Math Placement to Performance: Grades, Retention, Graduation, and the Path to EMPOWER.

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Abstract

While mathematics remains foundational to engineering and engineering science degrees, student pathways into their college-level mathematics coursework can be tumultuous. At the university in this study, students may place into their first semester's math course from an internal predictive model, the ALEKS Placement test, college-level testing (such as Advanced Placement or International Baccalaureate scores), or transfer credit from other institutions. Mathematics coursework for students in the college of engineering includes two possible calculus tracks and prerequisites to those calculus tracks. In this paper, gathered institutional data from Fall 2018 through Fall 2023 about all students who declared a major in the college of engineering at some point during that time (N= 3,672), their math placement mechanism and scores, their university application race and gender selections, GPA by semester, graduation information (if applicable), and some course grades (in math, physics, and chemistry, as available). In this paper, we assess the success of math placement mechanisms at the university as demonstrated by students' mathematics coursework, adjacent science coursework, and their degree attainment. We use multi-level logistic modeling to answer whether student placement mechanism predicts (1) graduation from the college of engineering, (2) retention after 1 year, (3) success in their first math course, (4) success in introductory chemistry, and (5) success in introductory physics while accounting for variation by different years of entry. When multiple levels are not necessary, we assess a single level of the data using Chi-Square tests. We predict that a student's math-placement mechanism will impact each of these variables of a student's success. We additionally suspected that the placement mechanism tied to the highest success in these variables is from college-level test scores and the lowest success may come from transfer credit placement. Considering the results about placement, course success, and graduation, we introduce and motivate the work from the institution's engineering math support program, which began its work at the end of the data set. The program includes math placement support for incoming students, math coursework support for early-degree students, and major-based coursework consultations for faculty peers.

Introduction

Mathematics success is integral to attaining an engineering or engineering science degree at The University of Oklahoma (OU). Students in these programs at OU must complete all or most of calculus. It is often the case that at least one Calculus course must be completed before being able to take major-based coursework within these undergraduate degrees. Most students starting college are not calculus ready [1], and students starting in courses prerequisite to Calculus are not as likely to graduate within 6 years [2]. Accurate placement is important, since high grades in precalculus and trigonometry lead to higher graduation success in engineering than low-but-passing grades in calculus [3]. Given what may feel like a time constraint, an accurate mathematics placement is a high-stakes task.

The purpose of this study is to assess whether a student's placement mechanism predicts (1) graduation from the college of engineering, (2) retention after 1 year, (3) success in their first math course, (4) success in introductory chemistry, and (5) success in introductory physics while accounting for variation by different years of entry. We use multi-level logistic modeling to address differences across different cohorts of students, and Chi-square tests or Kruskal-Wallis H tests when multiple levels are unnecessary.

While our research questions necessitate the use of university data and quantitative methods, our view of this line of questioning is person-centered in nature [4]. We hope to be on a path of student support to help our students meet their goals. Our research questions revolve around the university and college of engineering's ability to support their students. The academic success skills held by students are relevant to their individual success, but beyond the scope of this study. Similarly, we acknowledge that there will be many individual impacts on a student's life that affect their scores or graduation rates, including goals/motivation, self-efficacy, family emergencies, financial strain, and many more. We are taking this first step within our college to assess our baseline of support via placement mechanism to inspire new resources for students around placement as well as later work in those individual impacts on academic goal attainment and success.

In the remainder of this paper, we will discuss our approach to this study, the results of our various statistical analyses, and discuss the implications of how we approach support for math placement in our college of engineering at OU. We will introduce the Engineering Mathematics Program for Orientation, Workshops, and other Educational Resources (EMPOWER) along with preliminary evidence of its success and future directions in face of challenges.

Approach

In this section, we will give an overview of the data population and variables associated with them – major, graduation information, first math course, math placement mechanism, and grades.

