# Increasing Matriculation Rates: A Case Study of the Development, Launch, and Success of a New Approach

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## Abstract

In the College of Engineering at NC State, retention, matriculation, and graduation rates have remained largely unchanged. For almost three decades, students in the College of Engineering entered into a common first-year cohort and matriculated into a degree-granting engineering program after completing a specific set of courses with stated minimum grades. However, this process consistently prohibited a sizable number of students from entering an engineering program and ultimately graduating with an engineering degree. In this paper, we detail a case study of the process undertaken in developing our new matriculation process. We provide a discussion of the analytical approach taken to determine predictors of student success, the path taken in creating the new matriculation process, produce an overview of the launch of the new matriculation system, and share data that demonstrate the success and utility of the new program matriculation process in the College of Engineering at NC State.

## Keywords

Matriculation, retention and graduation rates; engineering graduation rates; use of data; regression analysis

## Introduction

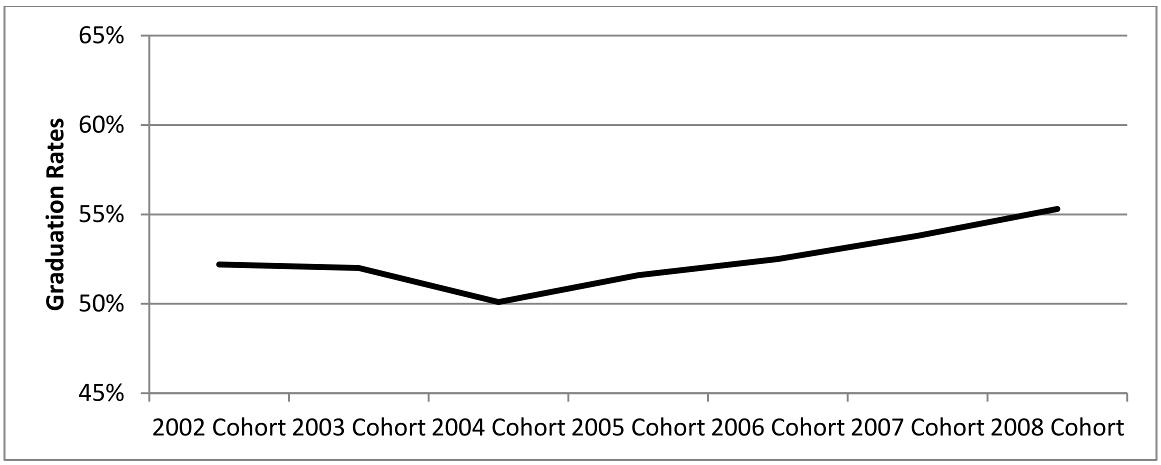
Analytics has become of increasing interest in recent years and for good reason. Data about people, events, and activities coupled with the ability of statistical software to quickly analyze data allows for decision-makers to make informed judgments in a highly sophisticated manner. In higher education, data and the ability to analyze data quickly and easily has transformed enrollment management functions, allowing administrators to determine where limited resources will produce the most useful results.

Meanwhile, engineering programs around the country are witnessing an increase in interest from students, and the call to produce more engineers is ubiquitous. In response, some institutions are choosing to increase the size of their undergraduate populations[1], yet the number of engineering students being produced is not sufficient to meet demand[2]. The call for more engineers coupled with stagnant graduation rates leads to a paradoxical solution for educators. On one hand, if there is a need to produce more engineers, simply admit more students. On the other hand, to produce more engineers, educators could focus on graduating larger proportions of engineering students.

Increasing graduation rates for engineers is no easy task and a number of studies have sought to understand factors related to increased propensity to complete an engineering degree[3-5]. While a complete and thorough review of the literature related to persistence to completion of an engineering program is beyond the scope of this paper, we are cognizant of the complexity of the graduation puzzle for engineers.

