2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33708

Promoting Success of Undergraduate Engineering Students Through Curricular Improvements in First-year Mathematics Courses

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Abstract

Norwich University, a private military college that serves both civilian and Corps of Cadets students, secured an NSF S-STEM award to develop a program to attract and retain highly talented, low-income students. Norwich recognizes that students who enter college with less experience in mathematics are less likely to graduate with a degree in a STEM discipline. With that in mind, the project aims to measure the benefits of a corequisite implementation of precalculus and calculus to help students complete the required calculus sequence by the end of their first year. In the first year of the study, 34 engineering students among 72 total STEM students that placed into precalculus by an institutional math placement exam were randomly allocated into either precalculus or a pilot corequisite calculus course with precalculus review. The content, delivery, and outcomes of the first semester offering of the corequisite implementation of precalculus and calculus will be discussed. The short-term success of the corequisite course using survey results, DFW rates, and retention in the engineering major will be examined.

Introduction

High school students interested in STEM (science, technology, engineering, and mathematics) disciplines are entering college unprepared to take calculus during their first semester at college. While many incoming college students are taking the prerequisite courses for calculus in high school, there are a growing number of students who either choose or are placed in college classes below the calculus level [1]. Despite success in precalculus in high school, many students across the country are not successful in the college level precalculus course. Even if the students are successful in precalculus (e.g., receiving a B or above), many do not go on to take calculus or fail to be successful in calculus [1, 2]. Single variable calculus is a major gatekeeper for students who want to pursue degrees in STEM [3]. The national trend of high attrition in university-level precalculus and calculus highlights the need to continue to assess and build on the best practices to strengthen these courses and increase students' success in STEM [4].

Efforts to reform courses before calculus have been discussed since the 1990s by the Mathematical Association of American [5]. During this time, there has been an increase in remedial mathematics courses such as precalculus in colleges across the United States but these courses fail to reach their educational potential to increase students' success in calculus [4]. The prevalent use of remedial mathematics courses has been found to delay STEM students' progress toward degrees and impede students from completing a STEM degree and entering the workforce [2, 3, 4].

According to a report from the Executive Office of the President (EOP) in 2014, low-income students are more likely to need remediation courses upon entering college. The report highlights that remediation courses designed with the intent to help students succeed are, in fact, more likely to prevent students from matriculating into college level courses, in part due to the additional time and costs associated with taking the courses. Evidence suggests the negative impact of these remedial supports increases the equity gap and reduces participation and success in STEM-related careers for underserved and underrepresented student groups [6, 7]. Recent reform efforts have replaced extended developmental mathematics sequences with accelerated corequisite models [6].

The corequisite approach has been found to be cost-effective and ensures better alignment between the needed academic support and the requirements of college level mathematics courses [6, 8]. Many states, such as Tennessee and California, have recently enacted widespread implementation of corequisite models across their states' college system [7]. It has been found that participation in accelerated remedial courses can promote persistence and academic success [9]. In particular, data demonstrate improved pass rates and retention for students in corequisite models in comparison to those in remedial mathematics models, and corequisite models shrink the equity gap [6, 7].

Recommendations are to scale up the programs that have shown promise of success and expand the evidence of what works [10]. An objective of the National Science Foundation (NSF) S-STEM program is for researchers to add to the knowledge of evidence-based practices to improve STEM education, with a focus on practices that increase success of low-income students. Our institution found that our students followed the national trend, meaning those that enter college with less experience in mathematics were less likely to graduate with a degree in a STEM discipline. This particularly impacted students who were considered low-income. A research objective of the Norwich University S-STEM award is to implement and assess a corequisite course model of precalculus and calculus to keep students on track to complete STEM degrees within four years. This corequisite course model allows the delivery of the content of calculus with contextualized instruction of precalculus as needed. It is hypothesized that the corequisite course will deliver the necessary content of both precalculus and calculus while retaining students in STEM and keeping students on track with respect to their curriculum maps.

Background

Norwich University (NU), founded by Captain Alden Partridge, is the oldest Senior Military College in the country and is known as the first private college to teach civil engineering in the United States. Norwich, located in central Vermont, is a small, community oriented, private, non-profit institution with approximately 2,500 campus-based undergraduates from across the U.S. and around the world. The University provides a unique learning environment that delivers a liberal arts and professional education to both civilian (~40% of undergraduate students) and Corps of Cadets students (~60% of undergraduates).

According to the Integrated Postsecondary Education Data System (IPEDS) demographic data from Fall 2019, approximately 81% of NU's undergraduate students are full-time, 83% are from out-of-state, 25% are female, 31% are non-white, 10% are Hispanic/Latino, and 32% receive Pell Grants. Of the full-time, first-time degree seeking undergraduates who entered in 2011-12, 61% received a Bachelor's degree from Norwich (IPEDS). The graduation rate for Pell Grant recipients was 48%, in contrast to 66% graduation rate of non-Pell grant recipients (IPEDS).