Participants

The data in this study includes university reports about first-year and transfer students into the university between the Fall 2018 semester and the Fall 2023 semester who declared an engineering degree at some point during those semesters. This date interval was chosen because a different placement test was used before 2018 and we requested the data in the spring of 2024. Cohorts were created in the dataset based on fall enrollment, including students who had their first enrollment in a summer program included in the following cohort. The data set originally included 4,624 students across five consecutive cohorts. After removing the 952 students with incomplete placement-related data, we have a sample of $N = 3,672$ students. Table 1 describes students in this data according to identity categories available on their application to admission to the university. This data is provided to orient the reader to the general population of engineering and engineering science majors at the university.

Majors

The students in the study are those in the college of engineering at OU and include those majoring in Aerospace Engineering, Mechanical Engineering, Biomedical Engineering, Chemical

Engineering, Civil Engineering, Environmental Engineering, Computer Science, Computer Engineering, Electrical Engineering, Industrial and Systems Engineering, Engineering Physics, and Engineering Analytics. In the first year, recommended coursework for these majors includes Calc 1-of-3 (refer to the Math Coursework section), Calc 2-of 3, English Composition 1, English Composition 2, and a course in Engineering Thinking. The first two Calculus courses are core requirements across all engineering majors. Chemistry 1 and Physics 1 are additionally required for most engineering majors and recommended to be taken in the first year. Students may additionally take other general education coursework during their first year. Like with demographics, this information is provided to center the reader to the context of the study. Making comparisons between majors is beyond the scope of this study.

Table 1. Population Summary of Students

Identity Category	***N* *(%)***	**Identity Category**	***N* (%)**	**Identity Category**	***N* (%)**
White	1,885 (*51.3%*)	American Indian or Alaska Native	90 *(2.5%)*	Not US Citizen	255 *(6.9%)*
Hispanic	458 (*12.5%*)	Native Hawaiian or Other Pacific Islander	3 *(0.1%)*	Female	984 *(26.8%)*
Asian	439 *(12.0%)*	Do Not Wish to Report Race	44 *(1.2%)*	Male	2,688 *(73.2%)*
Black or African American	141 *(3.8%)*	Multi-Race	357 *(9.7%)*		

Degree Completion, Retention, and Grades

We use multiple variables to assess the success of a math-placement mechanism for students. These include binary variables on whether a student graduated by the end of the data collection period; whether students were retained 1 year (that after a fall and spring semester, they then enrolled in and completed the next fall semester), and what grade a student earned in their first math course, Chemistry 1, and Physics 1. Because we are using binary (pass versus not-pass) variables on grades at this stage, we have accounted for the university's handling of a pass/no-pass option for students in the Spring 2020 semester.

Math Coursework

Students at OU may place into one of two Calculus sequences or their prerequisites. The two Calculus sequences are identical overall – covering 12 credit hours of Calculus content. They are split into a 3-course sequence (with 4 credit-hours per course) and a 4-course sequence (3 credit-hours per course). We refer to Calculus 1 as either Calc 1-of-4 (from the 4-course sequence) or Calc 1-of-3 (from the 3-course sequence) throughout. The terms "Calc 1", "Calc 2", and "Calc 3" are often interchangeable between the two sequences in terms of serving as prerequisites to other coursework. The prerequisite to either Calculus 1 course is Precalculus/Trigonometry, covering mostly trigonometry concepts. The prerequisite to Precalculus/Trigonometry is College Algebra, covering an introduction to functions. Prerequisite to College Algebra is introductory algebra coursework which at the time of this study was not offered for college credit.

