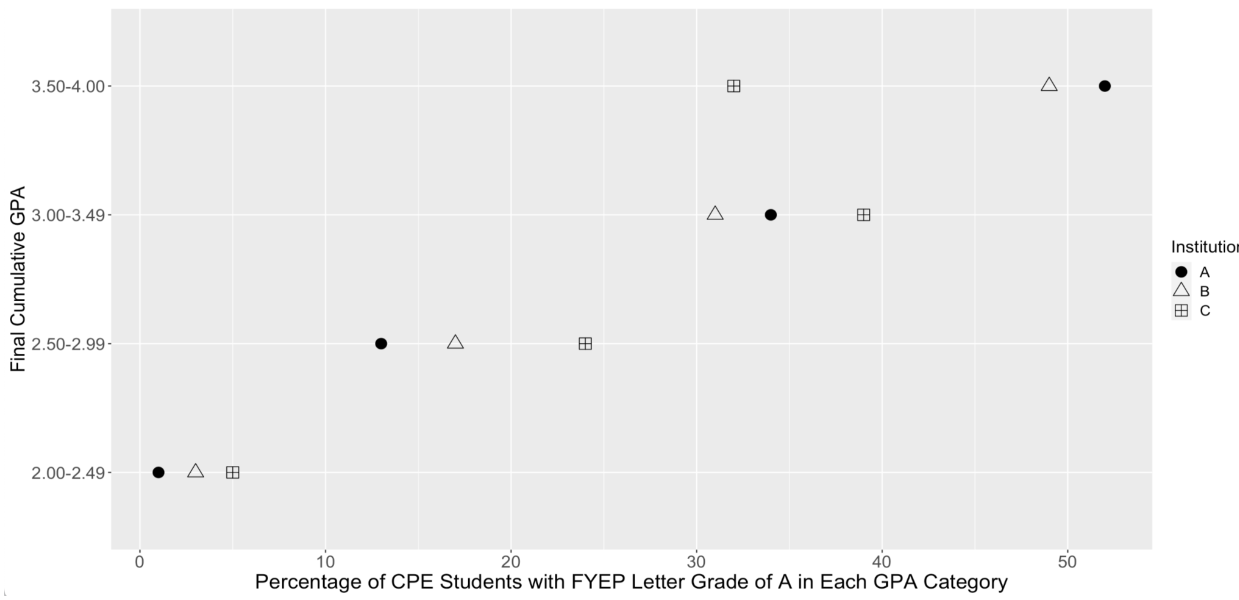

Figure 4 – Final Cumulative GPA of CPE Majors at Three Institutions

Conclusions

Academic performance in first-year engineering programs was the strongest observed predictor of future academic success in this study; however, the predictive abilities of performance in the FYEP did vary slightly for each degree-granting program. Low correlation between academic performance in the FYEP and declared major indicates that the structure of the curriculum at the institutions studied does not favor certain engineering disciplines in a way that precludes any particular major from academic success in a first-year engineering program; however, some majors may be more inclined to success due to other factors not controlled for in this study. The institution attended had a moderate correlation to the letter grade earned in the FYEP, but had little correlation with final GPA, indicating that high academic performance is not limited to certain institutions.

Students who earned higher letter grades in the engineering coursework of their FYEP tended to have higher final cumulative GPAs than their peers who earned lower letter grades. On average, students with higher letter grades in their FYEPs also enrolled in their graduation majors faster than those with lower letter grades. By performing statistical analysis, performance in the FYEP was seen to be moderately correlated with enrollment time to graduation major and final cumulative GPA; the extent of the correlation, however, was dependent on the degree-granting program of the student.

This data reinforces the importance of the first year for all engineering students, as well as instructors and academic departments. Helping engineering students succeed within their FYEP is important for ensuring the continuing success of the student throughout their entire undergraduate career. Encouraging students to understand the academic expectations within their engineering discipline in their first year could help them make more informed choices about which discipline to pursue in the future.

Limitations

No comparisons were made to universities with a direct-to-department matriculation model to better ascertain the benefits and drawbacks that arise from attending a university with an FYEP model. Including universities without an FYP matriculation model would help pinpoint differences in academic performance that are due to the structure of the FYEP. Additionally, this study only drew conclusions from graduates of degree-granting programs; excluding students who do not earn degrees in engineering may be detrimental to determining *why* students are not completing their degrees and if those reasons are correlated to the structure of the FYEP. As discussed in the Methodology section, some of this data is partly historical, so comparisons across institutions may not be completely equal. However, MIDFIELD is continuously updated, which will be beneficial to future studies.

Future Work

Future work would benefit from controlling for students' performance in high school and standardized test scores to determine the predictive ability of academic success in first-year engineering coursework more definitely. It would also be advantageous to consider the entirety of the coursework included in a first-year engineering program and its predictive qualities rather than the engineering coursework alone; however, coursework outside of engineering in the first year can vary more considerably by institution and major. Measuring the predictive quality of specialized classes for particular majors, like the predictive qualities of academic performance in chemistry classes for a chemical engineering student's academic success, would also be an insightful statistic for future students, educators, administrators, and other stakeholders in FYEPs.

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