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WIP: Study of Student Success and Retention based on Initial Math Placement

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Abstract

This work-in-progress (WIP) paper details a study of engineering student success and retention based on initial math placement. Many engineering programs' four-year plans of study are based on first-semester placement in a Calculus math class. This makes math placement a critical determinant for a student's ability to graduate in four years. Post-COVID, the math readiness of graduating high school students has been declining, resulting in more first-year engineering students being placed in pre-calculus math classes. Gonzaga University's School of Engineering and Applied Science was experiencing a similar rise in pre-calculus math placement. Readily available institutional data showed a decrease in student retention based on math placement, but it was unclear whether student success or concerns about the time to graduation were likely factors in the reduction of retention rates. Mitigation measures would differ depending on whether students were encountering lower academic success or concerns about the time and financial implications of taking longer to graduate. This led the School of Engineering and Applied Science to look deeper into student indicators based on initial math placement. These indicators included retention in engineering, four- and six-year graduation rates, and success in early math, science, and engineering courses. Data from first-year students entering engineering programs at Gonzaga University from 2012-2024 were analyzed. Data for each student included initial math course placement, scores on the ALEKS math placement exam, grades earned in typical math, science, and engineering courses, and graduating major and time to degree where available. The study was a collaborative effort between the engineering Dean's office and faculty from the math and science departments. The results of this study will be used to develop student programs aimed at mitigating the effects of pre-calculus math placement on their students.

Introduction

Gonzaga University's engineering programs in the School of Engineering and Applied Science (SEAS) are designed as four-year degrees, assuming that entering first-year students are prepared to begin the Calculus sequence in their first semester. Nationally, there's an increasing trend for engineering majors to be placed in Precalculus in their first semester [1]. This trend, coupled with concerns about the college enrollment "cliff" and a critical need for engineers, led the SEAS to explore issues around retention and student success outcomes in engineering [2]. Additionally, previous research into retention in engineering linked student confidence in college-level math and science (self-efficacy) to their persistence in the degree, which raises concerns when placing students in a math class that could be considered behind what is considered on track [3].

First Year Student Success and Retention in Engineering

A commonly quoted number is that roughly half of engineering students change out of engineering or leave college, with about half of that retention loss occurring between the first and second year, although this number does not appear to be grounded in research literature [4]. A 2002 study showed that 30% of engineering students did not finish their engineering degree [5]. An American Society of Engineering Education (ASEE) survey found retention rates to the second year for engineering majors increased nationally from 78% in 2003 to 82% [6]. The same study showed that four-year graduation rates in engineering increased from 29% in 2006 to 33%

in 2011. Results from a 2021 American Society for Engineering Education survey indicated a first-year retention average of 81.9% and a six-year graduation average of 55.2% among all engineering schools that self-reported.

A 2021 study at an engineering school similar to Gonzaga found that up to 25% of their 200 entering engineering first-year students were being placed in pre-calculus [1]. This study also found that first-year retention rates for these students dropped to 66% compared to 80% for all engineering students. The study also found that four-year graduation rates dropped from 69% to 43% for pre-calculus-placed first-year students.

For this effort the main questions investigated were:

- Are there differences in retention for engineering students based on initial math placement (i.e. pre-calculus versus calculus I or above)?
- Are there differences in graduation rates and academic success in key courses based on initial math placement?

The second question investigates whether the reduction in retention rates could be linked to concerns with a longer time to degree or with being academically unprepared for courses, since mitigation measures would likely differ depending on those concerns. The overall goal of this study is to inform the development of measures to address the increasing trend of students being placed below Calculus I their first semester to ensure we are adequately addressing the needs of a population the School has not historically had.