NC State's College of Engineering is a micro example of the macro problems facing the field of engineering education. Six and four-year graduation rates for engineering students have remained largely unchanged (see figure 1), and so too has the number of degrees earned (see figure 2). Concerned with the consequences of maintaining the status quo; leaders in the College of Engineering at NC State sought to find a means of increasing graduation rates and the number of degrees earned.

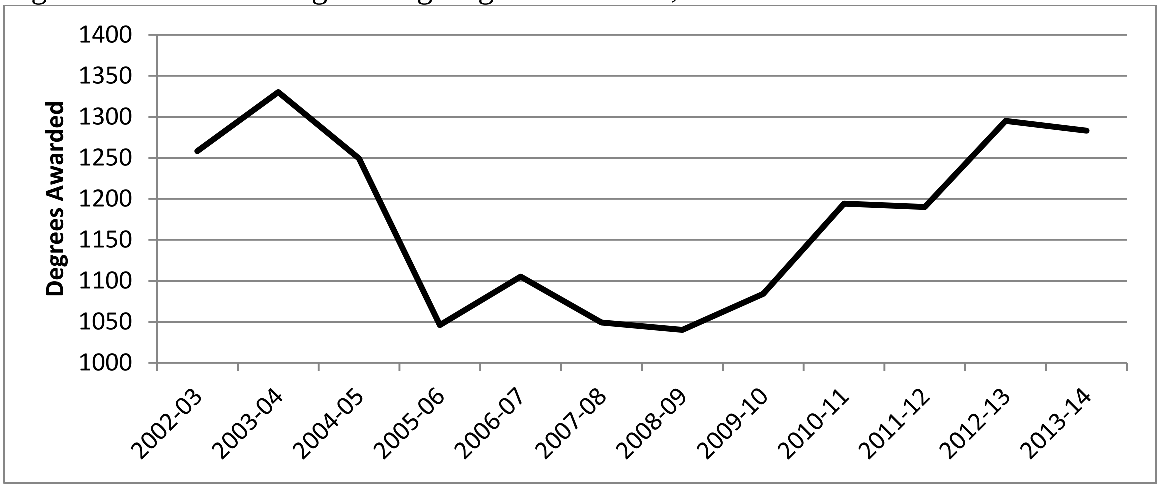
Figure 1: First-Year Engineering Graduation Rates, 2002 – 2008




The initial inquiry into how to increase graduation rates began in 2009, while state budget cuts were occurring due to the recession[6]. As a result, college leaders knew that few if any additional resources would be able to be commanded to address the issue of stale graduation rates, and there was a distinct possibility that there would actually be fewer resources in coming years. In practice this meant that the resources that would be needed to increase enrollment size would not be available. In response, administrators in the College of Engineering analyzed graduation rates with respect to variables of academic performance, including grades in Calculus I, Calculus II, Physics I, Chemistry and the accompanying lab, English, and cumulative GPA to find a solution to the graduation problem.

In this paper, we detail the process NC State College of Engineering administrators undertook to reinvent a matriculation process to address a flat-lining degree completion rate. We begin by discussing the matriculation process that was in place prior to the fall of 2012. Next, we detail the analytical approach undertaken to illuminate a new matriculation process, and describe the matriculation process developed and implemented in fall 2012. We conclude by providing early evidence of the success of the initiative, discuss the weakness in the process, and detail how other institutions may use this information to improve their own processes.

Figure 2: Number of Engineering Degrees Awarded, 2002 – 2013




## Matriculation in Engineering Prior to 2012

Prior to the fall semester of 2012, the process in the College of Engineering to matriculate students into degree granting programs was based solely on student success in college courses on the campus. Students were initially admitted to the university as undeclared engineering students in the College of Engineering. These undeclared engineering students enrolled in a number of common first-year engineering courses (including a first-year experience engineering themed course) and would matriculate into a degree granting engineering program once they completed basic eligibility requirements.

