Strategies for Improving Retention in a New Undergraduate Engineering Program

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Abstract

This Complete Evidence-Based Practice paper details steps taken to improve retention of students in a new undergraduate engineering program. The effort to improve retention began in the 2018-19 academic year after strikingly poor results for first-year students that entered the program in the previous year. It was also part of a campus-wide effort to improve the retention of all undergraduate students.

Several changes were made to improve retention, both in terms of retaining students in engineering and, failing that, at least retaining them as students at the college. These include the implementation of a math placement exam, a modification of the engineering curriculum based on best practices used at other engineering programs for improving retention, and the intentional grouping of first-year engineering students in a college success course that was led by an Engineering faculty member and a peer mentor who was a returning engineering student.

All of these engineering-focused efforts were coupled with college-wide efforts at improving retention which included an increase in staffing for the college's academic success/tutoring center, a re-design of the first-year college success course that put increased emphasis on building a sense of community and belonging and narrowed the objectives to aiding students in becoming strategic learners, exploring and reflecting on their skills, interests and abilities and developing tools and strategies for navigating social and professional situations.

The data show that the combined efforts of the engineering program and the college academic success team have resulted in the 1st year to 2nd year retention of engineering students exceeding 80% for the cohorts entering the program from the fall of 2019 through fall of 2022. This level exceeded that of non-engineering students in each of those years except 2022.

Detailed descriptions of each of the efforts are provided along with a discussion of other factors that may have impacted retention rates.

Introduction

The authors' college launched an Engineering program in the 2017-18 academic year. That first-year cohort had 30 students who took classes in Mathematics, Chemistry and Physics so they would be prepared for the full array of Engineering courses which the college would begin offering in the following academic year. Among those 30 students, five did not return for their second semester and only 16 returned for their sophomore year. Four more left after their third semester, and only six of the original 30 (20%) declared Engineering as their major during the second semester of their sophomore year. While all six eventually graduated with bachelor's degrees in engineering, it was clear that the college needed to do better at retaining students who were interested in studying engineering if the program was going to be sustainable.

Work began in earnest in the summer of 2018 to identify the primary reasons why students had left the program and to identify changes needed to address those issues.

The first step was to review the academic records of the students who left the program and compare them to those returning for the fall of 2018. From this, and from discussions with Math and Physics faculty, it was clear that several of the students who were not retained were simply not ready for Calculus I. Indeed, 48% of the prospective engineering students received either a D, an F, or withdrew from Calculus I in their first college semester. Another important observation was that nine of the 14 students who did not return for a second year never took an Engineering course, and of the five who did, it was only a half-unit course (equivalent to 2 semester hours) taught by a member of the Physics faculty. Consequently, students were deciding they did not want to continue studying engineering without ever having taken an engineering course from a degreed engineer.

Actions for Improvement – College-wide Initiatives

While the engineering program was being scrutinized for ways to improve retention, a college-wide effort was also being made to improve retention of first-year students and beyond. The results of that effort should also be considered when analyzing the outcomes for engineering students, and so they are described here.

Increased Staffing for Student Success

In 2018 the college's president appointed a long-time Student Affairs staff member to be the Associate Provost for Student Success and put the division under Academic Affairs. This move was intended to elevate the institution's commitment to student retention and persistence and place services and staff that supported retention under one umbrella. This position worked closely with Enrollment Services and the Institutional Research office to understand who the college's students were, what factors led to better persistence and what supports and services were needed to better support students and families. These collaborative efforts helped understand the demographic profiles of the students, the types of high schools they come from and the financial needs of their families. For example, when examining incoming students interested in engineering, it was found that several of them came from high schools where there were few or no higher-level math courses offered, and these incoming students were not prepared for the college's engineering curriculum. As a result, the college developed a tool to flag these students for conversations during spring/summer orientation programs to emphasize that the college would be supporting the enhancement of their math skills and knowledge. Through a Student Success focused lens, the staff used data to better understand incoming students and utilized that information as a tool to support them rather than to articulate their deficits.