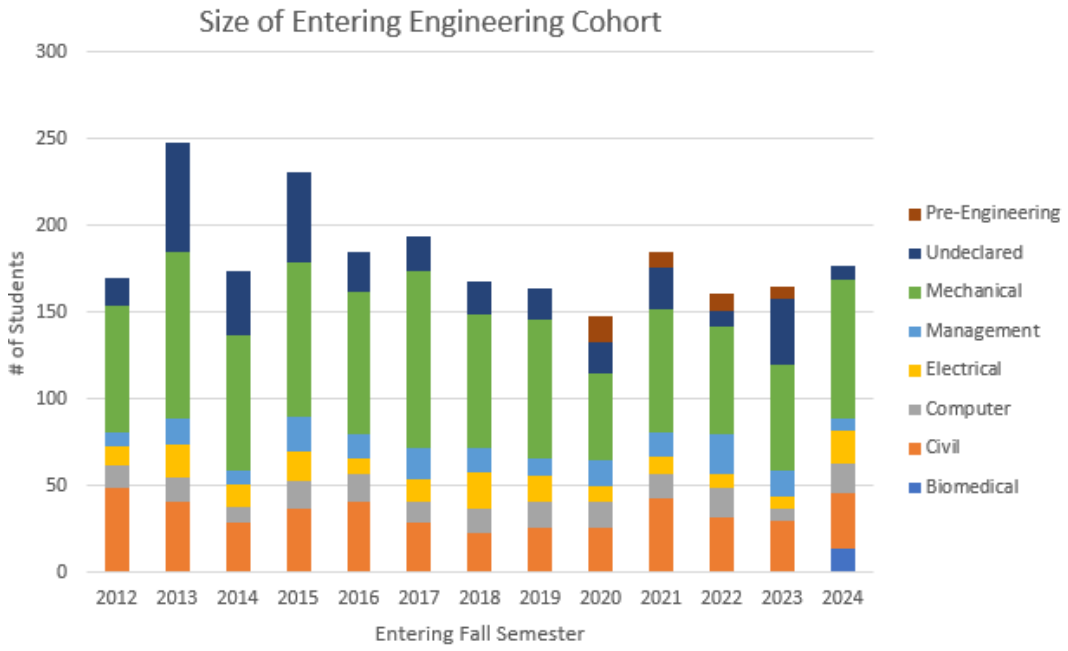
Methods

SEAS has six engineering programs in Civil, Computer, Electrical, and Mechanical Engineering, as well as Engineering Management. This year, a new program in Biomedical Engineering has admitted its first cohort. In addition, students can enter the School as Engineering Undeclared majors. From 2020 to 2023, students could also declare as Pre-Engineering majors when they were not eligible for direct admission into the School, often because they were not ready for Calculus 1. This designation was discontinued in 2024 when the School moved away from direct admission.

For this study, entering first-year students from 2012 to 2024 were included, which totaled 2,370 students. SEAS utilized a common first-year curriculum for most of the study years and has more recently moved to a common first semester. Because of this, there is a fair amount of movement between majors during the two semesters. For purposes of retention, a student is considered retained if they stay in one of the School's majors. Figure 1 shows the cohort size of each entering class for the study period and identifies the major at the time they begin their first semester. Gonzaga regularly reviews retention and time to graduation data based on several factors including age at start of undergraduate program, gender, race/ethnicity, minority status, first general status, Pell eligibility, and a student aid index. Previous reviews of this data have not indicated concerns with respect to these socioeconomic factors so they are not being considered in this analysis but those are factors that are being monitored on an annual basis in a separate analyses.

Math placement for incoming engineering majors is based on Advanced Placement Exam Scores, the ALEKS Math Placement Test, or transfer credit, including Running Start/Dual Enrollment or College in the High School courses. Gonzaga's AP policy accepts AP scores of 4 or above on the Calculus AB exam for 4 credits of Calculus I and scores of 4 or above on the Calculus BC exam for 8 credits of both Calculus I and II. Scores of 4 or 5 on the Pre-Calculus AP exam earn 3 credits of Pre-Calculus credit. Gonzaga also accepts IB and Cambridge International Exams, but those are less commonly seen.

