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Engineering Student Success based on Performance in First Semester Foundational Courses

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Abstract

Student success in engineering programs is known to be heavily impacted by incoming student preparedness and highly correlated to performance in first-semester technical courses such as math, physics, chemistry, and programming. Recent years have seen changes in the types and predictive power of incoming student preparedness information, as a result of the movement toward test-optional admission criteria. This paper presents a quantitative study of current and longitudinal data regarding success in the University of Kentucky Pigman College of Engineering as a function of first semester performance, including how that performance has changed post-Covid overall and within key demographic groups.

Three analyses are presented: 1) 6-year graduation within the Pigman College of Engineering as a function of grades in first semester math courses, grouped into six clusters and evaluated longitudinally for trends; 2) 6-year graduation within the Pigman College of Engineering as a function of grades in all first semester foundational courses, focusing on which are the most predictive indicators; and 3) Differential college / university graduation as a function of grades in first semester foundational courses. Results of the analyses indicates that math grades in first semester classes are, as expected, strongly predictive of 6-year graduation, and that those grades on average are rising, with a slightly increasing percentage of students in the high-performing groups and a slightly decreasing percentage of students in the low-performing groups. Differential college/university graduation retention numbers suggest that there are a small number of moderately-low performance indicators which are able to identify students who are much more likely to have academic success in fields outside of engineering.

Outcomes from these analyses include new mechanisms for early identification of at-risk students, for whom specialized advising and success coaching would be beneficial, as well as the development of new curricular planning options for students who are not yet calculus ready in their first semester and would benefit from customized curricular planning to support better first-year performance.

1 Introduction

The demand for engineers in the workforce continues to grow [1], but the number of engineering graduates is not keeping up with this demand [2]. One significant factor in this gap is the number of students who leave engineering before earning a degree, more than 40% [3]. As a result, student retention and graduation rates in engineering have received considerable study in recent years, in hopes of identifying ways to improve student persistence and help students obtain their educational and career goals.

There are a wide range of factors correlated with student retention and graduation in engineering, including academic preparedness, financial stability, student belonging and engagement, quality of advising, and support systems for developing time management and study skills [4-7]. It is well known that math readiness in particular is one of the most significant factors in overall academic preparedness [8-11], and success in freshman foundational courses, including mathematics courses, is a strong predictor of retention and graduation in engineering programs [12-17].

This paper presents and reviews current and longitudinal data regarding success in the University of Kentucky (UK) Pigman College of Engineering (PCOE) as a function of first semester performance. The primary dependent variable metric is average 6-year graduation rates for the Fall 2016, 2017, and 2018 cohort years, including both students earning degrees from engineering and students starting in engineering but earning four-year degrees in other majors at UK. Data includes first-time college students starting in the PCOE in

their first year at UK. Independent variables examined include grades in first semester foundational courses, including math, science, and engineering courses. Data is also examined along demographic categories including under-represented minority (URM) status and first-generation college student status. Results are only presented for data where the cohort size is minimum N=5.

2 University Retention and Benchmarking

The University of Kentucky (UK)is a public very-high research activity (Carnegie R1) land-grant university in Lexington, Kentucky. UK is one of only two R1 universities in Kentucky and has the highest institutional enrollment in the state, with over 36,000 students in Fall 2024, of whom almost 26,000 are undergraduates. UK comprises 16 colleges with 93 undergraduate programs and is one of only eight institutions in the country with liberal arts, engineering, professional, agricultural and medical colleges and disciplines on one contiguous campus. About 25% of UK's undergraduate students are first-generation college students.

Improving student success has focused on a holistic model consisting of four pillars: academic achievement, physical and mental wellness, inclusion and belonging, and financial stability. The six-year graduation rate from the Fall 2017 cohort of first-time incoming college students at UK was 69.7%, an increase of nearly 10 percentage points over the previous decade. This is just below the average six-year graduation rate of 72.1% for public R1 universities in the U.S for the 2017 cohort year [18]. As might be expected, graduation rate is strongly correlated with admission selectivity, as shown in Figure 1 below. UK has a 92% admission rate with low comparative selectivity, and the recent increase in six-year graduation rate places them at around the 75th percentile for universities with incoming ACT composite scores between 23 and 27.