Matriculation eligibility was based on completion of Calculus I, Calculus II, Physics for Engineers I, Chemistry, A Molecular Science and an accompanying lab, and English, Academic Writing and Research. In order to enter an engineering program, students had to complete each of those classes with a C- or better and have a cumulative GPA of at least 2.9. An analysis of matriculation rates revealed that approximately 64.5% of entering first-year cohorts would eventually matriculate into an engineering program (see Table 1).

Students who were unable to meet basic eligibility criteria had several paths. The first option would be for a student to continue trying to meet the basic eligibility criteria. This meant students would take the required courses multiple times in an attempt to achieve the minimum grade needed. Meanwhile, students who were below the 2.9 threshold would take courses not related to the engineering curriculum in an attempt to raise their cumulative GPA above the 2.9 threshold. For these students, the added time spent trying to become eligible increased their time to degree.

The second option available to students was contrary to the documented policy, but none the less occurred by allowing some ineligible students to matriculate into an engineering program for a variety of reasons. These decisions were normally made at the program level and were accompanied by a contractual expectation that a student maintain a minimum level of academic success to continue in the program. The decision to matriculate an ineligible student was made solely by program leadership, and departments had varying criteria for these ineligible students. Only limited students achieved the standards set forth by these contracts.

Table 1: Percent of Entering Cohorts Matriculating into an Engineering Program within Two-Years of Enrollment

| Cohort Year | % Matriculating |
|---|---|
| 2002 | 64.6 |
| 2003 | 65.7 |
| 2004 | 62.8 |
| 2005 | 61.6 |
| 2006 | 60.8 |
| 2007 | 62.2 |
| 2008 | 66.5 |
| 2009 | 63.4 |
| 2010 | 66.8 |
| 2011 | 70.7 |

The third and fourth options available to students would be to transfer to a non-engineering program at NC State or leave the institution, respectively. With regards to transferring to a non-engineering program, the College of Engineering matriculation process had many unintended consequences. For instance, students who were unable to gain engineering eligibility quickly would find it difficult to gain admission to other programs after having failed multiple attempts of the same engineering prerequisites. Consequently, students who stayed in an engineering non-matriculated status for multiple semesters (often into their third year) would find it nearly impossible to gain admission to any degree granting program at the university. Given the size of the College of Engineering relative to the rest of the university, this had significant negative influences on the university's overall graduation rate, as well as many negative personal implications for students.

Meanwhile, limited departmental resources were available to accommodate the growing number of first-year students. Students were focusing on specific engineering degree plans and discounting many other lesser recognized programs due to popularity or familiarity. Engineering students who achieved the 2.9 minimum GPA for program acceptance usually chose only a few engineering programs in which to enter, and administrators had no means of controlling this inflow of eligible students. This caused complications for these easily identifiable programs, as they were forced to increase class sizes, limit new offerings, and schedule additional course sections to successfully teach the overwhelming numbers of incoming students. Furthermore, when college leaders were faced with economic constraints limiting the hiring of new personnel, these departments had difficulty in accommodating their students' needs for effective advising and special student services. In addition, departments in less demand were not burdened with these problems and thus equity became an issue. Faced with all of the previously mentioned issues, administrators in the College of Engineering turned to data to define a new direction.

## Using Data to Improve the Matriculation Process

While there are a variety of statistical techniques that can be used to analyze data, regression analysis has proven to be particularly useful. At its heart, regression analysis is simply an attempt to draw a straight line through a series of data points, based on another series of data points[11]. However, part of the power of regression analysis lies in its ability to serve two unique purposes: one of explanation and one of prediction[7].

On the one hand researchers have used regression analysis to examine how variables working in concert and alone act upon other variables. For instance, in engineering education regression analysis has been used to examine the connection between professional development and institutional environment and faculty use of student-centered teaching[8], the connection between student perceptions of intelligence and course performance[9], and factors tied to graduating in an engineering field[3], to name just a few. On the other hand, regression can be used as a powerful means of prediction, where variables thought to influence outcomes are used to forecast events, effects, and decisions[7], and it is with prediction that we found the most utility for regression analysis, given our charge.