Figure 1: Size of Entering Engineering Cohort



Criteria for Initial Math Placement and Placement Trends

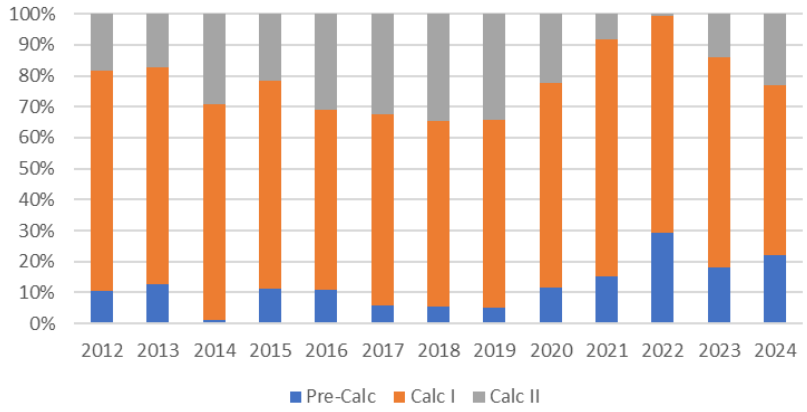
Gonzaga began utilizing the ALEKS Math Placement Test for the Fall 2019 cohort. Students need to score above 80 to be placed in Calculus I. Beginning in Fall 2022, Calculus I students with ALEKS scores between 81 and 87 were also enrolled in a 1-credit supplemental Math seminar to provide them with additional skills to ensure math success. The number of students each year taking the exam has ranged from about 100 to 140, with the highest number of 141 being in 2021, likely due to COVID effects on AP exam scores and the availability of taking the test. In this study, a total of 722 (30.4%) of the students had a math placement exam score.

Students were categorized for Math Placement in two ways. The first was based on their ALEKS score, if available, utilizing the thresholds above: <81, 81-87, and 88 and above. The second was based on whether their academic records showed a letter grade for Pre-Calculus, Calculus I but not Pre-Calculus, or a letter grade for Calculus II or above but not Calculus I.

Using the second method that is applicable to all students regardless of whether they took the math placement exam, 286 (12.1%) of the students had an initial math placement in Pre-Calculus; 1,562 (65.9%) in Calculus I, and 522 (22.0%) in Calculus II or above. Figure 2 shows

the year-by-year math placement trends. Prior to 2020, initial math placement in Pre-Calculus was all below 13%, with a low value of 1.1% in 2014. However, since 2021 it has remained above 15%, with the high value in 2022 of 29.2%. This trend corresponds to low percentages of students being initially placed in Calculus II and above, with values before 2020 ranging from 17.3% in 2013 to 34.5% in 2018, but since 2021 all dropping below 15%, with the lowest value being less than 1% in 2022.

Figure 2: Initial Math Placement Percentage by Year



Results

Graduation rates for students entering as engineering majors are shown in Figure 3. The figure shows the four-, five-, and six-year graduation rates from the University (U4, U5, and U6 respectively). Graduation rates are only classified by full years so students who started in Fall 2020 but graduated in December of 2024 are classified as five-year time to graduation. University four-year graduation rates for students entering as engineers range from 74% to 86%, and the six-year graduation rates increased to 82% to 91%. The figure also shows that most students graduate in four years, and there has been minimal difference between the five- and six-year graduation rates. The second series of lines shows the four-, five-, and six-year graduation rates for those same students who entered as engineering majors and also graduated with engineering degrees (S4, S5, and S6 respectively). Four-year graduation rates in engineering have ranged from 58% to 72% for this time period, and six-year graduation rates in engineering have been between 66% and 74%.