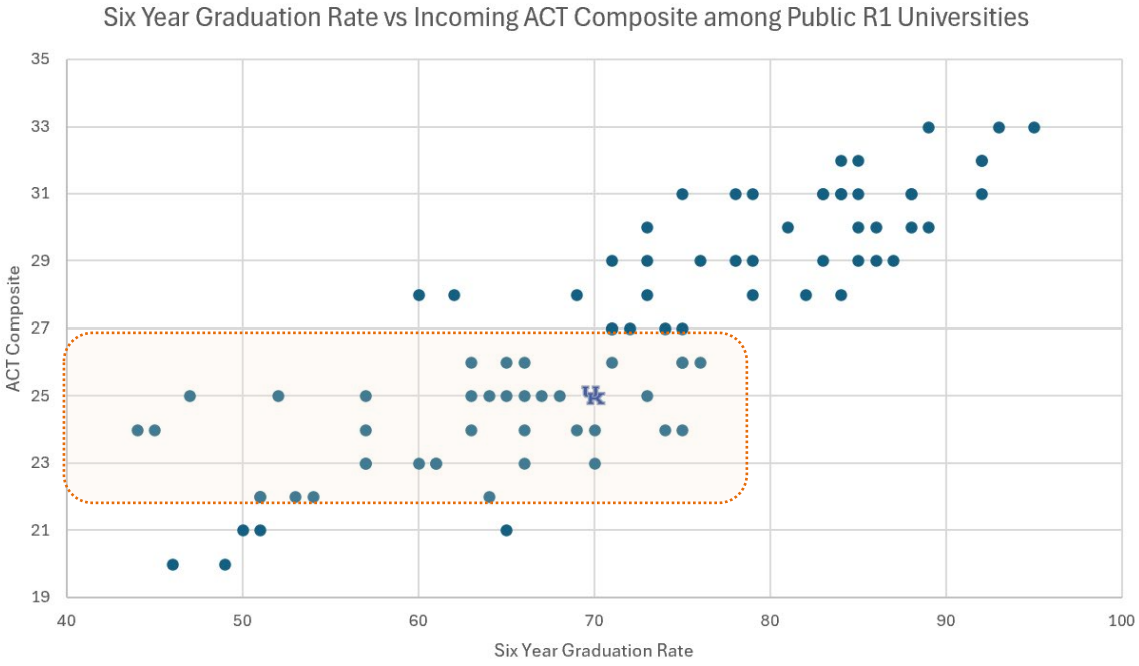

Figure 1 Six Year Graduation Rate vs. Incoming Student ACT Composite Score, for the 2017 cohort of first-time incoming college students among Public R1 Universities who reported both six-year graduation rate and ACT composite scores [18]. Universities with ACT Composites between 23 and 27 are highlighted. UK's six-year graduation of 69.7% and ACT Composite of 25 is indicated by the UK Logo.

3 College Retention and Demographics

The UK Pigman College of Engineering (PCOE) is Kentucky's largest and highest-ranked engineering college, offering 13 undergraduate degree programs including Aerospace Engineering, Biomedical Engineering, Biosystems Engineering, Chemical Engineering, Civil Engineering, Computer Engineering, Computer Engineering Technology, Computer Science, Electrical Engineering, Lean Systems Engineering Technology, Materials Engineering, Mechanical Engineering, and Mining Engineering. The college has a strong research program and also offers Master's and Doctoral degree programs in all engineering disciplines

The college's total undergraduate enrollment is over 3200 students. The six-year graduation rate for first-time college students starting in the Pigman College of Engineering was 71.9% for the 2017 cohort year, averaging 71.1% for the 2016, 2017, and 2018 cohorts. In comparison, the six-year engineering graduation rate for those same students was 54.5% for the 2017 cohort year, averaging 52.9% for the 2016, 2017, and 2018 cohorts.

Retention/Graduation Rates

Cohort Term	Cohort Size	Cohort Size with Exclusions	Retained % 1st Spring	Retained % 2nd Fall	Retained % 3rd Fall	Retained % 4th Fall	Graduated % 4 Years	Graduated % 5 Years	Graduated % 6 Years
Fall 2010	644	640	94.1%	82.6%	75.3%	71.9%	24.4%	56.1%	63.9%
Fall 2011	602	597	95.5%	85.0%	78.1%	73.8%	29.6%	59.0%	66.8%
Fall 2012	713	707	94.1%	85.4%	78.3%	73.4%	32.4%	63.1%	68.9%
Fall 2013	684	680	94.6%	86.1%	80.0%	75.3%	35.4%	63.2%	68.7%
Fall 2014	775	772	94.5%	85.3%	76.9%	73.5%	35.5%	62.7%	68.0%
Fall 2015	780	777	94.1%	83.8%	76.9%	71.8%	36.3%	62.0%	68.3%
Fall 2016	789	784	94.2%	87.8%	79.6%	74.9%	35.8%	64.7%	69.9%
Fall 2017	668	666	93.4%	86.2%	79.5%	75.6%	40.4%	67.3%	71.9%
Fall 2018	753	751	93.5%	86.1%	81.0%	76.1%	40.2%	68.3%	72.6%
Fall 2019	813	811	94.5%	88.8%	83.9%	78.8%	47.3%	70.5%	
Fall 2020	647	647	93.8%	88.4%	81.8%	77.6%	51.6%		
Fall 2021	655	655	96.2%	89.3%	84.7%	80.9%			
Fall 2022	771	770	96.6%	89.9%	84.6%				
Fall 2023	843	843	96.3%	89.8%					
Fall 2024	768	768	97.0%						