We began the process by surveying the literature related to engineering student success, and we found support in the literature for some of the activities that we are already engaged in, namely that calculus, physics, and chemistry were important determinants of student success in engineering courses[10]. Indeed, we had anecdotally observed the connection between these courses and engineering student success. The broader issue, however, was the level at which a student would need to demonstrate competency in order to be successful. To answer that question, we modeled the relationship between performance in calculus, physics, and chemistry courses and probability of graduating with an engineering degree.

Given the dichotomous nature of the dependent variable used in the analysis (a student either does or does not graduate), we opted to use a binomial logistic regression analysis. The use of ordinary least squares (OLS) regression with a discrete dependent variable violates the assumptions of normality undergirding OLS regression. In addition, the use of OLS regression may have resulted in predicted values greater than “1” and less than “0”, impossibilities given the nature of a dichotomous variable[11].

Moreover, to ease interpretation of the results, we chose to calculate an overall GPA based on performance in the calculus, physics, and chemistry courses. This also allowed us to examine how these courses, working in tandem, influenced a student’s probability of graduating with a degree in engineering. Given this information, we fit the following model:

$$\eta_i = \beta_0 + \beta_1 \frac{((Cal_1 * Cal_{1Hours}) + (Cal_2 * Cal_{2Hours}) + (Phy * Phy_{Hours}) + (Chem * Chem_{Hours}) + (Chem_{lab} * Chem_{labHours}))}{Hours_{Total}}$$

Where:

$\eta_i$ = the probability of a student graduating within 6-years with an engineering degree, in log odds.

$\beta_0$ = the intercept.

$\beta_1$ = the slope of average performance in Calculus 1 and 2, Physics, and Chemistry and Chemistry Lab.

$Cal_1$ = Student's Calculus 1 grade.

$Cal_{1Hours}$ = Calculus 1 hours.

$Cal_2$ = Student's Calculus 2 grade.

$Cal_{2Hours}$ = Calculus 2 hours.

$Phy$ = Student's Physics grade.

$Phy_{Hours}$ = Physics hours.

$Chem$ = Student's Chemistry grade.

$Chem_{Hours}$ = Chemistry hours.

$Chem_{lab}$ = Student's Chemistry Lab grade.

$Chem_{labHours}$ = Chemistry Lab hours.

$Hours_{Total}$ = Total number of hours for Calculus, Physics, and Chemistry courses.

Data for the study included all students who enrolled in the College of Engineering over a 10 year period, regardless of matriculation status, and results of this analysis showed a significant relationship between performance in the Calculus, Physics, and Chemistry courses and probability of graduating with a degree in engineering. For every $1/10^{th}$ increase in student performance, a student's probability of graduating would increase by more than 50%.

We also undertook a post hoc analysis to examine what level of performance was needed to demonstrate adequate propensity to be successful in an engineering program. Our post hoc analysis demonstrated that while students who were successful in the calculus, physics, and chemistry courses and who could obtain an overall GPA of 2.9 or better graduated at an almost 90% rate, students who earned the minimum C- in these matriculation courses were not as successful as those with better grades. We concluded from this information that at least a C in each of the courses was needed. Finally, additional analyses demonstrated that cumulative GPA at the university was a poor indicator of student performance.

Collectively this information pointed to major flaws in the matriculation process prior to fall 2012. The first was the requirement to complete the calculus, physics, and chemistry courses with at least a C-. Our research indicated that this threshold was set too low. The second flaw was the reliance on cumulative GPA, as additional analyses indicated that cumulative GPA was a poor indicator of probability of student success, as it was not a statistically significant factor. Moreover, a small but substantial number of students with a cumulative GPA below 2.9 were admitted to programs on a case by case basis. These students graduated at a rate on par with those students whose cumulative GPA was above a 2.9.

Essentially, the matriculation criteria employed up to fall 2012 was keeping out students who could be successful, while admitting students who would not be successful. Armed with this information, we designed a new a process for matriculating students into degree granting engineering programs.