Math-Placement Mechanism

OU has a multi-tiered system for placing students into their first mathematics course. If a student already has credit via coursework or test, such as transfer, Advanced Placement (AP), or International Baccalaureate (IB) credits, then they may or may not need to engage with the other tiers in the placement system. It is only with transfer, AP, or IB credit that a student could place into a course beyond either of the Calc 1 classes. Without these credits, however, their application data will be fed into a university-created model for predicting success, which we will refer to as the Internal Model (IM), and was implemented starting in 2019. Information about the Internal Model is not published but includes at least an SAT or ACT score. Using the IM, students may be placed into College Algebra, Precalculus/Trigonometry, or either of the Calc 1 classes. If a student does not have enough data to run the IM or they do not like the result of their IM, they can take the ALEKS Placement test, the score for which will determine that student's placement. The classes available from ALEKS scores are introductory algebra through either Calculus 1 course.

Many students in this study have data related to more than one math-placement mechanism. For example, a student is given their IM information in February, while AP tests are taken around May with results given later in the summer. Consider a student who gets placement in College Algebra using the IM while taking AP Precalculus at their high school. While waiting for the results of their AP test, they take the ALEKS placement test and place into Calc 1-of-3. Their AP results come in and give them credit for College Algebra, which would place them into Precalculus/Trigonometry. Complicated, right? For statistical analysis, we need to choose one of these mechanisms to represent this student's experience, but they have three mechanisms to choose from. We could choose the mechanism that university knew about first (IM), the one the student was actively working on first (AP), or the one with the highest results (ALEKS).

The logic we chose to employ, as laid out in Table 2, started with the class they enrolled in for their first semester.

Table 2. Placement Mechanism Logic

Checked Order in Coding	First Math Course	Order of Priority in Mechanism Categories
1	Calc 2 +	Transfer Credit, AP, IB, PLA
2	Precalc/Trig or Calc 1	Transfer Credit, AP, IB, IM, ALEKS
3	College Algebra	IM, ALEKS
4	Introductory Algebra	ALEKS

If a student took an introductory algebra course, they were given ALEKS as the placement mechanism. If a student took a class beyond Calculus 1 (either version), we looked at whether this was from Transfer, IB, AP, or a rarely granted departmental test called a Prior Learning Assessment (PLA). Given the way the data is reported, these would not overlap. If a student took

College Algebra, they would either have an IM for it or would be counted under the ALEKS placement mechanism. Students in Precalculus/Trig or either of the Calculus 1 classes were the most complicated. Priority was given to Transfer, IB, AP, or PLAs (that lead to that enrolled course) and if a student didn't have one of those, we would look for an IM. If none of these were available, they would be counted as ALEKS.

Table 3 shows how many students were in each placement mechanism category in this study. Note that the category called "University" referred to students who earned credit from OU as concurrent high school students, to distinguish this kind of previous college credit from those who transferred credit from another university. Notice first that the introduction of IM mostly impacted the number of students placed via ALEKS. Additionally, it appears that fewer students placed via AP since 2020 and ALEKS placement increased in 2021.

Table 3. Placement Summary of Students

Year with Total *N*	**Transfer *N* *(%)***	**University *N* *(%)***	**AP *N* *(%)***	**IB *N* *(%)***	**PLA *N* *(%)***	**IM *N* *(%)***	**ALEKS *N* *(%)***
2018 – 771 students	166 (*21.5%*)	21 (*2.7%*)	214 (*27.8%*)	7 *(0.9%)*	5 (*0.6%*)	N/A	358 *(46.4%)*
2019 – 725 students	137 (*18.9%*)	0 (*0.0%*)	194 (*26.8%*)	7 *(1.0%)*	16 (*2.2%*)	297 (*41.0%*)	74 *(10.2%)*
2020 – 725 students	165 (*22.8%*)	2 (*0.3%*)	145 (*20.0%*)	6 *(0.8%)*	19 (*2.6%*)	310 (*42.8%*)	78 *(10.8%)*
2021 – 713 students	189 (*26.5%*)	2 (*0.3%*)	112 (*15.7%*)	16 *(2.2%)*	18 (*2.5%*)	233 (*32.7%*)	143 *(20.1%)*
2022 – 786 students	179 (*22.8%*)	2 (*0.3%*)	139 (*17.7%*)	19 *(2.4%)*	11 (*1.4%*)	262 (*33.3%*)	126 *(16.0%)*