College Retention/Graduation Rates

Cohort Term	Cohort Size	Cohort Size with Exclusions	Retained in College % 1st Spring	Retained in College % 2nd Fall	Retained in College % 3rd Fall	Retained in College % 4th Fall	Graduated in College % 4 Years	Graduated in College % 5 Years	Graduated in College % 6 Years
Fall 2010	644	640	87.6%	64.4%	50.9%	46.1%	13.8%	36.4%	42.3%
Fall 2011	602	597	86.5%	67.8%	54.7%	50.5%	19.6%	41.9%	47.1%
Fall 2012	713	707	87.8%	69.4%	56.7%	50.1%	21.2%	44.6%	48.2%
Fall 2013	684	680	85.8%	68.3%	52.5%	49.9%	22.5%	43.1%	46.5%
Fall 2014	775	772	86.8%	69.4%	53.9%	51.2%	23.1%	43.4%	46.6%
Fall 2015	780	777	87.2%	67.9%	59.2%	52.3%	25.2%	45.2%	49.7%
Fall 2016	789	784	87.6%	75.7%	62.1%	55.3%	26.1%	48.0%	51.5%
Fall 2017	668	666	86.5%	75.0%	61.8%	57.6%	29.6%	51.1%	54.5%
Fall 2018	753	751	88.3%	75.2%	62.8%	56.4%	28.6%	49.7%	52.9%
Fall 2019	813	811	88.9%	78.2%	65.7%	59.5%	36.0%	53.6%	
Fall 2020	647	647	88.6%	76.8%	63.4%	59.0%	40.3%		
Fall 2021	655	655	91.6%	77.3%	68.2%	63.8%			
Fall 2022	771	770	90.5%	76.7%	66.9%				
Fall 2023	843	843	91.0%	76.9%					
Fall 2024	768	768	92.4%						

Figure 2 UK Pigman College of Engineering university (upper) and college (lower) retention and graduation rates. Peak values for each column are highlighted.

PCOE undergraduate cohort percentages for the key demographic categories of under-represented minorities, women, out-of-state, and first generation are shown in Figure 3.

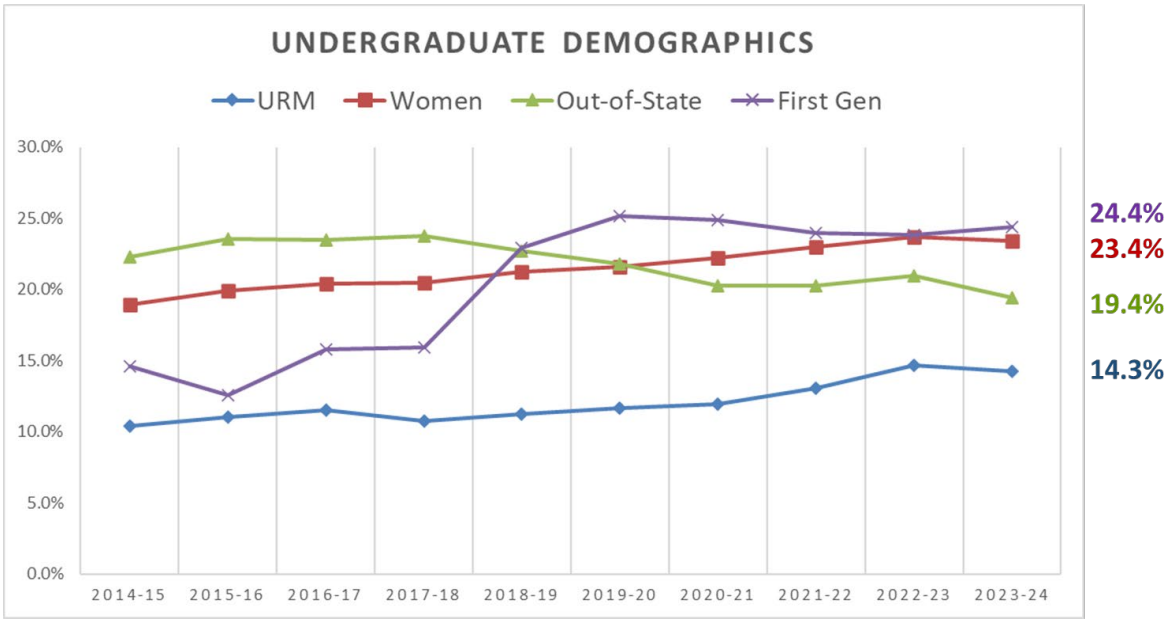

Figure 3 UK Pigman College of Engineering demographic time-series

Three-year average retention and graduation rates, as well as five-year trends in those same rates, are shown in Tables 1 and 2 below. URM and first-generation graduation rates are lower than that for the overall cohort, and female graduation rates are higher than for the overall cohort, all of which are consistent with national averages. The trend data in Table 2 shows that retention and graduation rates have been increasing in recent years, both overall and for each demographic subcategory. Improvements in first-generation and female graduation rates have out-paced the average, while improvements in URM graduation rates are less than that seen across all students.

