Advances in Engineering Education

2021: VOLUME 9 ISSUE 4

Persistence of Students who Begin Engineering Programs in Precalculus

SHARON A. JONES
University of Washington Bothell

CAITLIN CAIRNCROSS
Oregon Health Sciences University

TAMMY VANDEGRIFT
University of Portland

JULIE KALNIN
University of Portland

ABSTRACT

We developed various retention programs to support first-year engineering students who start behind their cohort in terms of the Calculus sequence. We focused on increasing the persistence of these students via counseling along with opportunities for students to regain cohort status. Although the retention program evolved, we retained enough of the main elements to a) develop a sustainable retention program, b) draw generalizable conclusions, and c) identify areas for more study. Overall, the assessment data supports our initial hypothesis that catching up academically with one's cohort is an important part of helping students to persist in an engineering major.

Key words: persistence, engineering pathways, first-year experience

RATIONALE FOR THE RETENTION PROGRAM

According to American Society for Engineering Education (ASEE 2015), approximately 51% of students at private universities who enrolled as first-year students in engineering graduated with that degree within four years and 67% within five years. The graduation rate is even lower at public universities (ASEE 2015). Based on ASEE data, along with other published studies, most of the attrition among engineering students occurs within their first two years in college (ASEE 2009). Private institutions have a 1st to 3rd semester engineering student retention rate of approximately 85% and a 1st to 5th semester retention rate of 75% (ASEE 2015). Similar data show worse results for public

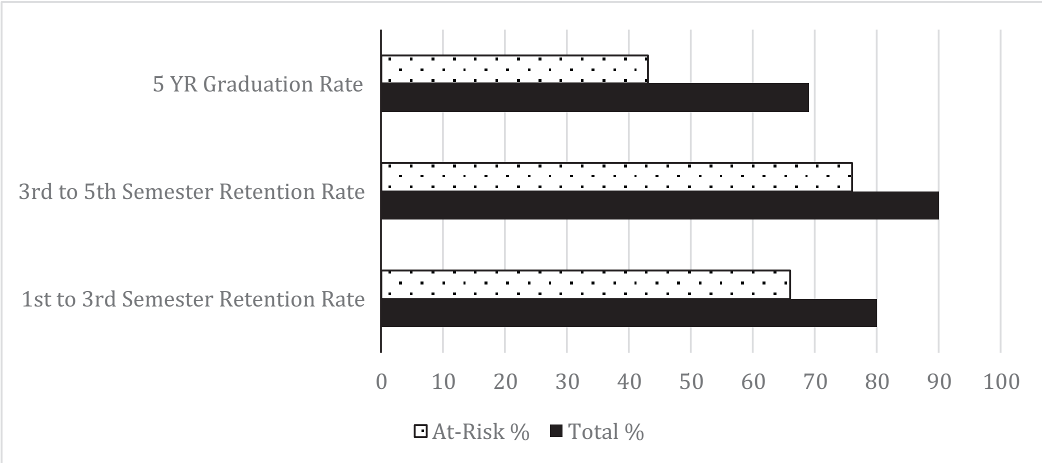

Figure 1. Baseline Data for Engineering Students: Retention & Graduation Data Averaged for Fall 2011 & Fall 2012 First-Year Student Cohorts.

institutions (ASEE 2015). In this project, our main goal was to address this "leaky pipeline" challenge in terms of the cohort of students who start engineering programs in Precalculus. Improving persistence for first-year students should reduce the "leaks" in the pipeline and result in a greater number of engineering graduates entering the nation's scientific workforce.

The work took place at a mid-sized, private university with approximately 3,700 undergraduate students, between 600 and 700 of whom are in the School of Engineering. Out of an entering class of approximately 200 first-time first-year students (FTFs), 25 to 50 (or up to 25%) are not ready to start in Calculus 1 based on a required placement exam administered by May 1st of the year they plan to start at the University. We used F2011 to F2012 as the baseline period because this Calculus 1 readiness test was first put into effect for F2011 and our retention program for the student cohort that began college in Precalculus started in F2013. As shown in Figure 1, the baseline (F2011–F2012) average 1st to 3rd semester all-student retention rate within engineering is 80%. However, students who start their engineering degrees in Precalculus have a baseline (F2011–F2012) average 1st to 3rd semester retention rate of 66%. The baseline (F2011–F2012) average 4-year graduation rates for the total vs the Precalculus cohort are 57% and 34% respectively. Similarly, the baseline (F2011–F2012) average 5-year graduation rates for the total and Precalculus cohort are 69% and 43% respectively. The School-specific data align with several national studies that show that program momentum matters in terms of graduation rates (Attewell 2016; Belfield 2016; Denley 2016).

We hypothesized that the Precalculus cohort of students 1) is self-conscious as compared to their peers; 2) grows more doubtful about their abilities over time; 2) is unsure of their future degree path since they started behind; 3) does not have a sense of what the work entails or the purpose for the curriculum; 3) and/or faces extra financial costs to graduate which may be prohibitive at a private institution where financial aid is only guaranteed for eight semesters.

Over 90% of the University's undergraduate students receive up to eight semesters of institutional financial aid. As a result, our engineering degrees are designed as four-year curricula that start with Calculus 1 (a corequisite with General Physics 1) in the fall of the first year. In addition, most engineering courses are only offered once in an academic year. Another challenge is that while the University is on a semester cycle, most of the state institutions in the surrounding area are on a quarter cycle. As such, students find it difficult to locate compatible summer courses to make up deficiencies. In other words, this University's students are at a significant financial disadvantage if they require more than four years to complete a degree and we speculated that some students who start as engineering majors may switch majors early in their college career to ensure on-time graduation. In addition to financial ability, self-efficacy (Bandura, 1977, 1994) may be affected when failing a placement test for the first Calculus course needed to pursue an engineering degree. A loss in self-efficacy may lead to less motivation to persist in an engineering program, and combined with financial challenges, may exacerbate engineering attrition.

Based on 2017 data (ASEE), six of the top 50 four-year engineering schools in terms of number of graduates are private institutions. The 2018 ranking of engineering programs shows that 38 of the top 50 engineering schools without a doctorate are private institutions, as are 24 of the top 50 engineering schools with a doctorate. In other words, while not the majority, a considerable number of engineering students in the US currently attend private institutions where the financial challenges may be similar as those at this University. In addition, a significant portion of engineering schools are likely to have a nontrivial number of students who cannot start in Calculus 1. While our study focused on students who start in Precalculus, there are also many engineering majors who fall behind their cohort in terms of STEM courses due to withdrawals and less than adequate grades, both of which may contribute to a loss of self-efficacy (Bandura, 1977, 1994). As such, an intentional study of how to help engineering students who are behind their cohort persist to graduation may address retention issues beyond our own institution.

THEORETICAL FOUNDATION FOR THE RETENTION PROGRAM FOR THE PRECALCULUS COHORT

In 2013, we were awarded a National Science Foundation (NSF) Graduate 10K+ Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) grant to assist with increasing the retention of engineering students who are behind their cohort academically (Jones et. al. 2014, 2015, 2016, 2017). With the NSF grant, we developed a retention program with a focus on first- and second-year students within engineering (in this paper, we only focus on the Precalculus first-year students). We used Tinto's classic model of retention along with his updated work on persistence for the initial program design. Tinto's model suggests both academic and social integration are needed for students to be retained at an institution.