Planned Analysis

To investigate whether student placement mechanisms were associated with college outcomes while accounting for cohort differences, we planned to use multi-level regression models. We first specified empty (intercept-only) multilevel logistic models. These models allowed us to calculate intraclass correlation coefficients (ICCs) to assess the proportion of variance attributed to cohort-level differences. The ICC values indicated substantial between-cohort variation for graduation ($ICC = 0.88$), suggesting that multilevel modeling was appropriate for these outcomes. In contrast, the ICC values for our other outcome variables were below 0.05, indicating limited between-cohort variation. Therefore, we continued a mutli-level logistic regression procedure for assessing graduation rates but explored other options for the remaining variables. After applying the multi-level logistic model, we assessed some individual comparisons with Chi-Square tests and Cramer's V posthoc tests.

We performed a Chi-Square test with Cramer's V posthoc test to assess differences in 1-year retention rates. We then attempted to explore the potential relationships between student placement mechanisms and academic performance in physics, chemistry, and their first math course using an

Analysis of Variance. Our data, however, did not pass the Levene test for equal variance ($p < .001$) or the Shapiro-Wilk test for normality ($p < .001$) for nearly all courses in nearly all cohorts. Instead, we performed a Kruskal-Wallis H test to evaluate these relationships instead. This non-parametric method is suitable when the ANOVA's underlying assumptions are violated.

Results and Discussion

In this section, we provide results of our multi-level logistic modelling, Chi-square tests, and Kruskal-Wallis H tests as they pertain to each of our research questions. We further discuss the implications of these results and how our college of engineering has started to work towards further supporting students in their placement process and beyond.

Graduation Rates

Our first research question asks whether a math placement mechanism has a long-term impact on graduation rates in engineering. Table 4 shows the graduation rates for engineering majors in the 2018 and 2019 cohorts. A student is included in the graduation rate if they earned their 4-year degree by the end of the data set (Fall 2023). In that sense, these are the 5.5-year graduation rates for 2018 and the 4.5-year graduation rates for 2019. Note that the number of students with PLA or IB placement is small and should not represent the overall success of these placement mechanisms. The total percentage of students in the 2018 cohort who at some point declared an engineering major and then graduated with an engineering degree by the end of the Fall 2023 semester is 60.5%. For the 2019 cohort, this is understandably lower at 50%.

Table 4. Engineering Graduation Rates for 2018 and 2019 Cohorts By Placement Mechanism

Placement Mechanism	2018 % Graduated	2019 % Graduated
PLA	100%	76.5%
AP	76.7%	69.1%
IB	71.4%	86.7%
ALEKS	58.2%	45.3%
Transfer	46.5%	34%
IM	N/A	44.6%
Total	60.5%	50%

We implemented a multi-level logistic regression model with placement mechanism as a categorical fixed effect (Level 1), using AP as the reference group. The choice of AP as the reference was arbitrary and random, given that the categories are not ranked in any way. Cohort-level random intercepts were included to capture Level-2 variation. The results for graduating with an engineering degree showed that relative to AP, the ALEKS, IM, and Transfer placement mechanisms supported lower graduation rates with an engineering degree ($p < .001$). Additionally, placement with a PLA supported higher graduation rates with an engineering degree ($p = .03$). Students placed with IB had no significant difference in graduation compared to AP ($p > .9$).

In observing finer-tuned comparisons between mechanisms, we used the post-hoc to a Chi-square test. In Table 5, we outline some pairwise differences in graduation rates with an engineering degree. We do not include the pairs featuring AP since that was the reference group in our multi-level logistic modelling. We additionally do not include years beyond 2019, because it is not reasonable to analyze less than a 4-year graduation rate.