	1st spring	2nd fall	3rd fall	4th fall	4Year Graduation	5Year Graduation	6Year Graduation
All students	**91%**	**77%**	**66%**	**61%**	**35%**	**52%**	**53%**
URM	91%	73%	57%	55%	27%	40%	41%
First-gen	89%	71%	55%	53%	28%	42%	44%
Female	91%	76%	65%	64%	40%	58%	58%

Table 1 UK Pigman College of Engineering average retention and graduation rates for the most recent three years. Of available data. Note that the data in each column is for a different group of cohort years.

	1st spring	2nd fall	3rd fall	4th fall	4Year Graduation	5Year Graduation	6Year Graduation
All students	**0.7%**	**-0.3%**	**1.0%**	**1.4%**	**3.5%**	**1.9%**	**1.7%**
URM	0.8%	-0.3%	1.0%	3.5%	4.5%	0.9%	0.8%
First-gen	0.5%	-1.3%	0.0%	1.6%	4.4%	2.8%	2.0%
Female	0.4%	-1.0%	0.0%	0.1%	2.6%	2.8%	1.8%

Table 2 UK Pigman College of Engineering linear trends for the most recent five years, in percent change per year. Note that the data in each column is for a different group of cohort years.

4 Student Math Readiness and Retention

The Pigman College of Engineering is a selective-admission college, but with lower admission thresholds than many of our benchmark institutions. Pre-covid, admission criteria was primarily based on ACT Math scores, and since 2021 has been based on test-optional admission criteria that is tied to math readiness. Through the 2018 cohort year, the admission threshold was an ACT Math score of 23, and starting in the 2019 cohort year that was increased to a score of 25. Since 2021 the admission criteria is directly connected to the Math department's eligibility requirements for pre-calculus.

The cohort breakdown for engineering students who were enrolled in their first-semester in Pre-calculus, Calculus 1, Calculus 2, Calculus 3, or other/no math is shown in Table 3 below. This data shows that the overall breakdown in math enrollment has been relatively consistent over the past 10 years, with about ¼ of students in Pre-calculus, ½ of students in Calculus 1, and ¼ of students in Calculus 2 or 3 or other/none. The only trend of significance is that the number of students in Calculus 1 is dropping by about one percent per year, which the number of students in Calculus 2 is increasing by about one percent per year, suggesting a slow increase in the number of calculus-advanced students over time.

Comparative averages and trends are shown in Tables 4 and 5 for URM and first-generation students. This shows that the percentage of students enrolled in pre-calculus is more than ten percent higher for URM and first-generation students, which likely significantly contribute to the lower graduation rates. In addition, trends show a slight increase in this number over time, as opposed to the slight decrease for the overall cohort.

	Pre-calculus	Calculus 1	Calculus 2	Calculus 3	Other/no Math
2014	26%	55%	8%	9%	2%
2015	24%	52%	8%	11%	5%
2016	25%	54%	7%	12%	2%
2017	24%	54%	6%	14%	3%
2018	20%	60%	5%	12%	2%
2019	25%	52%	7%	13%	3%
2020	16%	55%	10%	14%	5%
2021	16%	57%	11%	11%	5%
2022	27%	50%	10%	11%	2%
2023	29%	45%	12%	12%	2%
2024	22%	45%	19%	11%	2%
Average	**23%**	**53%**	**9%**	**12%**	**3%**
Trend/Year	**-0.2%**	**-0.8%**	**0.9%**	**0.1%**	**0.0%**

Table 3 UK Pigman College of Engineering first-semester math enrollment for first-time college students.
Note: Students enrolled in multiple math courses were considered to be enrolled in the highest-level class in which they earned a grade.

	Pre-calculus	Calculus 1	Calculus 2	Calculus 3	Other/no Math
All students	**23%**	**53%**	**9%**	**12%**	**3%**
URM	35%	45%	7%	9%	3%
First Gen	33%	49%	8%	6%	3%

Table 4 UK Pigman College of Engineering 2014-2024 average math enrollments for all, URM, and first-gen students.

	Pre-calculus	Calculus 1	Calculus 2	Calculus 3	Other/no Math
All students	**-0.2%**	**-0.8%**	**0.9%**	**0.1%**	**0.0%**
URM	0.4%	-0.9%	0.5%	0.1%	-0.2%
First Gen	0.1%	-1.2%	0.8%	0.3%	0.0%

Table 5 UK PCOE enrollment trends in percent per year for all, URM, and first-generation students.

Students in the PCOE participate in the First Year Engineering (FYE) curriculum program, which provides a common curricular structure across students regardless of major. All programs require EGR101 Engineering Exploration 1 (1-credit introductory course), EGR102 Fundamentals of Engineering Computing (2-credit programming course) in their first semester, and EGR103 Engineering Exploration 2 (2-credit team-based project course) in their second semester. Students in their first semester will have a curriculum that includes EGR101, EGR102, a math course, and either physics or chemistry.