While Tinto's model was not developed for engineering students specifically, several aspects of the model are compelling. Tinto's (1975, 1987, 1993) model theorizes that while a student's individual and family characteristics along with prior schooling contribute to his/her initial goals when entering college, these initial goals are reshaped by how well integrated (socially and academically) the student is on campus. Tinto (1975, 1987, 1993) argues that a student's decision to persist in an academic program can be predicted by the student's response to the transition process and the subsequent degree of academic integration and social integration in the first couple of years on campus. Nora et al. (1993) defines an academically-integrated student as one who has developed a strong affiliation with the college's academic environment and a socially-integrated student as one who has developed a strong affiliation with the synergistic social activities at a particular college campus.

Tinto (2015, 2) notes that "the impact of student college experiences on persistence can be understood as the outcome of the interaction among student goals, self-efficacy, sense of belonging, and perceived worth or relevance of the curriculum." Self-efficacy is prominent in the work by Tinto regarding persistence. Several other studies show that undergraduate engineering students' academic achievement and persistence can be predicted by their academic self-efficacy (Lent et. al. (2013); Hsieh et. al. 2012; Concannon et. al. 2010; etc.). As noted by Bandura (1977, 1994), academic self-efficacy can be defined as one's belief in the ability to learn and succeed and this belief is developed from one's experiences.

The work by Tinto and other scholars suggests that at-risk engineering students may not be fully integrated due to initial mathematics deficiencies that segregate them academically, and perhaps socially, from the more general cohort (Cairncross et. al. 2015). Experiences such as this could lead to stereotype threat and related self-efficacy issues (McIntyre et. al. 2003; Steele 1999). Creating conditions that acknowledge and address challenges to self-efficacy became a cornerstone of this University's retention program.

THE RETENTION PROGRAM FOR THE PRECALCULUS COHORT

We originally designed the retention program to primarily help the Precalculus cohort catch up academically with the traditional cohort that is on track to graduate in four or five years. In other words, we initially focused the retention program on improving academic integration. We used the hypothesis that at an institution such as this University (private with a high financial need student body and financial aid limited to eight semesters), persistence in the major is primarily driven by the perceived ability to graduate in four years. (This University typically reports a 5-year graduation rate since there is a sizeable population of ROTC students who graduate five years from when they entered the University, along with an optional co-operative program that results in a 5-year degree plan. That said, the average time to graduation for an engineering student at this University is four years.)

The main retention program elements for the Precalculus cohort were a) intentional counseling about how to design a feasible degree plan that includes catching up to the main cohort by Fall sophomore year, and b) an on-campus academic summer bridge that includes the course students need to catch up by Fall sophomore year. In addition to helping students to catch up academically, we designed all the Program elements to build community and belonging among the Precalculus cohort.

The intentional counseling initially occurred with a counselor actively inviting students to meet with her during the academic year. The students who received the invite were entering first-year students who did not pass the Calculus 1 readiness test, as well as first-year students who fell behind in the first semester, and second-year students who are behind their cohort by at least one STEM course. Students could not be on academic probation. Although participation began as optional, we included the incentive that if you actively participated, you would be considered for funding for STEM courses that following summer. The counseling included one-on-one discussions and group workshops about degree planning, study habits, time management, test-taking, effective writing, overcoming failure, and growth mindset. The counselor also hosted monthly student socials to build community, as well as an alumni dinner for sophomore students with informal conversations about careers. Participants self-reported that while they valued the counseling, it was very difficult to be motivated to participate. As such, in 2016, we converted the counseling portion to a required one-credit course in the students' first Fall semester on campus.

We initially designed the on-campus summer bridge as primarily an academic bridge that started out aimed at entering first-year students who did not pass the Calculus 1 readiness test and opted to spend six weeks in the summer before college started completing Precalculus and a core curriculum course. After learning more about the barriers to the students who primarily needed the Bridge, we changed the timing of the Bridge to the summer between the first year and the sophomore year to also include those first-year students who fell behind academically. The redesigned summer bridge included Calculus 2 and a core curriculum class. Once again, all students had to be in good academic standing and those invited must have actively participated in the counseling program. Participation in the summer bridge was optional. Students had to pay for meals, insurance, books, and a $150 deposit (deposit implemented in 2016). The University, via the grant, paid for faculty stipends, student housing, a 20-hours per week peer mentor, and

Table 1. Retention Program Components Across Precalculus FTFs.

Fall FTF Cohort	Program Participation via Intentional Counseling	Optional On-campus Academic Catch-up Summer Bridge
2013	Optional with Counselor	N/A
2014	Optional with Counselor	Pre-First year (Precalculus) & Pre-Sophomore Year (Calculus 2)
2015	Optional with Counselor & Pre-First Year 2-day Session	Pre-Sophomore Year (Calculus 2)
2016	Required with Counselor via EGR115 (Fall)	Pre-Sophomore Year (Calculus 2)
2017	Required with Counselor via EGR115 (Fall)	N/A

transportation for field trips. Team building exercises and group activities included trips to the zoo, the beach, and a street fair, day-hikes, a Portland boat tour, bowling, and game/movie nights. A professional integration component included weekly site visits to local engineering companies, a one-day externship with an engineer in each student's interest area, and workshops on resume and cover letter writing.

Table 1 shows the main program elements in the Retention Program and how they changed across the five cohorts while Table 2 shows student participation and catch up rates. As described above, we implemented several program changes over the five years based on lessons learned from the ongoing assessments. Other changes during the study period include the Math department's revision of the Calculus 1 Readiness score for the F2015 cohort, a new counselor in October 2017, and a temporary stoppage of the academic summer bridge in 2018 due to uncertainty regarding resources.

We used performance on the Calculus 1 readiness exam to select the cohort for this study. In terms of the cohort demographics, 33% to 55% of the Precalculus cohorts (2013–2017) identify as non-White and/or Hispanic, 17% to 38% are first generation college students, and 17% to 25% are female. For the subset of Precalculus cohort students who participated in the Retention Program, between 25% to

Table 2. Participation in the Precalculus Retention Program.

Cohort	Fall 2013	Fall 2014	Fall 2015	Fall 2016	Fall 2017
Total 1st year students	174	238	218	207	199
Eligible 1st year students (Precalculus starts)	28	42	48	38	25
Eligibility rate	16%	18%	22%	18%	13%
Total participants in one or more programming activities	16	23	22	38	25
Participation rate	57%	55%	46%	100%	100%
% Precalculus starts caught up by start of sophomore year with a bridge	N/A	36%	23%	24%	N/A
% Precalculus starts caught up by start of sophomore year w/o bridge	18%	10%	6%	11%	32%
% Precalculus starts caught up by start of sophomore year	18%	45%	29%	34%	32%

Table 3. FTF Engineering Demographics.

Cohort	Fall 2013	Fall 2014	Fall 2015	Fall 2016	Fall 2017
Male – Total	77%	75%	70%	68%	76%
Female – Total	23%	25%	30%	32%	24%
White – Total	57%	–	–	55%	50%
Non White & Hispanic - Total	34%	–	–	38%	49%
FGEN - Total	–	5%	6%	18%	17%
Male – Precalculus starts	82%	83%	83%	76%	75%
Female – Precalculus starts	18%	17%	17%	24%	25%
White – Precalculus starts	43%	36%	40%	62%	75%
Non White & Hispanic – Precalculus starts calc starts	36%	55%	33%	38%	25%
FGEN – Precalculus starts	18%	21%	25%	38%	17%
Male – Precalculus start participants	81%	78%	73%	76%	75%
Female – Precalculus start participants	19%	22%	27%	24%	25%
White – Precalculus start participants	50%	32%	40%	62%	75%
Non White & Hispanic – Precalculus starts participants	50%	68%	60%	38%	25%
FGEN – Precalculus start participants	36%	9%	30%	38%	17%

68% identify as Non-White and/or Hispanic, 9% to 38% are first generation college students, and 19% to 27% are female. Table 3 shows the comparison to the overall engineering student population that has similar characteristics with the exception that less females appear to be starting in Precalculus.