These types of collaborative efforts helped understand the multi-faceted aspects of supporting the four corners of the retention puzzle for each student: affinity, financial fit, academic preparedness and belonging. By working closely with the enrollment team, Student Success staff assessed each student's primary reason for attending the authors' institution and their commitment level. This information helped the staff measure affinity and be aware when they might need to work harder to help students build connections to the institution. In 2018, the institution, like many,

became test-optional and with that decision college staff no longer had access to student's standardized test scores, which had long been used as a strong preparedness and persistence predictor. Student success staff created a scoring system for our admission team to use when reviewing a student's high school transcript and the amount or availability of AP/dual credit courses offered. These scores were then reviewed by the Associate Provost to identify students that might be underprepared or at-risk and those profiles were shared with the student's academic advisor.

Financial fit plays a key role in persistence. Approximately one-third of the students at the authors' institution are Pell grant recipients. Understanding a student/family's financial situation helped Student Success staff work in partnership with the institution's Financial Services office to communicate billing and FAFSA deadlines and to highlight support resources well in advance of those deadlines. Bringing awareness of the strain of financial commitments to faculty/staff helped them better assist students, so that failure to make payments in a timely fashion would not impede student's course registration or starting the semester.

Finally, while engineering may be one point of connection or belonging for students, the authors' institution works to create multiple engagement points for students so that they have stickiness beyond their program of interest. Students' engagement is measured through a student involvement app that uses QR codes and gamifies reward to nudges behavior like attending campus events, workshops and programs [1]. Promoting an understanding of the four corners of student success and persistence helped everyone at the authors' institution have a more wholistic approach to supporting a student's persistence journey.

Redesign of First -Year Experience Course

Like many colleges, the authors' institution requires all incoming students to take a skills-based first-year seminar for .5 units (2 semester-hours). After a decade as the only course required for all students, it had become a catch-all for everything from teaching writing to informing students about the academic integrity policy to learning how to use the library. As a result, its concrete links to retention and persistence were loose. After completing an external program review in 2019-20, the course was revised to focus on four key learning objectives and five core assignments, listed below:

Learning Objectives

1. Students will become self-aware and strategic learners successfully able to navigate the academy and academic obstacles, utilizing resources for support and learning.
2. Students will learn foundational techniques that promote academic excellence, including effective notetaking, time management and study skills.
3. Students will enhance skills and strategies for navigating social and professional situations and managing stress.
4. Students will explore and reflect on their skills, interests, abilities, and aspirations.

Core Assignments

1. Four Reflective Journals at key times during the term: Goal Setting, Student Involvement Fair, Mid-terms, End of Semester
2. Faculty Interview: each student selects a faculty member in area of interest to interview and present to the class
3. Advising Portfolio: review core curriculum and create a list of potential courses for the next term
4. Career Exploration and Alumni Field of Interest Interview: complete a career/interests inventory and conduct a group interview with an alumni who works in a field of potential interest
5. My Improvement/Implementation Plan: review and reflect on the first semester, explore two possible majors and two possible career area of interests and lay out future plan for improvement and exploration

With the revision to the learning outcomes and core assignments it was also decided to make the class instructors a first-year student's academic advisor until they declare a major. This alignment made way to create specific classes for Engineering, Education, Health Sciences and Nursing and allowed for those students to be advised by a faculty member in their intended discipline from the beginning of their curricular experience. This shift also enabled those departments to tailor the core assignments to their specific majors, which helped first-year students build a better understanding of both the curricular and career possibilities within their major.

Learning Center

The authors' campus has a peer-based tutoring program managed through a Learning Center. Two types of tutoring are available: 1:1 tutoring and study groups. The latter are led by a student who had success in the college's most challenging courses, and that student-tutor works collaboratively with the faculty member to run a weekly study group for the course. For engineering students, the most relevant of these are the introductory Chemistry course, and the two introductory Physics courses. The study group leader also attends the lab for the course helping them be able to assist not only with assignments but also lab work. The Learning Center staff works closely with faculty to build referrals to tutors and study groups and offer incentives like 5 extra points on an assignment for seeing a tutor or attending the study group. Oftentimes before exams, the faculty member will work with the study group leader to provide practice problem sets for sessions. Tutor and study groups session notes about individual students can be shared with faculty members so they are aware of areas where a student or students may be seeking clarity or having difficulty. These types of collaborative efforts between faculty and the Learning Center staff help keep communication channels open and allow for direct and timely interventions when needed.