## Matriculation in Engineering after Fall 2012

In designing a new matriculation process in the College of Engineering, we had four primary goals:

1. Design a process that assists students in making progress towards completing a degree in a timely manner.
2. Increase College of Engineering and university first-time full-time 6-year graduation rates.
3. Increase the number of degrees being awarded.
4. Develop a mechanism to prevent overcrowding in programs and departments.

We started the processes by developing new criteria to evaluate student performance, and it was informed through the analysis of data we described previously. The results of the analysis indicated that performance in the calculus, physics, and chemistry courses were strong predictors of a student's likelihood to graduate, and that students who earned at least a C in each of those courses were the most prepared for the engineering curriculum. This formed the foundation for the new "Change of Degree Audit" process or CODA.

Students who entered the College of Engineering as first-time full-time first-year students in the fall of 2012 were guaranteed admission to an engineering program if they completed the calculus, physics, and chemistry courses with at least a C in each course. In addition, students had to successfully complete a first-year engineering experience course and English 101. Students were given four semesters in which to complete these requirements, and were allowed no more than two attempts at completing each course.

An Engineering Success Score (ESS) was calculated based on a student's performance in the calculus, physics, and chemistry courses and is simply a weighted average across those courses. To account for advanced placement (AP) credit or college transfer credit for these fundamental courses, an evaluation with the math department was performed to provide an equivalent grade for AP tests scores.

As part of this process, it was also decided that yearly program capacities would be established. These capacities would indicate the minimum number of first-year students a program would enroll each year. In order to establish a baseline capacity for each department, an analysis of the college's total faculty and teaching resources, as well as laboratory spaces, required teaching assistants, and effective classroom sizes was needed for each program . From this analysis, each program's ability to effectively teach and advise a percentage of the college's total number of first-year students was established.

One important note for the total capacity was the requirement to ensure that every engineering student in the first-year cohort was given a guarantee of a matriculated seat in one of the programs in the College of Engineering. The guarantee is not necessarily for a seat in their specific chosen program, but it ensures an opportunity to take classes towards some engineering degree program at NC State University. This guarantee was the premise behind department's meeting their capacity requirements, and the process by which the college would not only assist students moving around the campus but would aid in raising the graduation and retention rates of the first-year cohorts.

Students are informed about the CODA process at New Student Orientation, held in the summer prior to their enrollment. Details of the process are provided in the "Engineering First Year Orientation Handbook". In addition, the college's first-year engineering experience course expounds on the details of the method and encourages students to explore multiple programs in engineering. Since each department's coordinator of advising implements the CODA decisions for their program, students are urged consult advisers for additional information. Furthermore, as the CODA application is an on-line procedure with simple directions, students across campus can also become familiar with the requirements to transfer into the college of engineering. The web site for the CODA program has a GPA comparison chart allowing students to assess their GPA with the average GPA of students who successfully matriculated into a specific program. Students can quickly judge their chances of matriculating into the program of choice or calculating the minimum grades needed to achieve the desired degree.

In the semester in which a student anticipates becoming eligible to matriculate into an engineering program, the student applies for CODA and lists up to three program choices. There are a total of three CODA cycles occurring throughout the academic year: the first at the end of the fall semester, the second at the end of the spring semester, and the third at the end of the summer terms. Admission to programs is based on the students ESS score.

Individual departments assess their applicants and rank their students according to ability. Students who are not accepted to their first desired program are then automatically considered for their subsequent choices. Students who do not attain one of their three choices are given options to CODA into undersubscribed programs within the college. Those students refusing to accept one of these options is moved into a non-matriculated transfer status and assisted with finding appropriate programs on the campus in which they can be successful. The process we designed was believed to address all of our goals we detailed earlier.