In terms of incoming academic metrics (Table 4), the sample means for Math SAT and Verbal SAT scores for the Precalculus cohorts (2013–2016) are lower than those for the all-student cohorts (statistically significant at the 95% confidence interval) though the ranges are similar. The mean Math SAT and Verbal SAT scores for the Precalculus cohort range from 571 to 584 and from 542 to 571 respectfully. We did not collect formal data about high school course offerings. We also did not collect formal data about socioeconomic status of students, however, summer scholarship funds were available to students with need-based financial aid and over 90% of students qualified for those funds.

The research team intentionally made the program open to all students who started in Precalculus so there are no matched samples in the study design. However, for the cohorts prior to 2016 (when the Program became required), we compared retention rates and graduation rates for participants versus non-participants from the Precalculus cohorts as shown in Table 6.

We conducted quantitative assessments that include comparisons of retention rates and graduation rates for the Precalculus cohort versus the overall engineering student population, along with comparisons of similar indicators for participants versus non-participants in the Program, and the impact of the academic summer bridge. We also used logit regression models to evaluate the impact to retention and graduation rates of both catching up by Fall sophomore year and completing

Table 4. FTF Precollege Academic Metrics.

	Baseline Fall 2011 & 2012*	Fall 2013	Fall 2014	Fall 2015**	Fall 2016	Fall 2017
Average Math SAT – all students	645	651	647	637	641	656
Median Math SAT– all students	–	650	650	640	640	–
Math SAT Range – all students	–	410–800	420–800	420–800	440–800	–
Average Verbal SAT – all students	604	608	606	595	614	633
Median Verbal SAT – all students	–	600	600	590	610	–
Verbal SAT Range – all students	–	340–800	410–800	390–800	390–800	–
Average Math SAT – Precalculus starts		571	583	574	584	601
Median Math SAT – Precalculus starts		580	570	580	600	595
Math SAT Range – Precalculus starts		410–740	420–790	420–780	440–700	540–690
Average Verbal SAT – Precalculus starts		556	555	542	571	613
Median Verbal SAT – Precalculus starts		560	545	550	565	600
Verbal SAT Range – Precalculus starts		340–720	470–800	390–770	390–730	550–710
Average Math SAT – Caught Up		568	598	533	593	621
Median Math SAT – Caught Up		535	600	535	600	615
Average Verbal SAT – Caught Up		532	562	515	555	617
Median Verbal SAT – Caught Up		555	555	505	540	600
Average Math SAT – Not Caught Up		572	570	592	580	611
Median Math SAT – Not Caught Up		580	570	590	595	600
Average Verbal SAT – Not Caught Up		560	550	554	578	591
Median Verbal SAT – Not Caught Up		570	540	560	585	590
Average Math SAT – Participant		536	575	560	584	601
Median Math SAT – Participant		530	560	535	600	595
Average Verbal SAT – Participant		517	537	544	571	613
Median Verbal SAT – Participant		530	540	555	565	600
Average Math SAT – Non-participant		615	591	586	N/A	N/A
Median Math SAT – Non-participant		615	580	590	N/A	N/A
Average Verbal SAT – Non-participant		605	575	541	N/A	N/A
Median Verbal SAT – Non-participant		615	560	560	N/A	N/A

*1st class with Calculus 1 readiness exam = F 2011 FTFs.
** The University changes passing score on Calculus 1 readiness exam = F 2015 FTFs.

For Math SAT Precalculus start cohort, F-test for 2-sample variances shows that the variances are assumed unequal. Comparing Math SAT 2013 Precalculus start cohort to each of 2014, 2015, and 2016 Precalculus start cohorts shows that the observed differences between sample means is not statistically significant at the 95% confidence interval.

For Verbal SAT Precalculus start cohort, F-test for 2-sample variances shows that the variances are assumed equal. Comparing Verbal SAT 2013 Precalculus starts to each of 2014, 2015, and 2016 Precalculus start cohorts, shows that the observed differences between sample means is not statistically significant at the 95% confidence interval.

Comparing Math SAT 2013 Precalculus starts to the 2013 all student cohort, shows that the observed differences between sample means is statistically significant at the 95% confidence interval.

Comparing Verbal SAT 2013 Precalculus starts to the 2013 all student cohort, shows that the observed differences between sample means is statistically significant at the 95% confidence interval.

the summer bridge as compared with demographic and incoming academic characteristics. An independent evaluator conducted qualitative assessments include pre- and post-surveys along with focus groups at key milestones. We describe the results in the next sections.

QUANTITATIVE ASSESSMENT

Table 5 presents the overall retention rates to date as compared to the pre-project baselines, while Tables 6 and 7 show the retention data in terms of those who participated versus did not participate in the primary Program elements. While promising, the initial quantitative results are inconclusive in terms of the impact of the retention program as designed on overall engineering retention and graduation rates for the University. This overall result is explained below.

The overall 1st to 3rd semester retention rates for all engineering students during this timeframe (2013–2017) were similar. For the Precalculus cohort, the 1st to 3rd semester retention rate ranged

Table 5. Retention and Graduation Rates for FTF Cohorts.

	Baseline F2011 & F2012	Fall 2013	Fall 2014	Fall 2015	Fall 2016	Fall 2017
1st to 3rd Semester Retention Rate						
Total	80%	81%	87%	83%	78%	77%
Precalculus starts	66%	64%	86%	63%	74%	68%
4-YR Graduation Rate						
Total	57%	49%	58%	–	–	–
Precalculus starts	34%	39%	50%	–	–	–
5-YR Graduation Rate						
Total	69%	61%	–	–	–	–
Precalculus starts	43%	39%	–	–	–	–

Table 6. Retention for Precalculus Starts in Terms of Program Participation.

		Number	1st – 3rd Semester Retention	Graduation Rate
2013–14 Precalculus starts	Participants	16	63%	56%
	Non-participants	12	67%	17%
2014–15 Precalculus starts	Participants	23	91%	65%
	Non-participants	19	79%	47%
2015–16 Precalculus starts	Participants	22	77%	–
	Non-participants	26	50%	–
2016–17 Precalculus starts	Participants	38	74%	–
	Non-participants	0	N/A	N/A
2017–18 Precalculus starts	Participants	25	68%	–
	Non-participants	0	N/A	N/A