Table 5. Chi-Square Posthoc Tests for Significant Placement Mechanism Comparisons

Year	**Placement Mechanism A**	**Placement Mechanism B**	**% Graduated A**	**% Graduated B**	***p*-value**
2018	PLA	Transfer	100%	42.9%	.02
2018	ALEKS	Transfer	58.2%	42.9%	.01
2019	PLA	ALEKS	76.5%	45.3%	.03
2019	PLA	IM	76.5%	44.6%	.01
2019	PLA	Transfer	76.5%	34%	< .01
2019	IB	IM	85.7%	44.6%	< .05
2019	IB	Transfer	85.7%	34%	< .01
2019	IM	Transfer	44.6%	34%	.03

Overall, math placement mechanism appears to play a critical role in long-term academic success. These findings align with existing literature, which suggests that skills learned in advance of college coursework are strong predictors of persistence and graduation [3]. In this portion of the study, that is showcased by the consistently higher graduation rates with students taking a Prior Learning Assessment, Advanced Placement test, or International Baccalaureate curriculum for their placement mechanism. Similarly, transfer credit is not as supportive as other placement mechanisms [5]. Even though many students are encouraged to take concurrent college coursework during high school, this kind of placement appears to result in the lowest graduation rates. This may be a result of different expectations or curriculum across courses at different universities and colleges. The Internal Model and ALEKS test appear to perform similarly in terms of supporting a student's graduation in engineering.

Retention Rates

Since the empty model indicated limited differences between cohorts for 1-year retention rates, we performed a single Monte Carlo simulation (because of some of the low-counts in some categories) on 1-year retention rates with groupings by Placement Source, ($\chi^2(6, 3411) = 62.234$, $p < .0001$). This indicates that there are differences in 1-year retention based on math placement mechanism. The percentage of retained students is summarized in Table 6.

Like with graduation, students appear to be most supported by AP, IB, or PLA placement in terms of 1-year retention. The IM, ALEKS, and Transfer-related placement are less supportive, but not terribly different than each other for retention. Further research is needed to determine when transfer credit becomes less supportive than the IM or ALEKS in supporting retention as it leads to graduation.

Table 6. 1-Year Retention for 2018 through 2022 Cohorts by Placement Mechanism

Transfer	University	AP	IB	PLA	IM	ALEKS
83.8%	80%	92.1%	98.2%	98.6%	82.9%	81.7%

Grades

We performed a Kruskal-Wallis H test to evaluate whether math placement mechanism impacted students' academic performance in their first math course, Chemistry 1, or Physics 1. The first place where a students' placement mechanism may impact their success is in their first math course – the result of that math placement. The Kruskal-Wallis H test for first math course indicated that there were statistically significant differences in course performance across placement mechanisms. Table 7 shows these results for each cohort below.

Table 7. Kruskal-Wallis H Test Results on First Math Course by Year

Year	χ^2	df	*p*-value
2018	68.24	5	<.0001
2019	77.54	5	<.0001
2020	82.18	6	<.0001
2021	86.71	6	<.0001
2022	72.99	6	<.0001

Assessing further with pairwise Wilcoxon posthoc tests, we can see where these differences lie. In 2018, AP performed better than both ALEKS and Transfer mechanisms in placing students into their first math course ($p < .001$) and IB performed better than Transfer credit ($p = .03$). Other adjusted *p*-values were not significant. In 2019, 2020, 2021, and 2022, AP performed better as a placement mechanism than ALEKS ($p < .05$ or less), IM ($p < .0001$ each cohort), and Transfer credit ($p < .0001$ each cohort). Additionally, PLAs better placed students than IM and Transfer credit ($p < .05$) in 2019 and better than ALEKS in 2021 ($p < .05$). In 2021, IB performed better than ALEKS ($p < .0001$), IM ($p < .05$), and Transfer credit ($p < .01$). The IM also performed better than ALEKS ($p < .01$) in 2021.