Initially, the data were analyzed from a student retention perspective. As mentioned earlier, retention is defined as staying in the School but not necessarily staying within the major the student declared in their first semester. Figure 3 shows that the percentages of students who entered as engineering majors and enrolled in the next year's fall term at the University, regardless of major, have ranged from 90% to 96%. This figure also shows the lower percentage of students who entered as engineering majors and enrolled in the next year's fall term as engineering majors, ranging from a low of 65% in 2021 to a high of 87% in both 2016 and 2018. Retention in engineering has remained below 80% since COVID, although retention at Gonzaga has stayed high. (Note that this is the retention of students who entered as engineering majors and stayed at the University. The overall retention rate at Gonzaga is higher than shown here.)

Figure 3: University and Engineering 4-, 5-, and 6-Year Graduation Rates

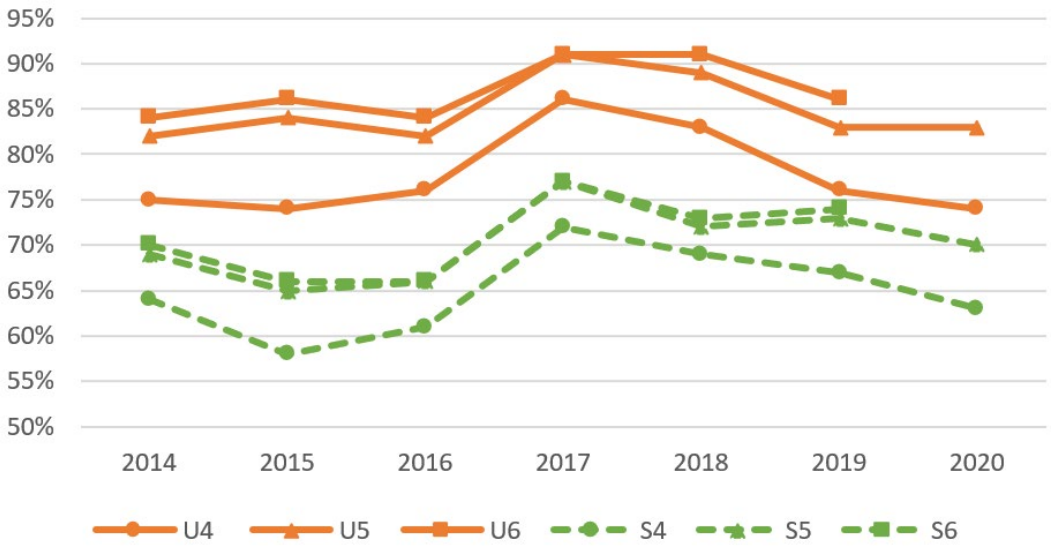
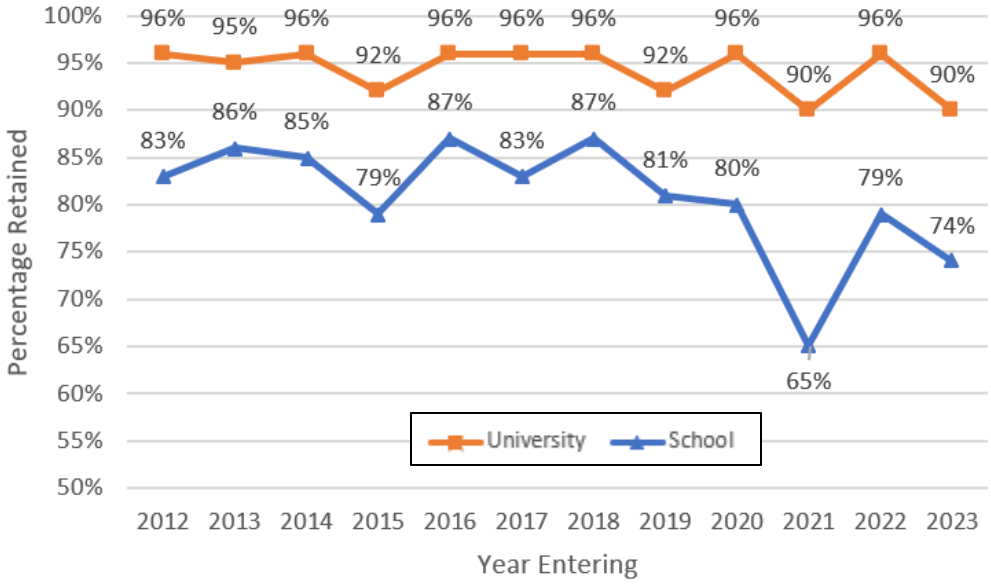