Actions for Improvement – Engineering-specific Initiatives

Math Placement Test

After witnessing so many students struggle in Calculus I, the Math faculty felt it was important to implement a Math Placement Test to ensure that students began their math studies in a course in which they were likely to succeed. After examining options, the faculty chose an on-line test which is available from the Mathematical Association of America [2].

Because it is available on-line, incoming first-year students were able to take the test before their course schedules for their fall semester were created. The test consists of 40 questions. The first 24 questions test the student's basic high school math knowledge, including algebra, a bit of geometry, graphs of linear equations, the basics of logarithms and their properties, the basics of right-triangle trigonometry, and function notation. If the student does well on these questions, they are placed out of Math 101 (Basic Math for Science); otherwise, that is where the student will start. The final 16 questions are aimed at students seeking to place out of pre-Calculus. The Math faculty set 29 as the minimum number of questions a student had to correctly answer in order to be placed into Calculus I. Students whose scores were above that needed to skip Math 101, but below that required for Calculus I were placed into a Pre-Calculus class.

Recently, [3] published the results of an analysis of how the combination of a student's first college math course and grade in that course impacted the probability of graduating with an engineering degree and found that students who got an A in pre-Calculus had a higher probability of completing their engineering degree (69%) than students who started in Calculus and received a C in that class (62%). This data reinforced the decision to use the placement test for incoming students.

Curriculum Changes

The college's new director of the engineering program arrived in the summer of 2018 and was asked to review the literature available on improving retention in engineering to identify best practices. One of the first papers the director read described the impact observed at the University of Colorado-Boulder (CU-Boulder) of having a "hands-on, team-based, projects-oriented" course for first year engineering students [4]. The CU-Boulder experience showed a 10-percentage point increase in the retention of students in engineering after their seventh college semester for students who took a hands-on, project-based engineering course in their first year. The paper also referenced experiences at other institutions with implementation of first-year engineering courses that also saw a marked improvement in retention.

During that same summer, the director reviewed textbooks to use in the program's initial Engineering Design course, scheduled to be offered in the fall 2018 semester to the returning engineering students. One of the books [5] was written by faculty from Harvey Mudd College's engineering program. Like the authors' college's program, Harvey Mudd only offers a multi-disciplinary degree in engineering, so the book seemed like a good fit. The textbook was created for Harvey Mudd's design course that is taught to first-year engineering students. While controversial when it was first created, [6] documented that the experience at Harvey Mudd has shown that first-year engineering students can, indeed, carry out meaningful engineering design

projects despite their lack of detailed engineering knowledge. This reinforced the message from the CU-Boulder paper, and, while it was too late to change the 2018-19 academic year schedule, a decision was made to modify the program's Introduction to Engineering and Design course so that it would not need Calculus I nor introductory Physics courses as prerequisites. The course was also reclassified as a 100-level course, ENGR 190. It was moved from the fall semester of students' sophomore year to the winter semester of their first year. This would give students a semester to improve their math skills before diving into their first design course. These modifications were in place for the 2019-20 academic year.

In addition to the reclassification of ENGR 190, the program's ENGR 101 course titled Exploring Engineering was moved from the winter semester to the fall semester, starting in fall 2019, so that first year students could also take an engineering course in their first semester in college. ENGR 101 is a half-unit course with no prerequisites that provides an overview of the various fields of engineering while also giving students a sample of the lab activities which are carried out in 200 and 300 level engineering courses and includes a tour of a local manufacturing facility.

Since the Math Placement Tests had shown that 77% of the incoming class of 2022 cohort (i.e., those first-year students starting in the fall of 2018) were not ready to take Calculus I, an alternative curriculum path was developed for those students. Since both an introductory level Computer Science course and an introductory Chemistry course were required for the bachelor's degree in Engineering and neither course required Calculus as a pre- or co-requisite, any first-year student who expressed interest in engineering and did not place into Calculus was directed to register for the Chemistry and Computer Science courses instead of the first two Physics courses which students that were ready for Calculus took. Those who began the Math sequence in either MAT 101 or Pre-Calculus, would take the Physics and Calculus sequence in their sophomore year. The two curriculum pathways are displayed in Figures 1 & 2.