One curriculum factor correlated to math readiness is the choice of physics vs chemistry in the first semester. For students at UK, chemistry tends to be more challenging and taking chemistry before physics has a larger negative impact on retention; however, the physics class that engineers are required to take has a co-requisite of at least Calculus 1, which means that students who are not Calculus 1 ready are forced to take chemistry in their first semester. Additionally, the physics sections tend to fill up more rapidly than chemistry, and as a result students who have earlier freshman orientation and registration time slots have a higher chance of being able to enroll in physics as opposed to chemistry. Since more prepared students (or parents) often sign up for the earlier orientation slots, there is a negative correlation between student preparedness and the ability to enroll in physics as opposed to chemistry.

5 Graduation rate as a function of success in first semester math courses

Retention and graduation data for PCOE first-time college students was separated according to the grades that students earned in their first semester mathematics, science, and engineering courses. The purpose of the analysis was to discover metrics that could potentially identify at-risk students who might benefit from our UK integrated success coaching program, career advising, or changing majors. The primary metric used for this analysis was the average six-year graduation rate for the 2016, 2017, and 2018 cohorts.

For the mathematics analysis, courses included [Pre-calculus, Calculus 1, Calculus 2, and Calculus 3] and grades included [2 D, E, W] (at UK the grade "E" is the grade corresponding to failure of the course, and "W" indicates withdrawal from the course), with a total of 48 grade categories. Graduation rates based on grades in first semester mathematics courses were manually clustered into groups based on gaps in the corresponding graduation rates. Some of those categories, notably the lower grades in Calculus 2 and 3, had a small number of individuals and were categorized as "low N" because there wasn't enough data on which to base conclusions.

The resulting analysis is shown in Table 6 below. Graduation rate follows the expected overall pattern of being higher for students with higher grades in first-semester math courses. It can be seen that students who receive an A in precalculus in the first semester are in the second-highest category and have a significant (63%) probability of earning an engineering degree, but that there is a large gap between this and other grades in precalculus (B=35%, C=15%, D=8%, E=1.5%, W=0%). Students receiving D, E, or W in precalc or an E in Calc1 had only single-digit six-year graduation rates.

Pre Calc	Calc 1	Calc 2	Calc 3	Cohort Percentage	Average Six Year Graduation Rate	(Min)	(Max)
	A	A B	A B	30.0%	83.8%	79%	88%
A	B		C	22.8%	68.3%	63%	70%
	C	C W	W	13.4%	47.7%	38%	53%
B C	D W			21.8%	22.7%	15%	35%
D E W	E			11.3%	4.1%	0%	8%
		D E	D E	0.9%			

Table 6 UK PCOE 2016-2018 cohort six-year engineering graduation rate as a function of grade in first semester math course. Green/yellow/red coloration corresponds to high/medium/low graduation rates.

Similar analyses were done for URM and first-generation students, with results shown in Tables 7 and 8. The most noticeable difference for both of these tables is that students earning an A in precalculus still have only modest six-year graduation rates (54% for first-generation students, and only 25% for URM students). Graduation rates for students earning an A or B in Calculus are still relatively strong.

Pre Calc	Calc 1	Calc 2	Calc 3	Cohort Percentage	Average Six Year Graduation Rate	(Min)	(Max)
	A B		A B C	3.8%	76.5%	72%	86%
	C			4.7%	51.7%	52%	52%
A B	D			1.6%	28.6%	25%	33%
C D	W			2.8%	11.7%	11%	13%
E W	E			1.5%	0.0%	0%	0%
		A B C D E W	D E W	0.6%			

Table 7 UK PCOE 2016-2018 cohort six-year engineering graduation rate as a function of grade in first semester math course for under-represented minority first-time college students.

Pre Calc	Calc 1	Calc 2	Calc 3	Cohort Percentage	Average Six Year Graduation Rate	(Min)	(Max)
	A B			3.5%	80.3%	76%	87%
A B	C			3.1%	53.7%	44%	58%
C D	D E W			4.3%	11.8%	9%	14%
E W				1.8%	0.0%	0%	0%
		A B C D E W	A B C D E W	1.1%			

Table 8 UK PCOE 2016-2018 cohort six-year engineering graduation rate as a function of grade in first semester math course for first-generation first-time college students.

One additional analysis was performed, which was to compare the six-year graduation rates to the four-year graduation rates for the same cohort years of 2016, 2017, and 2018, as a function of which course students took in their first semester, regardless of grade earned. These results are shown in Table 9 below.

The main observation from this data is that the likelihood of earning an engineering degree in four years is near zero for engineering students who start their academic careers in precalculus.

	All students		URM students		First-gen students	
	4 Year Graduation	6 Year Graduation	4 Year Graduation	6 Year Graduation	4 Year Graduation	6 Year Graduation
Precalculus	5.1	23.8	1.1	12.1	2.9	17.1
Calc 1	27.7	56.0	20.8	50.8	24.3	53.3
Calc 2	45.9	74.4	36.4	72.7	55.6	83.3
Calc 3	57.5	79.3	58.6	75.9	47.1	82.4

Table 9 UK PCOE 2016-2018 cohort four-year vs. six-year engineering graduation rate as function of first-semester math course, for all students, URM students, and first-generation students.