Figure 4: Student Retention at the University and School



Retention rates were next analyzed based on initial math placement by considering students who were placed in pre-calculus and those who were placed in Calculus I or above. Table 1 shows the differences in retention rates within the School (S) and at the University (U). The data indicate that retention rates both at the School and at the University lowered during COVID, but the impact within the School was much higher. The retention rate in the School in 2021 of 39% for students placed in pre-calculus was particularly alarming.

Table 1. Retention Rates by Math Placement

	2018		2019		2020		2021		2022	
	S	U	S	U	S	U	S	U	S	U
Pre-Calc	75%	100%	63%	100%	59%	88%	39%	86%	72%	93%
Calc I or above	89%	96%	86%	93%	85%	95%	73%	92%	77%	93%
Difference	-14%	4%	-23%	7%	-26%	-7%	-34%	-6%	-5%	0%

The data shown in Table 1 led to a meeting between the School and the Chairs of Math, Physics, and Chemistry in the summer of 2024 to discuss trends in the preparedness of incoming engineering students. While it was clear from the data that there were impacts on student retention based on math placement, it was determined that additional data were necessary before developing mitigation measures. In particular, student success in key courses in the engineering curriculum was identified as relevant. Specifically, Chemistry 1, Physics I, Pre-Calculus, Calculus I, Calculus II, Statics, and Electrical Circuits were selected for further study. It was also determined to consider the impact that time to graduation could have, since students placed in Pre-Calculus were also facing academic programs that would be difficult to finish in four years without taking summer courses or delaying graduation by at least a semester, both of which could have significant financial implications. Most courses at Gonzaga have a D or better grade requirement except for Math classes, which use a C- minimum grade for courses that are a prerequisite to another math class. The grades in the dataset represent the highest grade the student received in the courses. Unfortunately, the data did not capture the number of times a course was repeated.

The average course GPAs were first grouped by time to graduation rate, categorizing students as current students who have not graduated and those who took 4, 5, and 6 years to graduate. The results of this analysis are shown in Figure 5. The students represented in Figure 5 include all students who entered as SEAS majors from 2012 to 2024 who took that course before January 2025, regardless of whether they remained in an engineering major. As expected, average course GPAs declined as the time to graduation increased. The impacts of time to graduation on course GPAs seemed particularly noticeable in the Statics course. Because the data did not provide insight into how many times a course was repeated, it was not able to be determined how repeated courses impacted time to graduate but anecdotally students in the engineering majors do not tend to take reduced course loads to offset lower academic performance.

The average course GPAs were calculated for students who were initially placed in Pre-Calculus, Calculus I, or Calculus II or above. The results, as shown in Figure 6, were as expected: students with higher initial math placement received higher grades than those with lower math placement. It was noted that the effects of math readiness were prevalent even in Chemistry I, which doesn't require the same advanced math skills as the other courses, indicating that the issues may be more about overall academic readiness than just math readiness alone. It was also noticed that the GPAs in Calculus I for students who took Pre-Calculus were lower than those who were initially placed in Calculus I, which may indicate the need for the Pre-Calculus course to be adjusted to better prepare students for Calculus courses.