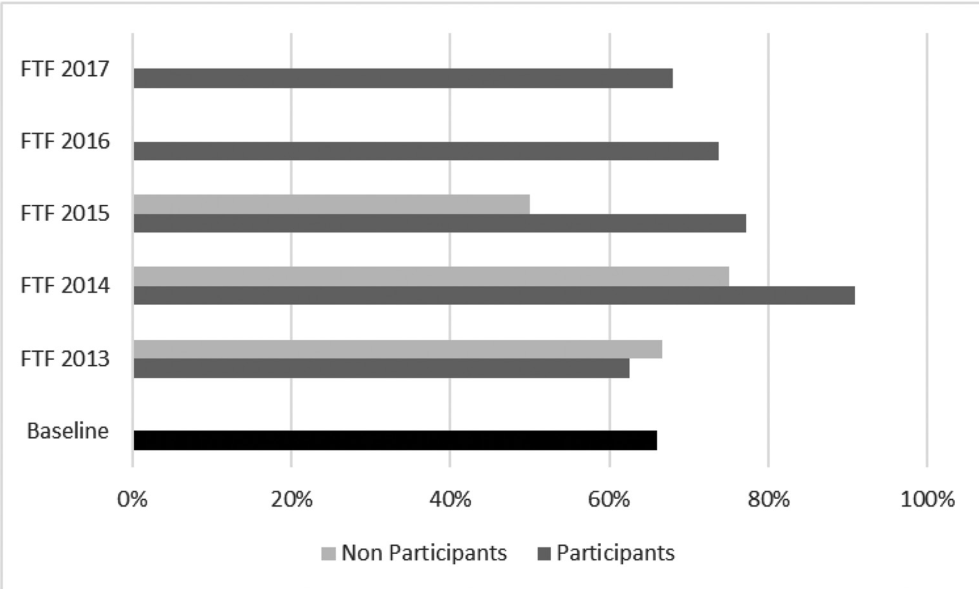

Figure 2. 1st to 3rd Semester Retention Rates for Precalculus Starts in Terms of Program Participation.

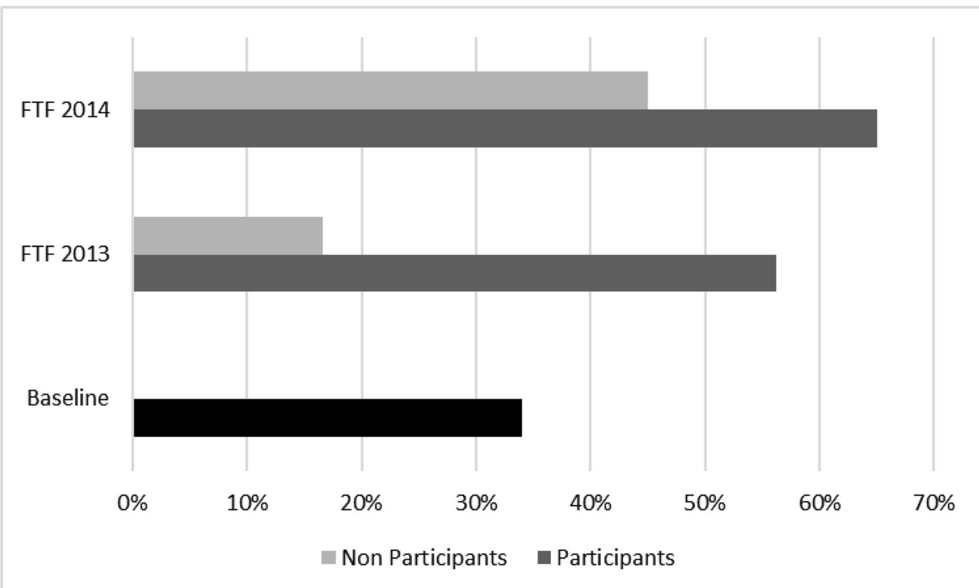

Figure 3. Graduation Rates for Precalculus Starts in Terms of Program Participation.

between 63% and 83% for the period 2013 through 2017 as compared to the baseline average of 66%. The only available data for graduation rates were for the F2013 and F2014 cohorts. The graduation rate for the F2013 cohort was similar to the baseline cohorts (and perhaps a bit lower), however the F2014 results were more promising. One possible positive trend is an apparent closing of the gap between the all engineering cohort and the Precalculus cohorts in F2014, F2016, and F2017.

The F2014 cohort presents several outliers although we only had five data points for retention and three for graduation. The 1st to 3rd semester retention rate for the F2014 cohort was 83%. The F2014 cohort was the group of Precalculus students who had the benefit of both a summer bridge before starting the first year and one in between the first and second years. In other words, this cohort had two ways to catch up with their peers by the start of Sophomore year. This initial success continued to graduation with a 4-year graduation rate of 50% compared to the baseline average of 34%. These retention and graduation rates compared very favorably with those for the F2014 total student cohort.

Since we designed the overall retention program with a primary emphasis on helping students who start in Precalculus to catch up to their cohort by the start of sophomore year (aka completed Calculus 2), we examined the impact of this achievement. Table 7 along with Figures 4 and 5 show a comparison of retention and graduation rates for those Precalculus cohorts who caught up by the start of sophomore year versus those who did not. This data suggests that catching up to cohort by the start of one's sophomore year is important in terms of retention and graduation in engineering.

While the result above seems obvious, i.e., if you catch up academically with your peers then you increase your chances of being retained, we were primarily interested in the impact of the year-long retention program and the academic summer bridge on student persistence. As such, we evaluated the F2013, F2014, and F2015 Precalculus cohorts in terms of their participation in the year-long retention program as shown in Table 6 and Figures 2 and 3. [from F2016 onward, all students

Table 7. Retention for Precalculus Starts - Caught Up by Start of Sophomore Year.

		Number	1st – 3rd Semester Retention	Graduation Rate
2013–14 Precalculus starts	Caught Up	5	100%	60%
	Not Caught Up	23	57%	35%
2014–15 Precalculus starts	Caught Up	19	100%	79%
	Not Caught Up	23	74%	39%
2015–16 Precalculus starts	Caught Up	14	93%	–
	Not Caught Up	34	50%	–
2016–17 Precalculus starts	Caught Up	13	100%	–
	Not Caught Up	25	60%	–
2017–18 Precalculus starts	Caught Up	8	100%	–
	Not Caught Up	17	59%	–

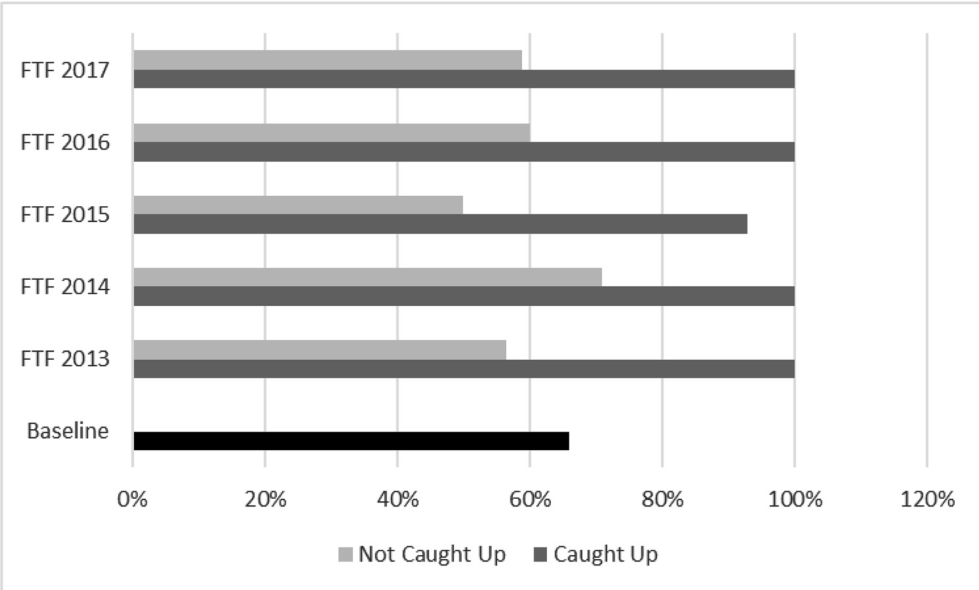

Figure 4. 1st to 3rd Semester Retention Rates for Precalculus Starts in Terms of Caught Up Academically with Entering Cohort.