This data is consistent with prior literature studying the connection between early success in mathematics and retention in engineering. The most direct comparison is Bego et. al [12] who presented data from the University of Louisville on second fall and third fall retention within engineering as a function of grade in first semester math courses showing similar patterns.

6 Trends and Pre/Post COVID comparison of first semester math performance

Change in first-semester math performance over the past 10 years was examined, both in terms of overall linear trend and in terms of pre/post covid differential. Results are shown in Table 10 below.

Results show an increasing cohort, about +2.1 percent per year in the two strongest performance categories, and a decreasing cohort, about -2.1 percent per year, in the two weakest performance categories, suggesting that overall first-semester math performance is improving slowly over time. Pre-post covid analysis shows similar results, with a roughly 8.9 percent increase in the two strongest categories and a 10.6 percent decrease in the two weakest categories. This correlates with the overall increase in six year graduation rates.

It should be noted that it is not possible to determine directly whether changes in first-semester performance are due to incoming math readiness, as opposed to changes in pedagogy or grading or other correlated factors. However, the parallel between increasing first-semester grades as shown in Table 10 and increasing graduation rates as shown in Figure 2 suggests the possibility that there is a significant readiness component.

	Category Cohort Percentage					
	1	2	3	4	5	6
2014	29.0%	19.8%	12.4%	25.1%	11.0%	1.7%
2015	31.2%	21.2%	13.0%	19.8%	12.1%	0.8%
2016	26.7%	24.2%	14.2%	22.7%	11.1%	0.9%
2017	34.4%	19.6%	11.7%	20.6%	13.6%	1.1%
2018	29.5%	24.2%	14.1%	22.0%	9.7%	0.7%
2019	35.3%	22.6%	10.1%	20.8%	11.0%	0.8%
2020	34.5%	34.8%	10.7%	13.9%	3.7%	1.3%
2021	39.7%	25.2%	13.8%	13.8%	5.9%	1.6%
2022	34.1%	29.7%	12.4%	15.1%	7.5%	1.3%
2023	32.4%	33.1%	12.7%	16.7%	3.0%	1.8%
Slope Percent/year	0.7%	1.4%	-0.1%	-1.1%	-1.0%	0.1%
Precovid 2018/19	32.4%	23.4%	12.1%	21.4%	10.3%	0.7%
Postcovid 2022/23	33.3%	31.4%	12.5%	15.9%	5.2%	1.6%
Net pre/post change	0.8%	8.1%	0.5%	-5.5%	-5.1%	0.8%

Table 10 UK PCOE Cohort percentage in Categories 1-6 corresponding to the first-semester math grades from Table 6. Green-to-orange shading indicates strength of graduation rate.

7 Graduation and differential graduation as a function of success in first semester courses

Six-year Graduation rates were examined across all common courses and grades for first semester engineering students, and sorted according to several criteria:

- Overall college-level six-year graduation rate: The purpose of this analysis is the same as that of the previous section - to identify students who are most at-risk and likely to benefit from academic interventions and specialized advising and support.

- Differential between 2nd fall retention and six-year graduation rate: The purpose of this analysis is to identify those students who are most likely to return to engineering for their second year but least likely to earn an engineering degree, i.e. those students who are likely to benefit from changing their academic or career path but may not realize it without intervention.

- Differential university graduation rate minus the college graduation rate: The purpose of this analysis is to identify those students whose first semester performance indicates the most potential benefit from considering a change of major, i.e. to identify students whose performance suggests a high likelihood of obtaining a degree from the university but a substantially lower likelihood of earning an engineering degree.

For each of these analyses, only course/grade combinations meeting an N=10 threshold on cohort size were included in the analysis, to place some boundaries on the accuracy of the averages. The N=10 threshold for data from averaging three cohort years corresponds to a cohort percentage of approximately 0.5%. Average cohort sizes (average number of students in that course/grade combination each year) are included in the analyses to provide an idea of the number of students impacted.

Results of the overall graduation rate analysis are shown in Table 11 below. All grade results that correspond to six-year graduation rates of less than 25% are included, with the top ten rows corresponding to single-digit six-year graduation rates. Note that while these grade instances do indicate high risk students, the number of grade instances is much higher than the number of unique students, because of grade correlation across courses, such as the small but non-negligible number of students who earn near-zero GPAs their first semester and are therefore represented across as many as four or five different rows.

Results of the second fall minus six-year graduation analysis are shown in Table 12. The seven orange-colored rows indicate new course/grade combinations that correspond to moderate (not “high-risk”) six-year graduation rates, but which have a relatively large number of students who stay in engineering past their second year but do not ultimately complete a degree, and therefore might benefit from more careful monitoring or success interventions.

Results of the university minus college six-year graduation differential analysis are shown in Table 13 below. The two blue-colored rows indicate course/grade combinations (Precalculus-B and Calc 1 - C) that may not indicate high-risk for engineering graduation overall, but do have a much higher university graduation rate, suggesting that these students might benefit from careful career advising and coaching.