Like with graduation and retention, the grades in a student's first math course are best supported by placement via AP, PLA, or IB testing. Additionally, the IM, ALEKS, and transfer credit are less supportive of good first-math course grades, but the IM may be slightly more supportive than ALEKS within that hierarchy.

We also performed these tests for two classes that use certain math courses as prerequisites. Table 8 shows the initial results for each cohort of Chemistry 1 below. There were differences between placement mechanisms on Chemistry 1 Grades in each cohort.

Table 8. Kruskal-Wallis H Test Results on Chemistry 1 Grades by Year

Year	χ^2	**df**	***p*-value**
2018	52.11	5	<.0001
2019	38.06	5	<.0001
2020	38.49	6	<.0001
2021	56.43	6	<.0001
2022	42.43	5	<.0001

Pairwise Wilcoxon tests with adjusted p-values from Bonferonni showed that AP performs better as a math placement mechanism in terms of Chemistry 1 grades in 2018 when compared to ALEKS ($p < .0001$), concurrent credit from OU ($p < .01$), and transfer credit ($p < .0001$). In 2019, AP performed better than IM ($p < .0001$) and transfer credit ($p < .0001$). Similarly, 2020, 2021, and 2022 showed that AP performed better than ALEKS ($p < .05$ or less), IM ($p < .01$ or less), and transfer credit ($p < .0001$). Additionally, ALEKS performed worse than IB ($p < .001$) and IM ($p < .0001$), but better than Transfer credit ($p < .01$) in 2021. Finally, IB performed better than ALEKS ($p < .01$) and transfer credit ($p < .05$) in 2022.

Regarding the most supportive math-placement mechanism for Chemistry 1 grades, AP continues to perform better than most other placement mechanisms, while ALEKS, IM, and Transfer credit are less supportive. Within the lower placement mechanisms, IM may support students better in Chemistry than ALEKS, while ALEKS may support students better than Transfer credit.

Table 9. Kruskal-Wallis H Test Results on Physics 1 Grades by Year

Year	χ^2	**df**	***p*-value**
2018	37.53	5	<.0001
2019	42.27	5	<.0001
2020	38.96	6	<.0001
2021	49.41	5	<.0001
2022	22.61	5	<.001

Table 9 shows the comparison results for Physics 1 grades. The pairwise comparisons showed that AP performed better than ALEKS ($p < .05$ or less) and transfer credit ($p < .0001$) in terms of Physics 1 grades in 2018, 2019, 2020, and 2021. In 2019, 2020, 2021, and 2022 AP also performed better than IM ($p < .0001$). In 2021, IB performed better than ALEKS ($p < .01$), IM ($p < .05$), and transfer credit ($p < .01$). There are less exciting distinctions in Physics 1's support by the various math-placement mechanisms, but AP continues to lead the others.

Conclusion

In each of our research questions – those about graduation, retention, and grades in various early-engineering coursework – AP appears to support students best as a math-placement mechanism. With fewer students affected, PLA and IB placement are also supportive. Math placement via ALEKS, IM, and Transfer credit are not in a consistent order of support across research questions, but they do tend to be lower than the other three placement mechanisms. These results are consistent with literature that have shown that students who have passing AP scores have higher success rates and are better prepared for college coursework than students without that early preparation [6]. While transfer credit placement (by way of concurrent or dual credit coursework) should also serve as early preparation for college, this study also finds similar success concerns with transfer credit as compared to AP and some other placement mechanisms [5].

These initial results, while anecdotally and empirically redundant, reveal part of the challenge facing the faculty and staff supporting students in colleges of engineering. Students arrive as prepared for class as they are going to be – there is typically minimal preparation entailed in the mathematics placement process itself, even for the placement mechanism with review modules built into the process.