The academic undergraduate residential programs at Norwich University offer traditional STEM majors such as biology, biochemistry, chemistry, civil engineering, computer science, computer security and information assurance, electrical and computer engineering, general engineering, mathematics, mechanical engineering, and physics. Based on internal data, approximately 26.9% of all undergraduates were STEM majors in Fall 2019 (13.7% engineering). The number of bachelor awards conferred in 2019-2020 for STEM degrees was 20.4% of all degrees conferred (8.4% for engineering) (IPEDS).

Students are enrolled in their first-semester mathematics course based on their performance on a departmental mathematics placement test (MPT) and their chosen program of study. The mathematics department has administered the MPT to incoming freshman for over 20 years. It is a self-administered, online, 90 minute, multiple-choice exam that students take during the summer prior to their freshman year [11]. The MPT scores place students into four levels: 0, 1, 2, or 3. STEM students that are placed into precalculus have a score of level 2 on the MPT and STEM students with level 3 are placed into a first semester calculus course. Of the STEM students entering Norwich University in Fall 2020, 49.5% of the students were placed into precalculus, whereas, 27.4% were placed into calculus. The remaining 23.1% were placed in college algebra or lower. For the engineering majors admitted in the fall of 2020 (n = 91), approximately 42.8% placed into precalculus (MPT = 2), 40.7% had a MPT of 3, and 16.5% placed into college algebra or lower (MPT = 0, 1).

Methodology

Corequisite Course Design

The designers of the course were mindful of the concern that corequisite models may decrease the standards of the college level course when under-prepared students are included (Unfried, 2019). The corequisite course was a blend of calculus and precalculus with particular attention paid to maintaining rigor in all the topics of calculus. The pilot corequisite course required an additional 2 credit hours to provide the contextualized instruction of precalculus in conjunction with the standard 4-credit calculus course.

The intent was not to teach a few intense weeks of precalculus followed by calculus content, but rather teach the precalculus content across the semester. Not all topics covered in our traditional precalculus course were covered in the corequisite course. However, the precalculus content needed to be thorough since the course was not considered a review of precalculus but rather a course teaching some topics like trigonometry or logarithms for the first time. Additionally, the department's learning objectives for precalculus needed to be met so the high-level concepts from precalculus were included to ensure the future success of students in both calculus and other STEM courses. This resulted in a cyclic approach to teaching calculus where the elements of calculus (limits, derivatives, and integrals) were used to motivate precalculus topics. The corequisite course first focused on limits, derivatives, and integrals on algebraic and piecewise defined functions, then revisited these topics using exponential/logarithmic functions and trigonometric functions (Table 1).

Table 1: Course content for the corequisite course of precalculus/calculus in comparison to the traditional calculus course.

Traditional Calculus	Corequisite Calculus
Limits	Limits and Differentiation (only polynomials and algebraic functions)
Differentiation	Antiderivatives and Integration (only polynomials and algebraic functions)
Derivatives of trigonometric functions	Exponential and logarithmic functions
Derivatives of exponential and logarithmic Functions	Limits, Derivatives, Integration of exponential and logarithmic functions
Antiderivatives	Trigonometry
Integration	Limits, Derivatives, Integration of trigonometric functions

Experimental Design

Data were collected from two experimental groups. The control group consisted of students enrolled in a traditional precalculus course and the treatment group were the students enrolled in the corequisite precalculus/calculus course. The population of students randomly allocated to the experimental groups had a level 2 on the MPT and required a second semester of calculus for their chosen program of study that included biochemistry, chemistry, civil engineering, electrical and computer engineering, general engineering, neuroscience, mathematics, mechanical engineering, or physics. Working with the Registrar's Office, these students were randomly assigned to the treatment and control groups resulting in 36 students enrolled in the traditional implementation of precalculus and 36 students enrolled in the corequisite implementation of precalculus/calculus.

In the fall of 2020, two mathematics faculty members each taught one section of traditional precalculus and one section of the corequisite implementation of precalculus/calculus (Figure 1). The following semester, the same faculty members taught calculus to students in the previous traditional precalculus course. The same approach will be used in the second year of the study.