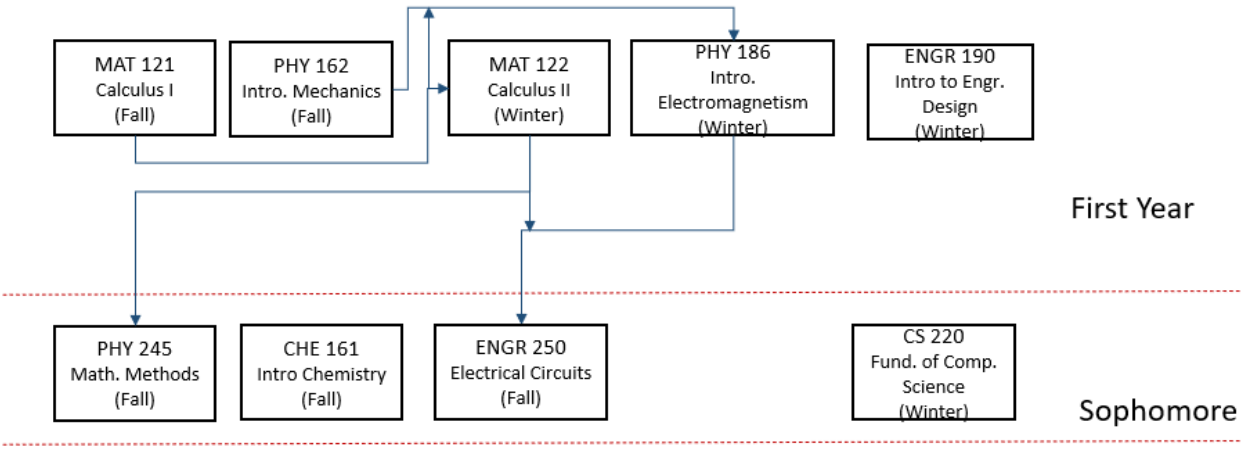

Figure 1 - Engineering Curriculum Pathways for First Two Years for Students Ready for Calculus I. Lines Indicate Pre-Requisites. Engineering Electives and Humanities Courses Not Shown.

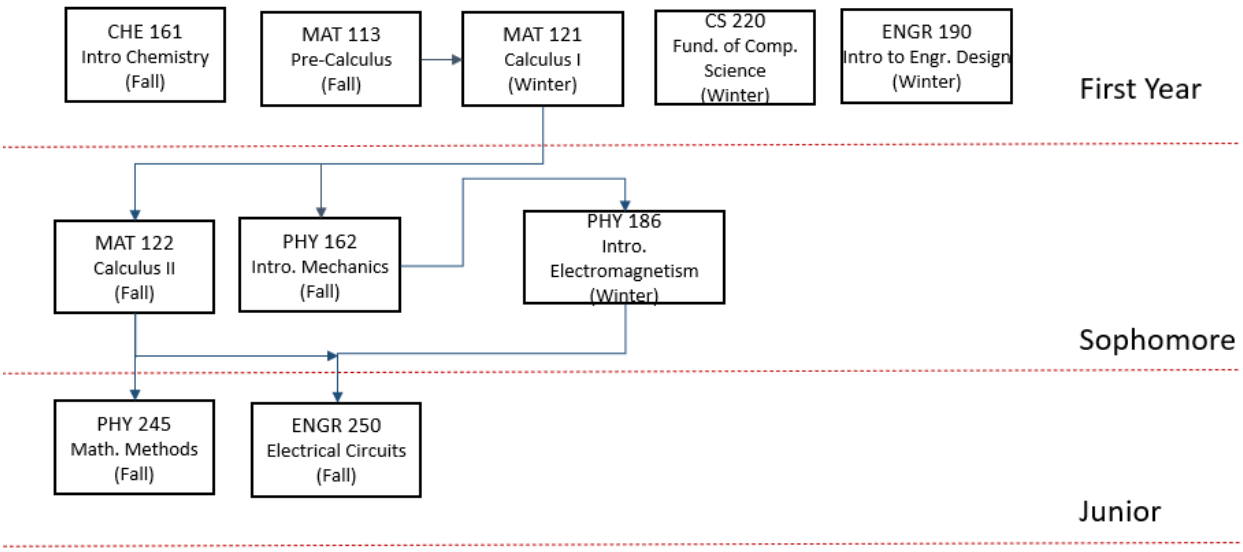

Figure 2 – Engineering Curriculum Pathways for First Three Years for Those Not Ready for Calculus I. Lines Indicate Pre-Requisites. Engineering Electives and Humanities Courses Not Shown.