As it relates to helping students make progress towards completing a degree, the process was designed to help students make a decision within the first two-years of enrollment. Most students were CODA eligible by the end of the second semester (approximately 65%) and would move into an engineering program or be assisted in finding a program outside of the College of Engineering. In addition, since students were only allowed two attempts at each of the required courses, students would no longer delay making a decision about matriculation in hopes of eventually passing required courses.

While it is too early to tell if this new process influences graduation rates, it is believed that by getting students in programs earlier and making progress towards their degree sooner, they will be more likely to graduate and to graduate sooner. The graduation rate of students who had matriculated into programs was much higher than the overall graduation rate (85% compared to 52%). While we do believe that we may observe a fewer percentage of matriculated students graduating in 6-years under the new process, our graduation rates should rise as we have matriculated more students into degree granting programs; students who would not have previously been able to enter a degree granting program. The increase in graduation rates coupled with the increased number of students matriculating into degree granting engineering programs, we believe, will result in an increase in the number of engineering degrees being conferred.

Finally, the use of departmental capacities would provide a mechanism to help manage access to programs. While we have guaranteed eligible students a seat in an engineering program, they are not guaranteed access to a particular program. As a result, we are able to limit the number of students flowing into departments, diverting students to less populated programs.

### Successes

The CODA process has completed one full, four semester cycle, and we have preliminary information that indicates the process is achieving its stated goals. First and in terms of managing department capacities and size, the new CODA process has managed to hold departments relatively unchanged in terms of their percentage of new students, so the goal of designing a mechanism to control relative program size was achieved. In terms of influence on students, many of the most important metrics are still several years away from being measurable. However, we do have some preliminary data that are encouraging.

First, second, and third year retention rates for the cohorts under the CODA process have increased slightly when compared to the retention rates of previous cohorts (see Table 2). This slight increase is an expected occurrence, and we were not anticipating large shifts in our retention rates. Analysis of enrollment patterns of previous cohort years showed that students persisted up to the third year, even if they had not matriculated into an engineering program.

It is with matriculation rates, however, where the most significant differences are being observed. As of the start of the fall 2014 academic year, almost 75% of the fall 2012 first-year cohort had matriculated into an engineering program, compared to an average of 64.5% from previous cohorts. This is a significant jump in matriculation rates, and one that we believe will influence our 6-year graduation rates and number of engineering degrees earned in subsequent years.

### Weaknesses

While the CODA process is proving to be a viable method for successfully matching large numbers of engineering students with the applicable resources in a college with numerous degree programs, we have encountered several challenges. Challenges have been mostly administrative in nature. The construction of the web-based program needed to incorporate data from a number of sources, including student transfer grades, AP equivalent scores, and on campus semester grades is one example. In addition, due to CODA class completion requirements, departments need information related to student performance in CODA classes to make a decision on candidates.

Some administrative problems have proved difficult to overcome. For instance, students submit their matriculation requests during the semester in which they anticipate becoming eligible to matriculate. However, it is not known if they qualified to matriculate until final grades are posted. Prima facie it would seem this would be an easy challenge to overcome by removing ineligible students from the system once final grades are posted. Yet, ensuring only eligible students are considered for matriculation has proven difficult. Moreover, some students were able to be awarded credit for more than two attempts at the calculus, physics, and chemistry courses by transferring in credit from outside the institution.

Table 2: College of Engineering Retention Rates (Engineering to Engineering)

| Cohort Year | 2nd Year | 3rd Year | 4th Year |
|---|---|---|---|
| 2002 | 86.1% | 71.1% | 61.9% |
| 2003 | 88.2% | 73.4% | 63.2% |
| 2004 | 85.2% | 67.7% | 59.8% |
| 2005 | 86.4% | 73.4% | 63.8% |
| 2006 | 86.3% | 71.9% | 63.7% |
| 2007 | 86.0% | 72.7% | 64.0% |
| 2008 | 89.3% | 74.5% | 62.9% |
| 2009 | 83.7% | 69.2% | 63.2% |
| 2010 | 85.4% | 70.8% | 63.6% |
| 2011 | 88.4% | 73.4% | 64.8% |
| 2012 | 88.6% | 76.5% | ------- |
| 2013 | 91.3% | ------- | ------- |

Other problems, while administrative in nature were easier to overcome. For instance, since each department is autonomous, decisions are made independently of the other programs in the college. This resulted in some students being approved by the 2nd choice department while awaiting a decision from the 1st choice department. This scenario created multiple programs accepting applications simultaneously. We addressed this issue by establishing a process were departments now accept 1st choice students on the first day and 2nd and 3rd choice students on the second day and third day, respectively.