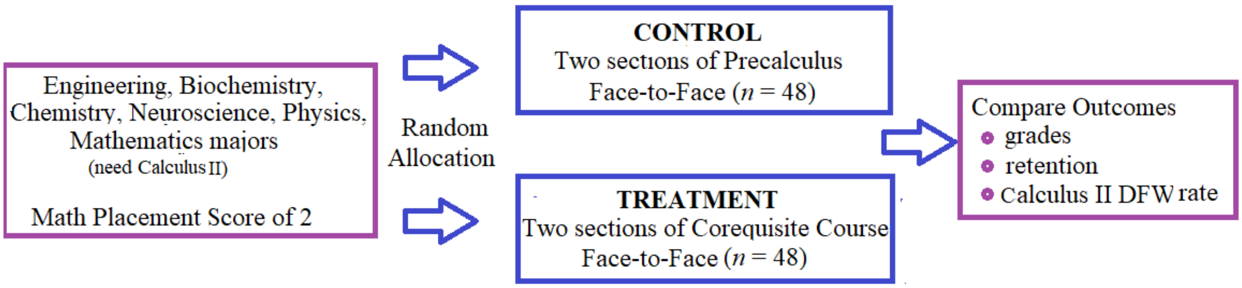

Figure 1: The intended experimental design of the implementation for year 1 (Fall 2020) for measuring the success of the corequisite model in comparison to traditional precalculus.

The study was implemented during the summer and the fall semester following the shutdown of colleges across the U.S. in March 2020 due to the global pandemic. COVID-19 restrictions prevented many key stakeholders from being on campus. As a result, there were challenges in implementing the experimental design of the study, especially with communication across campus during the summer freshman registration period. Despite attempts at clear communication, some students, administrative staff, and academic advisors were confused about the design and the intent of the corequisite course. Freshman STEM majors commonly enroll in laboratory science classes making it difficult to schedule these laboratory courses around the 6-credit corequisite course. Furthermore, overall freshman enrollment at the university was lower than expected based on previous years.

As a result, there was not a uniform distribution of majors for the students in the precalculus courses (control) and the corequisite courses (treatment) (Table 2). In particular, the precalculus classes had higher enrollment of undecided (historically at NU, these students do not perform as well) and non-matriculated students (early college students that historically perform well). In addition, some non-STEM majors were enrolled in the courses. The undecided, non-matriculated, and non-STEM students were removed from analysis.

Table 2: Distribution of students in the two experimental groups of the study.

	CONTROL **Precalculus** (2 sections)	**TREATMENT** **Corequisite Course** (2 sections)
NU S-STEM Major (bio, biochem, chem, neuro, physics, math)	4	8
Engineering	10	24
Other	2	2
Undecided	12	1
Non-matriculated (HS students taking college courses)	8	1
Total	36	36

In addition to the control and treatment groups, comparisons with students that placed into a first semester calculus course were included. Students in this group had a level 3 on the MPT and a declared major of biochemistry, chemistry, civil engineering, electrical and computer engineering, general engineering, neuroscience, mathematics, mechanical engineering, or physics at entry to the institution. While these students shared common majors with both experimental groups, the math placement test suggests they had a higher level of mathematics preparation in high school. It is important to note that students in the first semester calculus course were taught by different instructors than the experimental groups and there was no oversight in this study to the method of instruction and assessments used for these courses.

Returning to campus under COVID-19 restrictions posed some challenges in offering mathematics courses to the first year students. During the fall semester, Norwich offered face-to-face hybrid instruction as well as remote instruction. COVID-19 restrictions reduced the occupancy in classrooms across campus so students alternated between face-to-face sessions and remote participation. Additionally, during the 11th week of the semester, all face-to-face and hybrid courses were changed to fully remote instruction. Face-to-face hybrid and remote instruction for both experimental groups was similar; synchronous class meetings were still held for both experimental groups in the study and remote exams were not proctored. However, instruction methods varied for those students enrolled in Calculus I during the fall semester. The intention for the spring semester was to offer hybrid classes following the methods used in the fall. However, due to an increased caseload of the coronavirus when students returned to campus after the winter break, all classes were offered remotely. Spring instruction varied from synchronous to asynchronous remote classes among the mathematics courses. Remote assessment strategies varied among instructors.

Metrics for comparing outcomes between the two experimental groups and students enrolled in Calculus I during the fall semester include survey results, DFW rates (percentage of students who received either a D, F or withdrew from the course) in the first semester courses and the subsequent mathematics courses, and retention rates in both students' major and at the institution. Survey data were collected by external consultants and the design was approved by the Norwich University Institutional Review Board. Course grades and retention in majors were collected from the BannerWeb system and analyzed using R. Institutional data were collected within one week of the end of both the fall and spring semesters.

The control and treatment groups had similar grading scales throughout the fall semester; 70% of the grade was determined by hourly exams and 30% of the grade was determined by homework and quizzes. Due to the challenges of remote learning, for the students in the control group that enrolled in Calculus I in the spring, the grading scale was changed to 50% of the grade determined by hourly exams and 50% of the grade determined by low stakes assignments. Assessments in the course offerings outside of the study (fall sections of Calculus I and the spring sections of Calculus II) varied.