Figure 5. Average Course GPAs by Time to Graduation

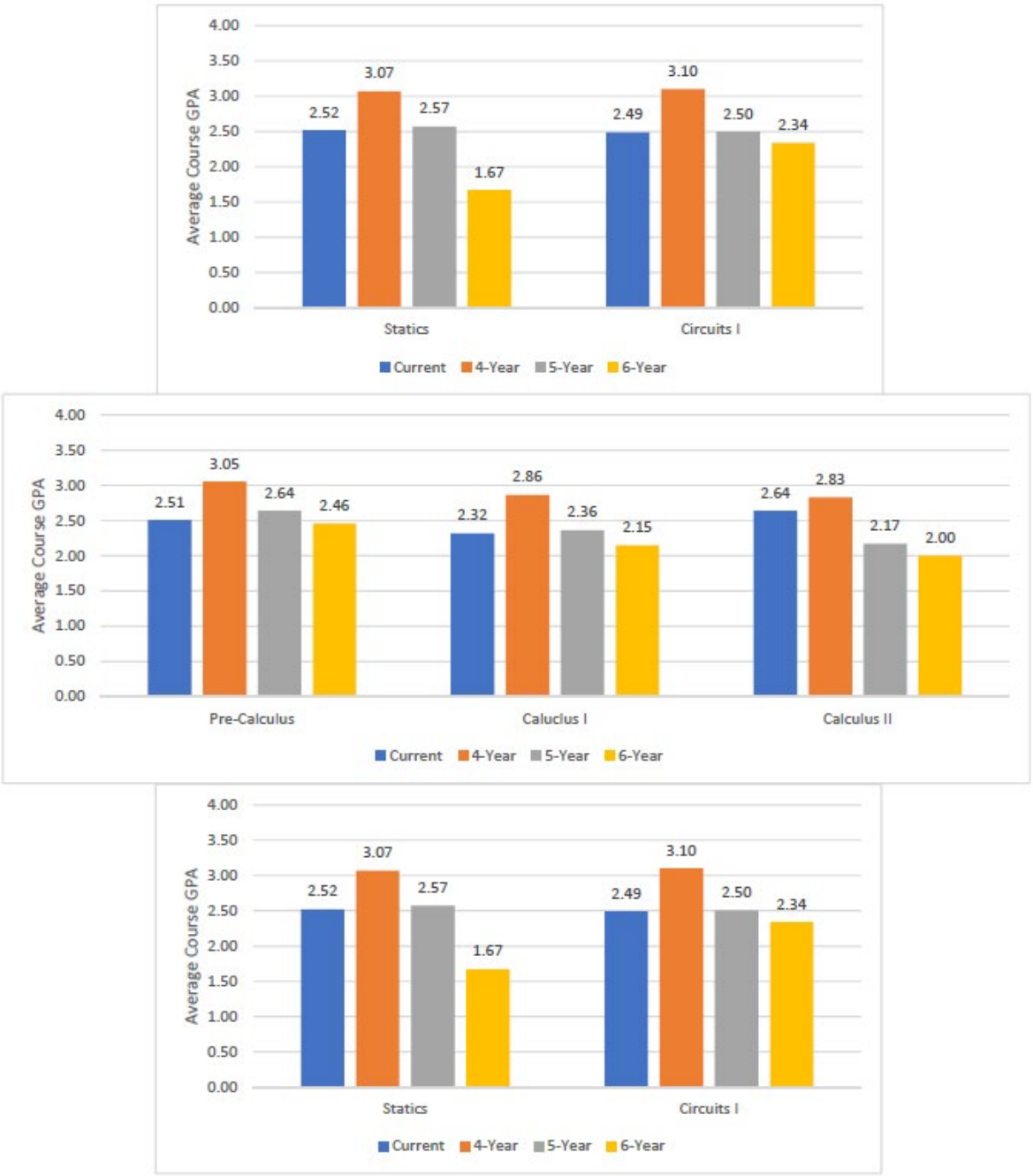