Community Building

As described previously, beginning with the fall of 2020 a new strategy was implemented in which all incoming first-year students who expressed interest in studying engineering were grouped together in a FY 101 course section taught by a member of the Engineering faculty together with a "peer mentor" who was an Engineering major with junior class standing. The motivation for this was two-fold: first, it would help build an "esprit de corps" among this cohort of engineering students and, second, it would allow them to be advised by an Engineering professor from the start of their academic careers. The latter was important because the engineering curriculum is heavy with courses, and students must carefully select those courses to complete their degrees in four years.

By grouping the incoming engineering students together, they would immediately have a group of friends who could study together and encourage each other so that they did not feel they were on their own in a college in which more than 90% of the students are not studying engineering.

Separately, the Engineering department requested a federal work study-funded position for a second engineering student who would serve as a faculty assistant in ENGR 101 and 190. This would be a second experienced engineering student that the first-year students would get to know and could turn to for advice. McPherson [7] in 2022 reviewed efforts by other engineering programs that used peer mentors in first-year engineering courses to enhance student learning and retention. McPherson further reported an increase in first semester to second semester retention to 91% at Anderson University compared to values ranging from 52 to 83% over the previous three years.

Other Factors Which May Have Impacted Retention Rates

As is common in assessments of the impact of education strategy changes, it was not possible to keep all inputs constant while the changes were made. Consequently, other factors could, and most likely did, impact retention rates. The most important of these are described here.

Each year, the students were different, and the level of preparedness of those students to tackle an engineering curriculum was different. It is postulated that the results from the Math Placement Tests serve as a reasonable surrogate for incoming student preparation. Those data are summarized in Figure 3. They indicate that the quality of the incoming students did improve over the first three years in which the placement tests were used, but then dropped off, and the percentage of students who started in the fall of 2022 prepared for Calculus I was less than the percentage of students who entered in fall 2018. A logical explanation for this trend is that the move to on-line classes in high schools due to the Covid-19 pandemic significantly impacted the math preparedness of the students. According to the organization that administers the ACT, the percentage of students who exceeded the college preparedness benchmark on the math section of the ACT fell from 39% in 2019 to 31% in 2022 [8]. The authors' college was not immune to this trend.