As the program becomes more sophisticated, communication between the departments and the college's administrative director for CODA has become paramount. The requirement for departments to meet its minimum capacity with freshman engineering students has been the single most difficult concept to overcome. The old matriculation process allowed only students with a 2.9 or better to enter a program and continue towards the degree. However, CODA requires that students with a "C" or better have access to a department if their capacity is not been met. Since all eligible students in the College of Engineering are guaranteed an opportunity to matriculate, most programs are reluctant to claim students with lower ESS scores and poor overall grades. This has caused disputes between the college administration and the program directors for each department. Although these students account for less than 10% of the eligible candidates, time spent evaluating each student reduces the opportunity for early notification and changes in class registrations.

## Implications for Practice

A number of implications for administrative practice can be gleaned from the process we detail in this paper. Administrators and faculty at engineering colleges who are considering addressing enrollment management concerns may consider the following.

*Think Critically About the Best Way to Address the Graduation Problem*

As addressed in the introduction of this paper, tremendous attention is being given to both the number of engineers being produced by American universities, as well as the graduation rates of engineering students, and leaders of engineering schools have an obligation to be responsive to calls for greater accountability related to the production of engineers. However, given the complicated nature of persistence patterns in engineering programs, adding more students to the engineering production pipeline may not be the only approach. An alternative solution might be to consider process and system changes that better facilitates students making progress towards a degree.

*Use Data to Illuminate Problems and Solutions*

Administrators would be well served to use data to help address many of the problems facing engineering degree completion. While data have long been used to study retention and graduation trends in engineering in aggregate, greater care and awareness of how data can be used on an individual campus will be useful in assisting administrators in identifying solutions. Indeed, other administrative units on campuses have used data with increasing levels of sophistication with positive results[12]; academicians would be well served to consider adopting some of the same ideas.

*Involve Faculty and Program Leaders*

Aside from the role faculty play as teachers and researchers, faculty play a vital role as it relates to communicating the culture of an organization and prior to any change in process that relates to academic systems, faculty must be involved and consulted in the decision-making process. Our experience has shown that long held opinions and conceptions are difficult to overcome, regardless of the amount and quality of data demonstrating the erroneous nature of those opinions. Astute administrators will recognize the need for ensuring inclusive decision-making processes that foster needed results.

*Seek Support from Campus Partners*

While there are some standalone engineering schools, most engineering colleges reside in larger institutions of higher education and as a result, there are number of campus partners that should be involved in the development and design of new systems and processes. Institutional researchers can play a critical role in assisting in the collection and analysis of data. Information technology managers will be critical allies in the design of new system architectures. Few leaders work in environments where shifts in operations would not have consequences to the broader campus environment.

## Conclusion

As has been stated a number of times in this paper, the issue of graduating more engineers is a complicated problem with a myriad of possible solutions. We have detailed one response undertaken to address a marginalized engineering graduation rate, at one institution. Using data to examine systems and processes, we constructed a new data informed system of matriculating students into programs. While the process has not been without its weaknesses, overall the designed matriculation system is positively influencing the stated goals and objectives.

It is important and relevant to also stress that the shift in matriculation process is but one of several student success initiatives. Other initiatives include the use of intrusive advising, the development of second semester experiential course for academically struggling students, as well as cadre of student and academic support services. Collectively, these programs and the new matriculation process detailed in this paper demonstrate a strong and unwavering commitment to student success.

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