	2nd Fall Ret 2021,22,23	4th Fall Ret 2019,20,21	6yr Grad 2016,17,18	Avg N 2016,17,18
EGR102 E	17.6%	3.6%	0.0%	24
MA110 E	35.6%	7.1%	1.5%	15
EGR102 W	20.3%	5.7%	1.5%	21
EGR102 D	41.1%	24.6%	2.0%	24
EGR101 W	26.4%	6.5%	3.4%	17
EGR101 E	21.1%	2.9%	3.7%	25
CHE105 E	18.2%	3.3%	3.8%	14
MA113 E	46.9%	10.6%	5.6%	10
MA110 D	45.8%	15.2%	8.3%	8
CHE105 W	33.9%	13.7%	8.9%	19
CHE105 D	60.2%	22.1%	11.7%	43
EGR102 C	59.7%	25.7%	13.7%	71
MA110 C	37.5%	20.0%	15.5%	18
EGR101 C	61.6%	25.8%	15.5%	40
MA113 W	40.6%	18.8%	16.5%	34
EGR101 D	38.2%	13.3%	19.5%	11
MA113 D	55.8%	33.8%	23.5%	25

Table 11 UK PCOE 2016-2018 cohort by course and grade in first semester math, science and engineering courses, sorted by six-year graduation rate

	2nd Fall Ret 2021,22,23	6yr Grad 2016,17,18	2nd Fall Ret - 6yr Grad 2016,17,18	Avg N 2016,17,18
CHE105 D	60.2%	11.7%	48%	43
EGR101 C	61.6%	15.5%	46%	40
EGR102 C	59.7%	13.7%	46%	71
MA113 E	46.9%	5.6%	41%	10
MA114 C	93.1%	53.3%	40%	9
EGR102 D	41.1%	2.0%	39%	24
EGR101 B	68.6%	30.2%	38%	101
MA110 D	45.8%	8.3%	38%	8
CHE105 C	70.1%	32.8%	37%	90
EGR102 B	75.2%	39.1%	36%	162
PHYS231 C	73.3%	38.5%	35%	34
MA110 E	35.6%	1.5%	34%	15
CHE105 B	89.9%	57.0%	33%	102
MA113 D	55.8%	23.5%	32%	25

Table 12 UK PCOE 2016-2018 cohort by course and grade in first semester math, science and engineering courses, sorted by differential between second fall retention and six-year graduation rates. Highlighting corresponds to course/grade combinations that have above 25% six-year graduation rates and are not in Table 11 above.

	Univ 6yr grad 2016,17,18	PCOE 6yr grad 2016,17,18	Retention Delta	Avg N since 2016
MA110 C	55.5%	15.5%	40%	18
MA113 D	56.9%	23.5%	33%	25
MA110 B	64.8%	35.2%	30%	32
CHE105 C	61.9%	32.8%	29%	90
EGR102 C	41.1%	13.7%	27%	71
CHE105 W	36.0%	8.9%	27%	19
EGR102 B	65.7%	39.1%	27%	162
EGR101 B	56.6%	30.2%	26%	101
PHYS231 C	64.9%	38.5%	26%	34
MA113 W	42.9%	16.5%	26%	34
EGR102 W	27.5%	1.5%	26%	21
CHE105 D	37.2%	11.7%	26%	43
MA110 D	31.9%	8.3%	24%	8
MA113 C	71.1%	48.2%	23%	74

Table 13 UK PCOE 2016-2018 cohort by course and grade in first semester math, science and engineering courses, sorted by differential between university and college six-year graduation rates. Highlighting corresponds to course/grade combinations that were not previously highlighted in Table 11 or Table 12.

8 Discussion and Conclusions

This study has examined 6-year graduation rates within the UK Pigman College of Engineering, as a function of performance in first-semester foundational courses. Results of the analyses show that math grades in first semester classes are, as expected, strongly predictive of 6-year graduation, and that those grades on average are rising, with a slightly increasing percentage of students in the high-performing groups and a slightly decreasing percentage of students in the low-performing groups. Although the results are similar for URM and first-generation students, there are noticeably lower graduation rates for students in those demographics who start in pre-calculus, even when earning an A, which suggests that URM and first-generation students who are also academically underprepared in mathematics face an uphill battle to earn a degree. Differential college/university graduation retention numbers in Table 13 suggest that there are a relatively small number of first-semester course/grade combinations which correspond to low engineering graduation rates but high graduation rates in fields other than engineering.

These results provide insight that may be used for early identification of at-risk students, for the purpose of providing interventions such as tutoring, advising, and success coaching. Given the extremely low 4-year graduation rate for students who start their academic careers in pre-calculus, there is also clear support for development of 5-year curriculum plans for this group of students, which at UK PCOE makes up about one-fourth of the overall incoming freshman class each year, and nearly 35% of URM and first-generation students. Finally, the indicators from Table 13 can be used for early identification of students who may have a higher chance of academic success in fields outside of engineering, to make sure they are either fully committed to pursuing an academic career in engineering or provided with good information for considering alternative career directions.