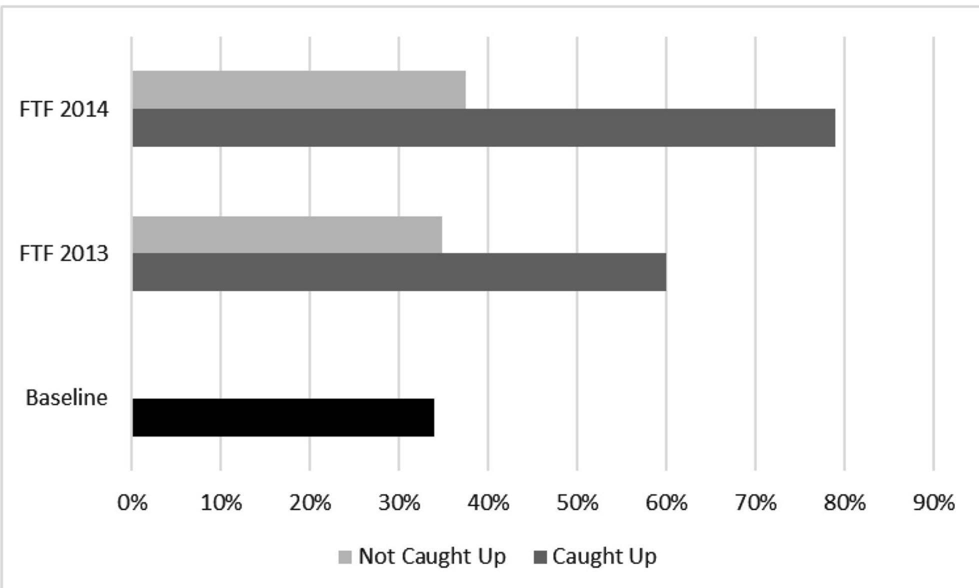

Figure 5. Graduation Rates for Precalculus Starts in Terms of Caught Up Academically with Entering Cohort.

Table 8. Impact of Academic Summer Bridges on Retention for Caught Up Cohort (no bridges in summers 2014 & 2018).

		Number	1^{st} – 3^{rd} Semester Retention	Graduation Rate
2014–15 Precalculus starts	Summer Bridge	15	100%	86%
	Other	4	100%	75%
2015–16 Precalculus starts	Summer Bridge	11	91%	–
	Other	3	100%	–
2016–17 Precalculus starts	Summer Bridge	9	100%	–
	Other	4	100%	–

participated as part of the required first-year course] In almost all cases, students who participated in the program demonstrated higher retention and graduation rates than those who do not. The F2014 Precalculus cohort is once again an outlier in terms of the non-participant group's retention and graduation rates. We also examined the impact of academic summer bridges on retention and graduation rates for the Precalculus cohorts. As shown in Table 8, the data is less clear in terms of this impact particularly in the earlier years of a student's academic career. It is possible that the impact is more significant in the junior and senior years, but there was not enough data for this paper.

To further explore some of the suggested cause and effect relationships given the limited amount of aggregate data, we explored the role of two parameters on the dependent variables of retention and graduation rates — catching up to cohort by sophomore year and completing an academic summer bridge. We also explored the role of voluntarily participating in counseling on catching up to cohort by sophomore year. We combined the individual student data for each of the cohorts and categorically coded the parameters and dependent variables. We tested each of the three independent parameters along with demographic parameters (gender, ethnicity/race, first generation) and incoming academic parameters (SAT math and SAT verbal).

We first performed a logit regression analysis to determine if catching up to cohort status in terms of Calculus (i.e., completing Calculus 2 before the start of sophomore year) is a significant positive predictor for 1^{st} to 3^{rd} semester retention rate, 3^{rd} to 5^{th} semester retention rate, and graduation rate within engineering, and how that predictor compares with the effect of demographic and academic characteristics. As shown in Table 9, the odds of a student who started in Precalculus being retained in engineering in the fifth semester is 9.74 times higher if the student catches up in Calculus (completed Calculus 2) by fall sophomore year compared to not catching up. Similarly, the odds for that cohort is 16.01 times higher in terms of successfully graduating for those who catchup versus not. However, we cannot conclude that catching up results in a significant effect on being retained in engineering in the third semester as opposed to other factors.

Table 9. Catching Up with Cohort (Calculus sequence) as a Predictor of Degree Persistence (logit regression analysis).

Dependent Variable	1st to 3rd semester retention = Yes	1st to 5th semester retention = Yes	Graduation rate (within 5 years) = Yes
Model Parameter	18.1	2.28	2.77
Standard Error	1667.43	0.5	0.98
Wald Chi^2	0	21.16	7.99
Pr > Wald	0.99	<0.0001	0.005
Odds Ratio	–	9.74	16.01
95% CI Lower Odds Ratio	–	3.64	2.34
95% CI Upper Odds Ratio	–	25.71	109.45
Number of Observations	131	130	56
Degrees of Freedom	130	129	55
Area Under Curve	0.81	0.79	0.88
Correct Predictions	75.57%	70.77%	76.79%
Significant	No	Yes	Yes
Other parameters	None are statistically significant using Wald Odds ratio >1 for SAT math, SAT verbal	No parameters are statistically significant using Wald Odds ratio >1 for ethnicity/race, SAT math, SAT verbal, first generation	Ethnicity/race is only other parameter statistically significant using Wald Odds ratio >1 for ethnicity/race (9.26), SAT math, SAT verbal, first generation

Similarly, we performed a logit regression analysis to determine if completing an academic summer bridge (where relevant) is a significant positive predictor for students for 1st to 3rd semester retention rate, 3rd to 5th semester retention rate, and graduation rate within engineering, and how that predictor compares with the effect of demographic and academic characteristics. As shown in Table 10, the odds of a student who started in Precalculus being retained in engineering in the third semester is 4.84 times higher if the student completes an academic summer bridge versus not. Similarly, the odds of a student who started in Precalculus being retained in engineering in the fifth semester is 7.81 times higher if the student completes an academic summer bridge versus not. Finally, the odds are 49.26 times higher in terms of successfully graduating if the student completes an academic summer bridge versus not.

Finally, we performed a logit regression analysis to determine if choosing to participate in retention counseling (where relevant) is a significant positive predictor for students in terms of catching up to cohort status (i.e., completing Calculus 2 before the start of sophomore year), and how that predictor compares with the effect of demographic and academic characteristics. As shown in Table 11, the odds of a student who started in Precalculus catching up with cohort in terms of Calculus is 10.87 times higher if the student engages with the intentional academic counseling versus not.

Table 10. Completing a Summer Academic Bridge as a Predictor of Degree Persistence (logit regression analysis).

Dependent Variable	1st to 3rd semester retention = Yes	1st to 5th semester retention = Yes	Graduation rate (within 5 years) = Yes
Model Parameter	1.58	2.06	3.9
Standard Error	0.76	0.52	1.47
Wald Chi^2	5.51	15.47	7.99
Pr > Wald	0.02	<0.0001	0.01
Odds Ratio	4.84	7.81	49.26
95% CI Lower Odds Ratio	1.3	2.81	2.75
95% CI Upper Odds Ratio	18.06	21.77	881.82
Number of Observations	111	110	36
Degrees of Freedom	110	109	35
Area Under Curve	0.71	0.77	0.91
Correct Predictions	75.68%	68.18%	80.56%
Significant	Yes	Yes	Yes
Other parameters	None are statistically significant using Wald Odds ratio >1 for SAT verbal	None are statistically significant using Wald Odds ratio >1 for gender, SAT math, SAT verbal, first generation	None are statistically significant using Wald Odds ratio >1 for ethnicity/race, SAT verbal, first generation

Table 11. Participating in Counseling as a Predictor of Catching Up to Cohort (logit regression analysis).