EMPOWERing Students

The first author on this paper works for the college of engineering almost exclusively to help students navigate the mathematics portion of their degree. At a programmatic level, it is unsatisfying to find that what appears to be the most supportive math placement mechanism in terms of grades, retention, and graduation is entirely out of our control. Rather, we prefer to be able to assist students in making strong decisions about their degree from the moment they are admitted, and that moment is too late to suggest they take an AP Precalculus or AP Calculus course their senior year. In fact, we have about 13% of incoming engineering students who do not take a mathematics course at all during their last year of high school. It is for these students (and any others who need an additional math resource along the way) that the first author created the Engineering Mathematics Program for Orientation, Workshops, and other Educational Resources (EMPOWER). This program provides support for math placement via consultations and content-based programming, including research-supported targeted email campaigns to introduce the program and reinforce placement policy information from the university, as supported by research [7]. Once a student is taking math coursework for their degree, they may also attend study events and workshops, open support hours, or individual consultations with any of the program faculty. We have also implemented a 1-credit hour course to support students who need more structured guidance, particularly in math-specific academic success skills. Beyond their math coursework, EMPOWER supports other faculty in developing efficient review materials for major-based coursework.

The various programmatic supports that EMPOWER provides have been iteratively piloted over the course of two years after the dataset included in this study. In terms of mathematics placement, we began sending targeted email campaigns about mathematics placement and preparation in late Summer 2023. That first summer saw 18.7% of incoming engineering students taking a second ALEKS placement test (and engaging in required study modules between attempts), and by Summer 2025 that number jumped to 23.4% of incoming engineering students taking a second attempt. We suspect that the increased engagement with ALEKS has not only meant placement into a different course, but additional preparation for that course by reviewing prerequisite content. The EMPOWER program continues to enhance student support for incoming and ongoing students. In Summer 2026, we are piloting a new Summer Math Launch to serve as an online summer bridge option for incoming students looking to prepare for university-level calculus coursework.

Future directions include a more full-fledged analysis of EMPOWERs supports, but preliminarily we have seen that students who engage with additional placement support over the summer preceding their first fall semester perform better in their first math course. Students who engage in more EMPOWER events during their math coursework similarly perform better than those who do not engage in such support. Part of these results are obvious, since students engaging in more study-related activities should do better in their coursework. Therefore, as we consider the results of this study and our preliminary successes with EMPOWER programming, we will develop a research protocol that considers factors beyond success in a class. These considerations may include motivation, emotion, and persistence gathered in mostly qualitative methods.

Limitations

We must point out that this study is limited by its reliance on institutional data from a single university. In terms of traditional quantitative analysis, this is limiting in its generalizability to other institutions. In reality, the limitation is that we are unable to showcase student-level impacts. This study is administratively strong in using a large data set and accounting for a number of complex variables, but at the student level many of these results are superficial at best. We are unable to show you the hard work that each student put in to their placement process, the hours of taking in the content from their chemistry class, the time they pulled out an A on a really tough math exam, the times they considered withdrawing from physics or switching majors, and all the personal, motivational, and emotional strengths and resources that carried them through the semesters, whether they finished their degree or not. Other variables that can affect grades, retention, and graduation include prior GPA, resources or preparation features of their high school based on socioeconomic factors, and their sense of belonging. This limitation motivates our work moving forward to incorporate qualitative analysis to understand these other potential impacts of mathematics placement for engineering majors.

Future Directions

As we move forward with EMPOWER and our research directions, we are reminded that our overarching goal is to support students in attaining their own goals for an engineering degree and to ensure that mathematics is not the barrier to that attainment. For that reason, we anticipate our next steps to revolve around various motivational factors (e.g., sense of belonging or expectancies/values), measured both quantitatively and qualitatively, of students at various stages of their degree and levels of engagement with EMPOWER. We expect to continue seeing students who engage with EMPOWER's resources and study events to do well when compared to those who do not engage with these supports. Therein lies the rub, though, as we face the classic struggle to encourage more engagement from students who are struggling (academically or motivationally) with their engineering coursework. EMPOWER's main focus and future direction is to increase student engagement using empirical evidence from motivation research.

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