References

[1] U. S. D. o. Labor, "Occupational OUtlook Handbook, Architecture and Engineering Occupations." [Online]. Available: https://www.bls.gov/ooh/architecture-and-engineering/

[2] J. B. Abhi Kodey, Jonathan Nipper, Nancy Post, Sibley Lovett, and Adriann Negreros, "The US Needs More Engineers. What's the Solution?." [Online]. Available: https://www.bcg.com/publications/2023/addressing-the-engineering-talent-shortage

[3] ASEE, "Engineering by the Numbers: ASEE Retention and Time-to-Graduation Benchmarks for Undergraduate Engineering Schools, Departments and Programs," in "Engineering by the Numbers," 2017. [Online]. Available: https://ira.asee.org/wp-content/uploads/2017/07/2017-Engineering-by-the-Numbers-3.pdf

[4] B. French, J. Immekus, and W. Oakes, "An examination of indicators of engineering students' success and persistence," *Journal of Engineering Education,* vol. 94, pp. 419-425, 10/01 2005, doi: 10.1002/j.2168-9830.2005.tb00869.

[5] J. Letkiewicz, H. Lim, S. Heckman, S. Bartholomae, and J. Fox, "The Path to Graduation: Factors Predicting On-Time Graduation Rates," *Journal of College Student Retention: Research, Theory and Practice,* vol. 16, pp. 351-371, 11/01 2014, doi: 10.2190/CS.16.3.c.

[6] J. A. Levin and J. Wyckoff, "Findings--Effective Advising: Identifying Students Most Likely to Persist and Succeed in Engineering," 1988.

[7] N. B. H. a. P. Ralston, "Freshman engineering retention: A holistic look," *Journal of STEM Education and Innovation,* vol. 14, no. 2, 2013.

[8] B. D. Bowen, J. L. M. Wilkins, and J. V. Ernst, "How Calculus Eligibility and At-Risk Status Relate to Graduation Rate in Engineering Degree Programs," (in English), *Journal of STEM Education : Innovations and Research,* vol. 19, no. 5, pp. 26-31, Jan-Mar 2019 2019.

[9] W. Pearson and J. D. Miller, "Pathways to an Engineering Career," *Peabody Journal of Education,* vol. 87, no. 1, pp. 46-61, 2012. [Online]. Available: http://www.jstor.org/stable/23120554.

[10] J. Callahan and M. Belcheir, "Testing Our Assumptions: The Role of First Course Grade and Course Level in Mathematics and English," *Journal of College Student Retention: Research, Theory & Practice,* vol. 19, 10/28 2015, doi: 10.1177/1521025115611620.

[11] G. David, R. Olivia, N. James Nathaniel, and T. Hamidreza, "Impact of Math Placement on Persistence and Time to Graduation In Engineering," Boston, Massachusetts, 2024/07/28. [Online]. Available: https://peer.asee.org/48626.

[12] C. R. Bego, J. L. Hieb, and P. A. Ralston, "Barriers and bottlenecks in engineering mathematics: Math completion predicts persistence to graduation," presented at the 2019 IEEE Frontiers in Education Conference (FIE), Covington, KY, USA, 2019. [Online]. Available: https://doi.org/10.1109/FIE43999.2019.9028542.

[13] D. Budny, G. Bjedov, and W. LeBold, "Assessment of the Impact of Freshman Engineering Courses*," *Frontiers in Education, Annual,* vol. 2, pp. 1100-1106vol.2, 11/05 1997, doi: 10.1109/FIE.1997.636047.

[14] R. Felder, G. Felder, and E. Dietz, "A Longitudinal Study of Engineering Student Performance and Retention. V. Comparisons with Traditionally-Taught Students," *Journal of Engineering Education,* vol. 87, 10/01 1998, doi: 10.1002/j.2168-9830.1998.tb00381.x.

[15] J. J. Pembridge, *First-Year Math and Physics Courses and their Role in Predicting Academic Success in Subsequent Courses*. 2013, pp. 23.605.1-23.605.12.

[16] H. Robin, J. R. Sigler, and L. Andrew, "Breaking The Cycle Of Calculus Failure: Models Of Early Math Intervention To Enhance Engineering Retention," Pittsburgh, Pennsylvania, 2008/06/22. [Online]. Available: https://peer.asee.org/4172.

[17] K. Whitcomb, Z. Y. Kalender, T. Nokes-Malach, C. Schunn, and C. Singh, *A mismatch between self-efficacy and performance: Undergraduate women in engineering tend to have lower self-efficacy despite earning higher grades than men*. 2020.

[18] National Center for Education Statistics *IPEDS : Integrated Postsecondary Education Data System : four-year institutions*, National Center for Education Statistics. [Online]. Available: https://nces.ed.gov/ipeds/use-the-data