Dependent Variable	Caught Up = Yes
Model Parameter	2.39
Standard Error	0.62
Wald Chi^2	14.57
Pr > Wald	0.000
Odds Ratio	10.87
95% CI Lower Odds Ratio	3.19
95% CI Upper Odds Ratio	36.99
Number of Observations	95
Degrees of Freedom	94
Area Under Curve	0.79
Correct Predictions	75.79%
Significant	Yes
Other parameters	None are statistically significant using Wald Odds ratio >1 for gender, ethnicity/race, SAT math, SAT verbal, first generation

QUALITATIVE ASSESSMENT

For the F2013, F2014, and F2015 Precalculus cohorts, we obtained feedback from those who participated in counseling via an online survey conducted at the end of each fall semester and a focus group conducted at the end of each spring semester. Results from these first three years of the program show that students appreciated the counseling because it helped them develop a plan for getting back on track and tackling academic challenges. Students also felt that the program helped them gain confidence in their major. For the F2013 cohort (focus group), student feedback suggested that the initial messaging for the program was intimidating and/or stigmatizing (students particularly did not like the use of the word “retention”). For the following years, we revised the messaging to be more positive and reassuring and students in the F2014 cohort (focus group) found the messaging to be appropriate.

We also evaluated the academic summer bridges using pre and post- surveys along with a focus group at the end of each offering in summers 2014, 2015, 2016, and 2017. Feedback from both the post-surveys and the focus groups show that taking math over the summer helped the students build foundational skills and gain more confidence with their academic abilities. Students also said that they benefited from building community with their peers and learning about the range of professional opportunities within engineering/computer science.

The feedback also suggested that an academic bridge between the first-year and the sophomore year may work better for students once they understand, from the year-long counseling sessions, the need to catch up with their cohort. Unfortunately, participation in the summer bridge did not increase significantly. Table 12 summarizes the qualitative data from the various cohorts.

Table 12. End of FY Feedback from Precalculus Participants.

Cohort	Feedback
F 2013	Program helped with confidence about engineering and the resources available Low participation due to intimidation (particularly around title “retention program”), or lack of awareness Lack of community amongst Precalculus FTF cohort
F 2014	Logistics make it difficult to attend pre-first-year Summer Bridge Need to attend some events to realize benefits of Program Meeting with professionals who struggled academically is encouraging for students Professional development in Summer Bridge (job shadows and site visits) is valued
F 2015	Increased confidence in ability to graduate Social and academic activities helped build community Even though workshops beneficial, difficult to fit into students’ schedule
F 2016	Supported transition to sophomore year Expanded understanding of engineering as a career and how to direct personal path Built confidence Built community among students

Note: most feedback from focus groups during summer bridge

Despite the benefits described above, Table 2 shows that participation rates for eligible students were approximately 50% when the counseling was optional. Feedback from the focus groups suggested that, even with the improved messaging, students might first need to attend some of the events to realize the benefits so that they continue participating. After trying various techniques to encourage more students to participate, we decided (starting F2016) to require all entering students in Precalculus to enroll in a one-credit course that includes much of what was covered in the optional counseling program. The new, required, Fall semester, first-year, one-credit course is called EGR 115 Pathways to Engineering Success. We used pre and post-surveys and course evaluations to evaluate this one-credit course. The surveys from F2016 showed that the students made positive gains in every metric: relationship with peers, understanding of academic expectations, developing an engineering student identity, awareness of the STEP program, and degree planning. Feedback from the course evaluations also showed that students valued learning how to get caught up in their degree and the skills necessary for success in engineering. Table 13 presents the assessment results for EGR 115 course.

Table 13. Pre and Post Student Perceptions about Required FY Course.

	F 2016	
Question 1 (low) to 5 (high)	**Pre**	**Post**
I would rate my relationship with peers as strong	2.9	3.8
I have a high level of understanding of the academic expectations of engineering	3.2	4.5
I have a high level of understanding of my engineering student identity	2.6	3.9
I have a high level of understanding of my degree plan	2.7	4.0

INITIAL CONCLUSIONS

Although the retention program has evolved over the last five years, we retained enough of the main elements of the Program to allow us to a) develop what we believe will be a sustainable retention program at the University, b) draw several generalizable conclusions, and c) identify areas for more study.

Sustainable Program

Moving forward, the University's retention program for those students who have to begin the engineering curriculum in Precalculus due to lack of readiness for Calculus 1 includes three primary components as shown in Table 14 — EGR 115 Pathways to Engineering Success, a partial summer academic year bridge where first-year students can complete Calculus 2 at no cost at the University

Table 14. Design for the Retention Program for Precalculus Engineering FTFs 2018+.

Program Element	Term	Target Audience	Professional Formation	Academic Integration	Social Integration	Assessment Method
One-Credit First-Year Course (required)	Fall	Precalculus first-year students	class sessions on teamwork, long-term goal planning, value of non-technical skills, the engineering profession	class sessions on resilience, growth mindset, study habits, degree planning cohort with dedicated coach	icebreakers, team-building, small-group discussions	course evaluations tracking retention/ graduation rates & catch-up rates
Eight-Week Calculus 2 Summer Bridge	Summer	rising sophomores who are behind cohort in STEM courses and in good academic standing	weekly site visits to local engineering companies, one-day job shadow workshops on resumes and cover letters	course = Calculus 2	N/A	retention/ graduation rates
Summer Scholarships (eligible based on participation)	Summer	rising sophomores who are behind cohort in STEM courses and in good academic standing	N/A	$1,000 scholarship towards each University STEM summer course(s) successfully completed to catch up with cohort	N/A	retention/ graduation rates

while participating in several professional development activities, and the availability of partial summer scholarships so that first-year and sophomore students who fall behind cohort can catch up in required STEM courses during either the summer after the first year or the second year. Eligible students must be in good academic standing throughout. Figure 6 illustrates a preliminary cause and effect model that guided this final program design.

We decided on these elements based on the evaluation results to date that show the positive influence on long-term persistence within an engineering major of both catching up academically with the students' overall cohort by the start of sophomore year, as well as completing an academic summer bridge. In addition, the data shows that participating in an intentional counseling program significantly influences a student's decision to catch up with their cohort. We also considered long-term financial sustainability since we are a resource-constrained institution. As such, we had to reduce the scope of the academic summer bridge and remove the pre-first-year summer bridge even though the initial data suggests that multiple summer bridges may be needed to have significant impact. To counter this loss, we hope that providing partial scholarships for summer courses at the University in multiple summers will facilitate several ways for students to persist with engineering via catching up with their cohort early in their academic pathway.