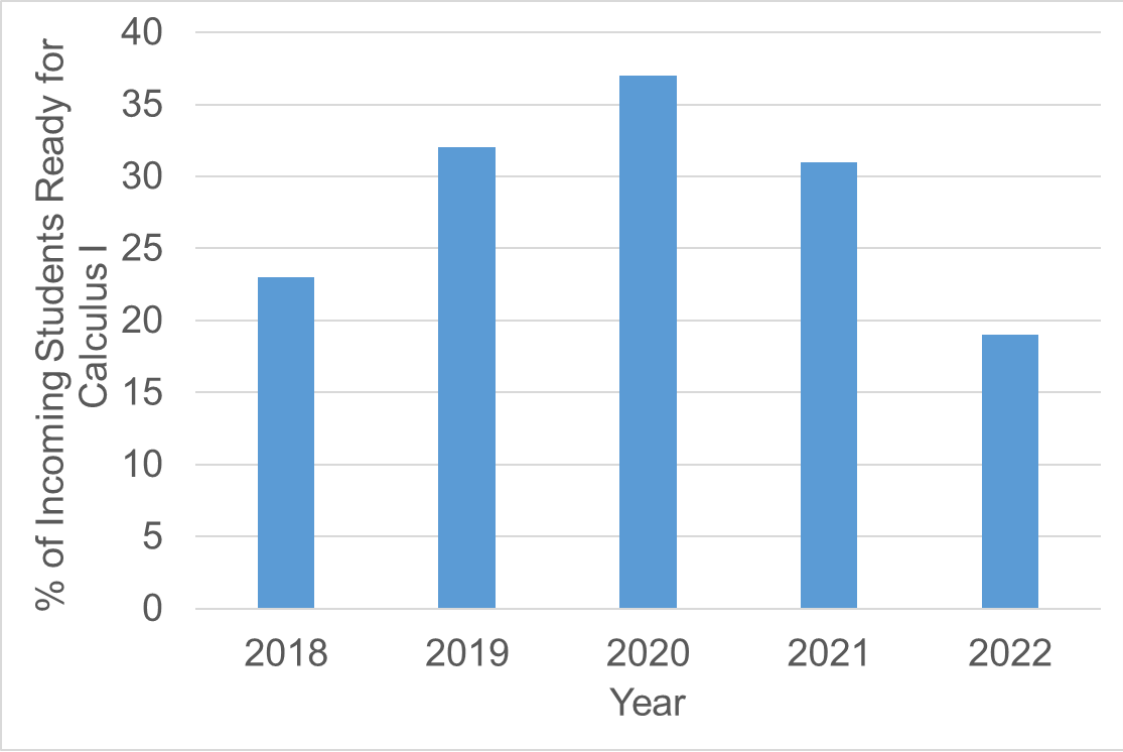

Figure 3 – Results from Math Placement Tests for Incoming Engineering Class Cohorts.

The Covid-19 pandemic hit during the winter 2020 semester. Classes at the institution moved on-line mid-semester, and students were allowed to take all classes that semester on a pass-fail basis if they wished. As is described in the Results section, the retention rate of both engineering students and all first-year students who started at the college in the fall of 2019 increased

significantly. It is reasonable to conclude that at least some of this increase was due to the more lenient grading policy in place during those students' second semester. Among all the students at the college there was a larger decrease in retention from their 3rd to their 5th semester than seen in the previous two cohorts, indicating that once grading returned to normal standards some of the retention gains were lost. However, the retention of engineering students remained high throughout their four years, so it is argued that Covid-19 did not have a meaningful impact on the engineering retention rates.

Just as the students change each year, the faculty also changes. While the Engineering program director, who taught the program's courses related to Mechanical Engineering and Design was with the program from fall 2018 onward, he did not have experience teaching those courses before starting at the college. Consequently, it is reasonable to assume that his teaching became more effective with experience. For the program's courses related to Electrical and Computer Engineering, there was a change in faculty after the 2018-19 school year, and the new instructor was also recruited from industry and therefore was new to teaching these courses. Hence, some of the improvement in engineering student retention is likely due to the increased effectiveness of teaching in engineering courses as the faculty became more experienced.

Results

Because efforts were being made to improve the retention of all the of the college's students while changes were also made in the engineering program, the improvement in the college's overall retention rate will be reported along with that of engineering students.

Since students at the college are not asked to declare a major until the winter semester of their sophomore year, one important question that had to be answered before any analysis of student retention was done was how to identify a first-year engineering student from all other first-year students. It was agreed by a faculty committee responsible for evaluating the effectiveness of new programs that any incoming student who stated at one of the college orientation sessions held in May or June that they were interested in pursuing an engineering degree would be counted as a first-year engineering student regardless of what courses they elected to take in their fall semester. In addition, any student who expressed interest in Engineering to the program director and who took at least one Engineering course and two required cognate courses in their first year was also counted as a first-year engineering student. The students were then tracked on a spreadsheet maintained by the Engineering program director for the remainder of their time at the college. The spreadsheet noted whether the student was still enrolled at the college in November and in April of each year and whether they had declared engineering as their major or selected a different major. Lastly, there was a designation of whether the student had completed their degree or not. An example of the spreadsheet, without the lines for tracking each student, for the incoming cohort of fall 2017 is shown in Table 1. The use of the term LEAP in the spreadsheet refers to the college orientation sessions.

Table 1 – Example of the spreadsheet used for tracking retention of a cohort of engineering students.

Cohort entry: 2017								
Date data is measured	Nov-17	Apr-18	Nov-18	Apr-19	Nov-19	Apr-20	Nov-20	May-21
Source of data	LEAP interest	LEAP interest minus attrition	LEAP interest minus attrition	Declared major	Declared major	Declared major	Declared major	Graduate
Remaining at College	30	25	16	12	12	12	13	13
Declared Engineering (LEAP interest)				5	5	5	5	5
Declared Engineering (no LEAP interest)				1	1	1	2	2
Declared non-Engineering major				6	6	6	6	6
Left College	0	5	9	4	0	0	0	0
ENGR major (LEAP and non-LEAP interest)				6	6	6	7	7

As shown in Table 1, 16 of the incoming 30 engineering students returned to the college for their sophomore year. Therefore, the first-year to second-year retention rate was 53.3%. This compared to a rate of 77.0% for the 313 non-engineering students who were part of the fall 2017 incoming cohort.