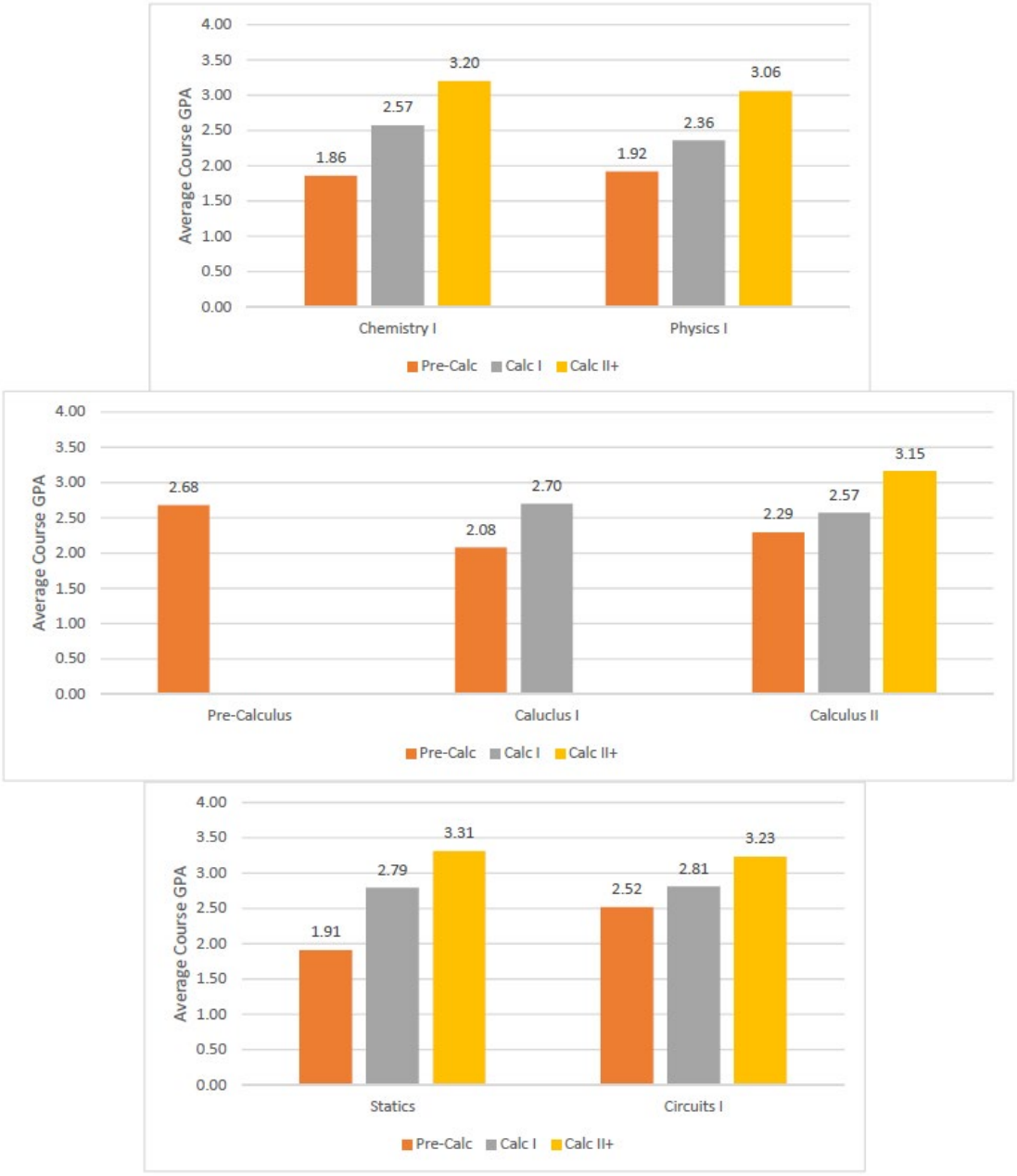
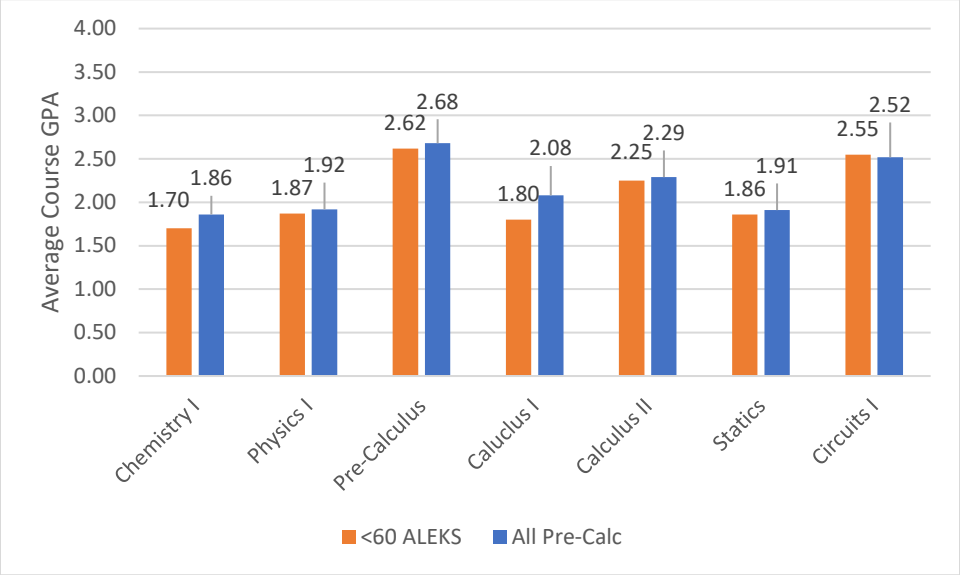