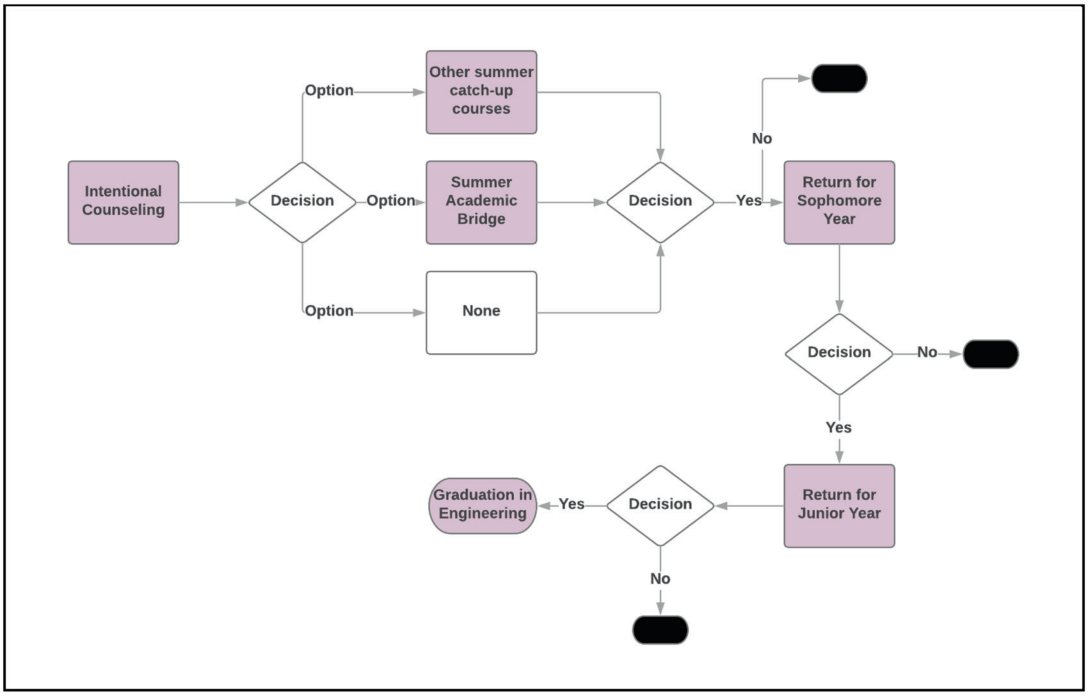

Figure 6. Preliminary Cause and Effect Model for Persistence of the Precalculus Cohort.

In EGR 115, we ask students to think about what makes a successful engineer and what steps they need to take to become that engineer. This course focuses on helping students understand how to graduate within four years (eight regular semesters) by catching up in the Calculus sequence before the start of sophomore year. And, the course also tries to help students understand how to self-regulate their learning. Self-regulated learning is a broad term for various models and frameworks that describe the "cognitive, motivational, and emotional aspects of learning" (Panadero, 2017, p. 1). The course includes seminar-style leadership and goal-setting discussions about topics such as growth mindset and self-efficacy, motivational professional development panels of young engineering professionals who overcame academic adversity, and individual counseling customized to the students' needs in areas such as time management and study strategies. It is taught as a positive leadership-oriented experience rather than a remedial session. We also recognize that during this course, some students may decide to switch majors because the engineering pathway is not what they want so we provide positive examples for this choice as well.

As described by Zimmerman (2000), we use the course to help students understand how to apply a self-reflection process about their approach to college in conjunction with what they learn about how to control their own learning to influence their decisions regarding persistence in an engineering major. By requiring the course, we overcame the reluctance of students to participate in voluntary counseling and used a group setting to further integrate the students socially and build their sense of belonging in engineering despite being in Precalculus.

One of the goals of EGR 115 is to motivate and show the Precalculus students how they can catch up academically so that they graduate within four years (or five years if co-op or ROTC). Besides EGR 115, we support this goal by providing convenient and affordable ways to catch up. For the University context, we maintain that an academic summer bridge is critical because a) many of our students' home regions do not include compatible institutions for semester courses and b) the summer provides an opportunity for professional integration and our initial data suggests that this is an important integration factor for persistence in engineering.

After four years we realized that this type of academic summer bridge is not financially sustainable at the University. As such, we designed a partial summer academic year bridge where first-year students can complete Calculus 2 at no cost at the University. Students have to support themselves financially in terms of housing which we suspect is feasible for rising sophomores given the availability of sublets etc. in the vicinity. Since courses meet four times a week during the summer session, we used every Friday for professional development activities that are required as a condition for receiving the tuition-free course. This summer bridge option is available to any rising sophomore who is in good academic standing but needs Calculus 2 to catch up. In addition, the partial summer scholarships provide all first-year and sophomore students in good academic standing the opportunity to complete catch-up STEM courses before they start the junior year. With these two "bridging" options, we did not include intentional social integration activities given the context of the University as a small, student-centered residential institution where student community and belonging are already emphasized.

Generalizable Conclusions

Although we ran our study across four years, the data to date is limited since the interventions occur early in a student's academic pathway while the effect is not fully realized until four or five years later. That said, we were able to draw some preliminary conclusions that are generalizable to contexts beyond our University.

Overall, the data supports our initial hypothesis that catching up academically with one's cohort is an important part of helping students to persist in an engineering major that goes beyond any impact of demographics or incoming academic metrics. Although more cohorts need to be studied, the logit regression model showed the impact of catching up to be even more pronounced for the 1st to 5th semester retention rate and graduation rate. In the logit regression model, the influence of catching up was more of a predictor than various demographics and incoming academic measures. We suggest that this result, as shown in Figure 6, is generalizable across institutions although each institution needs to determine what motivates students to catch up in their own context. This result may also suggest that categorizing a particular cohort as "at-risk" and/or in need of special intervention may be better achieved using objective measures of readiness for key foundational courses than using demographics or incoming academic measures such as SAT.

Areas to Study

As stated, more longitudinal data is needed to determine the validity of our preliminary results. Beyond that, a second area for further study is to examine first-year and sophomore students who started college in Calculus 1 but fell behind at some point during those initial years. While we originally intended to address this issue as part of our study, we did not have the resources to thoroughly evaluate what was needed at each milestone where students can fall behind. The literature also suggests that the second college year is a critical and often neglected year in terms of academic interventions (Schaller 2005).

A third area for further study is the role of professional integration on self-efficacy and ultimately persistence in engineering. The feedback from our study suggested that for engineering students, the professional integration component may have significant weight in terms of *do I feel part of the engineering student community and do I see myself capable of ultimately being an engineer?* Professional integration (or professional identity development) is noticeably absent from Tinto's model of student retention. That said, it seems plausible that various professional experiences affect outcome expectations, self-efficacy, and sense of belonging, particularly for engineering students, which in turn affect a student's changing identity as an engineer and therefore his/her motivation to persist with an engineering major.

There are several theories and studies that address professional identity development as distinct from just identity development including self-determination theory (Deci and Ryan 2017) as it relates to developing a community of engineers, along with the dimensions of motivation as they relate to academic success (Linnenbrink and Pintrich 2002). Godwin and Lee's (2017) study of identity development across the four years of undergraduate education shows that development progresses with time in majors with the highest levels of professional identity measured in the senior year and a drop during the second year. This finding aligns with the prior work by Tonso (2014) and other who show that identity development is both a result of personal experiences and a connection with the overall community. As such, Godwin and Lee's (2017) findings are expected given the traditional design of engineering curricula that engages students in more recognized engineering activities as they move to the junior and senior years.

However, if professional identity development significantly affects self-efficacy etc. with regards to engineering retention, the findings in the studies described above do not bode well for at-risk students during the first two years of college and that is particularly true for students whose only connections to engineering are through the curricula. Goodwin and Potvin (2016) used a case study of one student's experiences to demonstrate how the initial engineering curriculum and class structures reduced the student's identity as an engineer and led to the student switching majors. They also showed how for first-year women, math and physics identities, along with a perception of how science can improve society, are important predictors of career choice (Godwin et. al. 2016). Another study (Verdin et. al., 2018) used structural equation modeling to show that first-generation college students persist in engineering when they can see themselves as capable of engineering. We suggest that integrating professional experiences into retention programs can be part of the solution for at-risk students.