It can also be seen that the first-year to third-year retention in the engineering program was 6 of 30 or 20%, while an additional six students stayed at the college to pursue other majors. Consequently, the college retention rate of the incoming engineering students was 40%. This compares to a rate of 68.7% for non-engineering students in the same cohort.

In the fourth year, one student who originally set out to obtain a Physics degree decided to switch to an Engineering degree, so the number of Engineering majors increased by one. However, this student is not counted in the retention data reported in this paper.

The retention data for the full (engineering and non-engineering) cohort of first-year students who enrolled in the fall of 2017 are compared to that of only the engineering students in Table 2.

Table 2 – Comparison of College Retention Data for Engineering and All Fall 2017 First-Year Students

	Engineering Only	Non-Engineering	Total Cohort
Fall 2017 Enrollment	30	313	343
Fall 2018 Enrollment	16	241	257
Fall 2019 Enrollment	12	215	227
Fall 2020 Enrollment	12	197	209
1st to 2nd Fall Retention	53.3%	77.0%	74.9%
1st to 3rd Fall Retention	40.0%	68.7%	66.2%
1st to 4th Fall Retention	40.0%	62.9%	60.9%

The cohort entering the engineering program in fall 2018 were the first who had the Math Placement Test to determine their initial courses. The tracking data shown in Table 3 indicate this may have had a measurable impact on retention as three quarters of the first-year engineering students returned for their sophomore year, and their retention rate was only 4 percentage points below that of all non-engineering students in the cohort. However, there was a significant decline in retention of the engineering students in years 3 and 4 compared to their non-engineering cohort. In addition, only four of the original 29 students in the cohort completed an engineering degree (13.8%). Therefore, while the use of the Math Placement Test may have been helpful in overall retention, perhaps by steering students with weaker math skills to non-engineering majors, it was not sufficient to provide improvement in 1st year to 4th year retention in engineering.

Table 3 – Comparison of College Retention Data for Engineering and All Fall 2018 First-Year Students

	Engineering Only	Non-Engineering	Total Cohort
Fall 2018 Enrollment	29	327	356
Fall 2019 Enrollment	22	258	280
Fall 2020 Enrollment	17	237	254
Fall 2021 Enrollment	16	223	233
1st to 2nd Fall Retention	75.9%	78.9%	78.7%
1st to 3rd Fall Retention	58.6%	72.5%	71.3%
1st to 4th Fall Retention	55.2%	68.2%	65.4%

The fall 2019 cohort bore the brunt of the Covid pandemic, but those students turned out to be highly successful in terms of retention in engineering. Fall 2019 was also when significant

changes were made to the Engineering curriculum to allow first-year students to take engineering courses in the fall and winter semesters of their first year, and it was the first time incoming engineering students were grouped into a FY 101 section with an Engineering professor as their instructor and academic advisor. Table 4 shows the data for both engineering and non-engineering members of that cohort. As the data in Table 4 show, the retention rate of the incoming engineering students exceeded that of their non-engineering classmates in each year. In addition, 12 of the 19 members (63.2%) of the cohort declared a major in Engineering and 11 (57.9%) either graduated in May 2023 or returned for a fifth year to complete their degree. Based on these data, it appears that the changes made to the Engineering program and grouping students in FY 101 were more impactful than the changes made to improve college-wide retention.

Table 4 – Comparison of College Retention Data for Engineering and All Fall 2019 First-Year Students

	Engineering Only	Non-Engineering	Total Cohort
Fall 2019 Enrollment	19	270	289
Fall 2020 Enrollment	18	226	244
Fall 2021 Enrollment	17	198	215
Fall 2022 Enrollment	16	174	190
1st to 2nd Fall Retention	94.7%	83.7%	84.4%
1st to 3rd Fall Retention	89.5%	73.3%	74.4%
1st to 4th Fall Retention	84.2%	64.4%	65.7%

While the cohorts which entered in the fall of 2020, 2021, and 2022 have yet to complete their four years of college, the data from those classes also show an improvement in retention of engineering students (see Tables 5, 6, and 7). For the first two cohorts, the engineering students have exceeded the retention rates of their non-engineering classmates, and for the 2022 cohort the engineering students were only 1.4 percentage points below their classmates in retention rate.