Figure 6. Average Course GPA by Initial Math Placement



Gonzaga does not currently have a policy for placing engineering students below Pre-Calculus. Historically, this was not an issue because direct admission standards would not allow many students into SEAS who were not Calculus I ready. With the removal of direct admissions, the question arises whether additional math placement thresholds should be added. The analysis of course GPAs was performed again, but this time the students were limited to those who scored below 60 on the math exam. As shown in Figure 7, the slight impacts of very low math placement exam scores can be seen in all the courses except Circuits. The largest differences between all the Pre-Calculus placed students and those with a score below 60 were seen in Chemistry (0.16 average GPA reduction), and Calculus I (0.28 average GPA reduction). These results indicate that there may need for setting additional ALEKS thresholds for math placement.

Figure 7. Average Course GPAs for ALEKS Scores <60 Pre-Calc versus All Pre-Calc Placed Students



Conclusions and Future Work

The results show increasing trends in the percentage of students being placed in pre-calculus along with reductions in retention for students initially placed in pre-calculus. The results also indicate a continuing downward trend in retention since COVID. The results also showed that students placed in pre-calculus had lower GPAs in key courses than students placed higher, even in Chemistry, which is not a math intensive course which indicates that academic readiness likely extends beyond mathematics. Lastly, the math placement scores indicate that exploration of thresholds to identify students who may not be ready for pre-calculus may be necessary.

The early results clearly indicate a need for the development of mitigation strategies to address the math readiness of incoming engineering students. Additional investigation into the relationship between math placement scores and course GPAs will be conducted to refine possible new and/or additional thresholds for math placement. As the COVID-impacted students continue to progress through the programs, the effects on time to graduation and retention will be monitored. As mentioned previously, the data in this study currently do not consider the socioeconomic factors of the students, but this may be added as the demographics of incoming students change and the longer-term impacts of COVID on the K-12 system continue to be felt.

The insights gained from this work will be used to inform the development of academic support and retention programs within SEAS. A 2022 ASEE workshop outlined a retention program that included a range of student-focused strategies, including summer bridge programs, the use of e-portfolios to reflect on learning, collaborative courses that supplement the more challenging first-year courses like Calculus and Physics, monthly social learning communities, progress reports, community volunteer activities, and program coaching [7].

This project was reviewed by the Gonzaga IRB received exempt status under 45 CFR 46.101(b).

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