REFERENCES

American Society for Engineering Education. 2009. *Creating a Culture for Scholarly and Systematic Innovation in Engineering Education*. Accessed July 2017. http://www.asee.org/about-us/the-organization/advisory- committees/CCSSIE.

American Society for Engineering Education. 2015. *Databytes*. Accessed August 2018. http://www.asee-prism.org/databytes-jan-2/.

Bandura, A. 1977. "Self-efficacy: Toward a Unifying Theory of Behavioral Change." *Psychological Review* 84: 191–215.

Bandura, A. 1994. "Self-efficacy. In V. S. Ramachaudran (Ed.)," *Encyclopedia of Human Behavior* 4: 71–81. New York, NY: Academic Press.

Belfield, C., D. Jenkins, and H. Lahr. 2016. "Momentum: The Academic and Economic Value of a 15-credit First-semester Course Load of College Students in Tennessee." In *FFRC working Paper No. 88*, New York, NY: Columbia University, Teachers College, Community College Research Center.

Cairncross, C., T. VanDeGrift, and S. A. Jones. 2015. "Building a Summer Bridge Program to Increase Retention and Academic Success for First-year Students." *Annual Conference for the American Society of Engineering Education* Seattle, WA, June.

Concannon, J. P. and L. H. Barrow, 2010. "Men's and Women's Intentions to Persist in Undergraduate Engineering Degree Programs." *Journal of Science Education and Technology* 19, no. 2: 133–145.

Deci, E. L. and R. M. Ryan. 2017. *Self-determination Theory*. Accessed August 2017. http://selfdeterminationtheory.org/

Denley, T. 2016. "Choice Architecture, Academic Foci and Guided Pathways." *Presentation to the AACC Pathways Institute* Denver, CO, October.

Godwin, A., Potvin, G., Hazari, Z., and Lock, R. 2016. "Identity, Critical Agency, and Engineering: An Affective Model for Predicting Engineering as a Career Choice." *Journal of Engineering Education*, 105, no. 2: 312–340.

Goodwin A. and W. Lee. 2017. "A Cross-sectional Study of Engineering Identity During Undergraduate Education." *Annual Conference for the American Society of Engineering Education* Columbus, OH, June.

Goodwin, A. and G. Potvin. 2017. "Pushing and Pulling Sara: A Case Study of the Contrasting Influences of High School and University Experiences on Engineering Agency, Identity, and Participation." *Journal of Research in Science Teaching* 54, no. 4: 439–462.

Hsieh, P., J.R. Sullivan, D.A. Sass, and N.S. Guerra. 2012. "Undergraduate Engineering Students' Beliefs, Coping Strategies, and Academic Performance: An Evaluation of Theoretical Models." *Journal of Experimental Education* 80: 196–218.

Jones, S., Z. Naegele, Z., and T. VanDeGrift. 2014. "Increasing Retention in Engineering and Computer Science with a Focus on Academically At-Risk First Year and Sophomore Students." *Annual Conference for the American Society of Engineering Education* Indianapolis, IN, June.

Jones, S., C. Cairncross, and T. VanDeGrift. 2015. "Building a Summer Bridge Program to Increase Retention and Academic Success for First-Year Engineering Students." *Annual Conference for the American Society of Engineering Education* Seattle, WA, June.

Jones, S.A. and C. Cairncross. 2016. "Two-tiered Summer Bridge Programming for At-risk Engineering and Computer Science Students." *Envisioning the Future of Undergraduate STEM Education: Research and Practice* Washington D.C. April.

Jones, S.A., C. Cairncross, and T. VanDeGrift. 2017. "NSF Grantees Poster Session: Using Assessment to Continuously Improve the Retention & Persistence of At-Risk Engineering Students" *Annual Conference for the American Society of Engineering Education*, Columbus, OH, June.

Lent, R. W., M.J. Miller, P.E. Smith, B.A. Watford, R.H. Lim, K. Hui, . . . and K. Williams. 2013. "Social Cognitive Predictors of Adjustment to Engineering Majors across Gender and Race/Ethnicity. *Journal of Vocational Behavior* 83: 22–30.

Linnenbrink, E. A. and P. R. Pintrich. 2002. "Motivation as an Enabler for Academic Success." *Social Psychology Review* 31, no. 3: 313–327.

McIntyre, R. B., R.M. Paulson and C.G. Lord. 2003. "Alleviating Women's Mathematics Stereotype Threat Through Salience of Group Achievements." *Journal of Experimental Social Psychology* 39: 83–90.

Nora, A. and A. Cabrera. 1993. "The Construct Validity of Institutional Commitment: A Confirmatory Factor Analysis." *Research in Higher Education* 34, no. 2.

Panadero, E. 2017. "A Review of Self-regulated Learning: Siz Models and Four Directions for Research." *Frontiers in Psychology* 8, no. 422.

Schaller, M. 2005. "Wandering and Wondering: Traversing the Uneven Terrain of the Second College Year." *About Campus* 10, no. 3.

Steele, C. 1999. "Thin Ice: Stereotype Threat and Black College Students." *The Atlantic* Monthly 284, no. 2: 44–47, 50–54.

Tinto, V. 1975. "Dropouts from Higher Education: A Theoretical Synthesis of Recent Research." *Review of Educational Research* 45.

Tinto, V. 1987. *Leaving College*. Chicago: University of Chicago Press.

Tinto, V. 1993. *Leaving College: Rethinking the Causes and Cures of Student Attrition.* Chicago: The University of Chicago Press.

Tinto, V. 2015. "Through the Eyes of Students." *Journal of College Student Retention: Research, Theory & Practice* 0 no. 0: 1–16.

Tinto, V. 2017. "Reflections on Student Persistence." *Student Success* 8, no. 2, 1–8.

Tonso, K. 2014. "Engineering Identity." In *Cambridge Handbook of Engineering Education Research*, edited by Johri and Olds, Chapter 14.

Verdin, D., A. Godwin, A. Kirn, L. Benson, and G. Plotvin. 2018. "Understanding How Engineering Identity and Belongingness Predict Grit for First-Generation College Students." *The Collaborative Network for Engineering and Computing Diversity Conference*, Crystal City, VA, April.

Zimmerman, B. J. 2000. "Attaining self-regulation: a social cognitive perspective," In *Handbook of Self-Regulation*, eds. M. Boekaerts, P. R. Pintrich, and M. Zeidner (San Diego, CA: Academic Press), 13–40.

AUTHORS

Sharon A. Jones is the Vice Chancellor for Academic Affairs and Professor of Engineering at the Bothell campus of the University of Washington. Her research interests include applying decision-making methods to evaluate sustainability policies, improving engineering ethics education, broadening participation in STEM, and bridging engineering and the liberal arts.

Tammy VanDeGrift is a Professor of Computer Science at the University of Portland. Her research interests include computer science education, supporting novice computer scientists, computational theory, and computational biology. She is an Associate Editor for the Association for Computing Machinery's Transactions on Computing Education and advises the University of Portland's Society of Women Engineers chapter.

Julie Kalnin is an Associate Professor in the School of Education at the University of Portland. In addition to engaging in and studying program evaluations that build capacity for change, her research interests include the use of formative assessment for instructional improvement and collaborative inquiry for teacher learning across the career span. With other teacher educators across the state of Oregon, she serves as a coordinator for teacher performance assessments.