While the two-fold increase in 1st to 4th year college retention of the incoming engineering students from 40% to greater than 80% shows the positive impact of the combination of the strategies implemented, examining the retention of engineering students into engineering degrees shows an even greater change. As displayed in Figure 4, the retention of incoming engineering students into engineering majors has grown from 20% in the cohort of 2017 to 73% in the cohort of 2021. This is more than a three-fold increase.

Table 5 – Comparison of College Retention Data for Engineering and All Fall 2020 First-Year Students

	Engineering Only	Non-Engineering	Total Cohort
Fall 2020 Enrollment	17	253	270
Fall 2021 Enrollment	15	202	217
Fall 2022 Enrollment	15	178	193
Fall 2023 Enrollment	15	171	186 (inc. 8 early grads)
1st to 2nd Fall Retention	88.2%	79.8%	80.4%
1st to 3rd Fall Retention	88.2%	70.4%	71.5%
1st to 4th Fall Retention	88.2%	67.6%	68.9%

Table 6 – Comparison of College Retention Data for Engineering and All Fall 2021 First-Year Students

	Engineering Only	Non-Engineering	Total Cohort
Fall 2021 Enrollment	11	265	276
Fall 2022 Enrollment	9	206	215
Fall 2023 Enrollment	9	195	204
1st to 2nd Fall Retention	81.8%	77.7%	77.9%
1st to 3rd Fall Retention	81.8%	73.6%	73.9%

Table 7 – Comparison of College Retention Data for Engineering and All Fall 2022 1st-Year Students

	Engineering Only	Non-Engineering	Total Cohort
Fall 2022 Enrollment	22	258	280
Fall 2023 Enrollment	18	215	233
1st to 2nd Fall Retention	81.8%	83.3%	83.2%

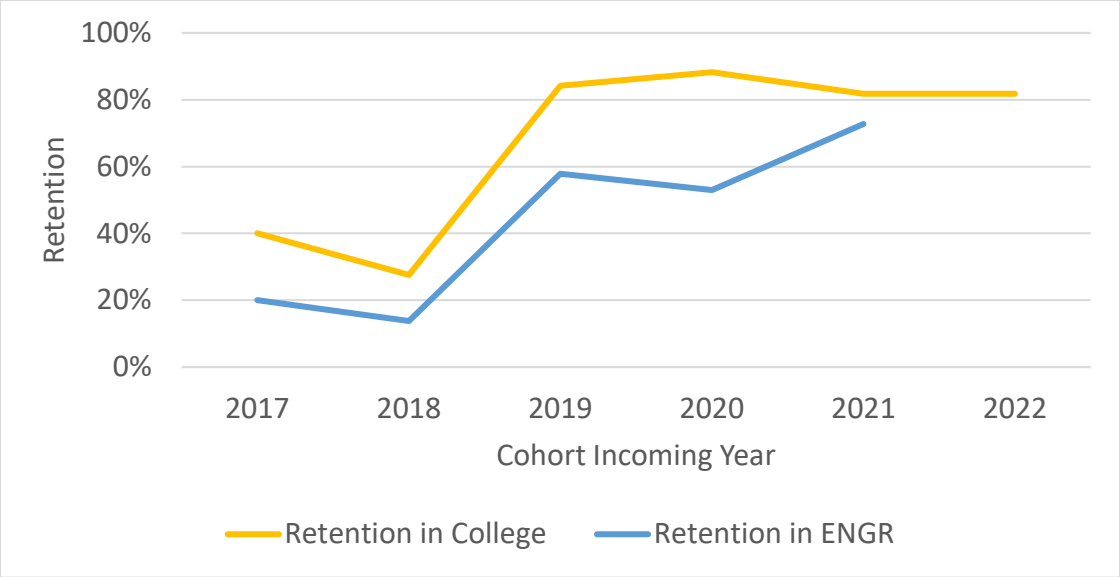

Figure 4 – Four-Year Retention of Incoming Engineering Students at the College and as Engineering Majors

Conclusions

The data show that the combined efforts of the engineering program and the college academic success team from 2018 through 2023 have resulted in the first to fourth year retention of engineering students growing from 40% to greater than 80% based on students remaining enrolled at the college and from 20% to 58% based on students remaining in Engineering. The greater than 80% level compares well with the college-wide first to fourth year retention rate which has grown from 61% to 69% over the same period.

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