Survey Instruments

In December 2020, a survey was distributed to all students currently enrolled in either the traditional precalculus (control) or corequisite precalculus/calculus (treatment) mathematics course and the S-STEM scholarship recipients. Demographic information, including household income and first-generation college student status was collected, in addition to information on students' high school math preparation, attitudes toward the current math course, and strength of their identification as a STEM major.

Of 79 surveys distributed, 26 were completed. The survey was left open for five weeks, with six reminders sent at random intervals (between 3 and 13 days) to students who had not yet submitted the survey. Reminders were distributed on different days of the week and at different times of day to maximize participation. While a response rate of 32.9% is not optimal, no statistically significant differences were found between the demographic information of respondents in the treatment group versus the control group (gender identification, race/ethnicity, household income, first-generation status) minimizing the chance of differences in survey results due to the composition of the groups. However, survey results may not be generalizable to all students in the study.

A number of factors may have affected students' survey completion. First, the intent was to administer the survey during face-to-face class sessions with the students; however, in the fall Norwich made an immediate decision to transfer to remote learning a week prior to the planned date, so students returned home earlier than expected. The distribution of the survey was through email only. Second, because the survey was distributed after students went home and during the week preceding full term final exams, students may have been focused on studying and/or less likely to check their Norwich email accounts. Finally, anecdotal information indicates that students were overly fatigued at the end of the Fall 2020 semester, as COVID-19 requirements and restrictions increased feelings of isolation and anxiety, and safety concerns.

A comparable survey was distributed in April 2021 to all first-year students majoring in biochemistry, chemistry, civil engineering, electrical and computer engineering, general engineering, neuroscience, mathematics, mechanical engineering, or physics at admission to the university and enrolled in any mathematics course in Spring 2021. Most items from the Fall 2020 survey were repeated, and items were added to assess students' current attitudes, majors, and identification with STEM. Of 265 surveys distributed, 75 were completed (response rate: 28.3%). Six reminders were sent over a period of 11 days. As surveys were distributed immediately before final exams, similar factors are believed to have contributed to the low response rate. Again, no statistically significant demographic differences were found among students who completed the survey from the treatment versus control group.

Survey records were matched by unique identifiers assigned to email addresses, which were then deleted. Matching records not only provided longitudinal data for some students across semesters but also allowed us to check the consistency of self-reported demographic information and fill in missing fields for some common items completed in one semester but not another. Three records from Spring 2021 and one from Fall 2020 were excluded because students either did not agree to participate or were younger than 18 years. One record from Spring 2021 was excluded because it was incomplete. After matching and removing records accordingly, 23 records remained for Fall 2020 and 69 for Spring 2021 (11 of these were common across semesters).

Since survey data for any given item were limited, descriptive statistics are provided here in addition to nonparametric analyses, as appropriate. The Kruskal Wallis test, in particular, was employed as an alternative to other analyses of variance for determining group differences. All analyses were executed in R. In future semesters, as additional data are collected and response rates improved, the aim is to conduct more complex analyses in order to compare treatment and control groups in greater depth across semesters and to follow the corequisite precalculus/calculus (treatment) group and S-STEM scholarship recipients over time.

Focus Groups

Focus groups were conducted in December 2020 and January 2021 to obtain students' perspectives of the precalculus/calculus corequisite course and to contextualize the quantitative data presented here. All participants have been deidentified to protect their anonymity.

Focus group participants were sampled from the students enrolled in the corequisite course (treatment group) only. The students sampled were from two strata; students with high performance at the time of selection (B- or above) and those with low performance. Students were reluctant to participate at the end of fall semester so the focus group sessions were eventually opened up to all students in the two sections of the corequisite course. Six students from one section participated and two from the other section. There was a range of grade distribution for these students, with five of the eight in the high performance strata and three in the low performance strata. Focus groups were held virtually.

All sessions were transcribed and an evaluation rubric guided the evaluator's categorizing the data. This resulted in 40 categories, of which seven categories did not draw from the evaluation rubric. The quotes presented here exemplify the highest frequency categories.

Results

Placement and Preparedness

One question germane to NU's efforts to improve access and instruction for STEM majors who place into precalculus is whether the MPT ensures appropriate math placement. Survey results indicate that, in general, students felt prepared for their first mathematics course at the university. Across semesters, in response to the item, "I was underprepared to take the first mathematics course I was enrolled in in my first semester at Norwich University," 86.7% responded "disagree" or "strongly disagree", and 13.3% "agree" or "strongly agree" ($n = 75$, excluding neutral responses). No statistically significant differences were found among students by demographic characteristics, including gender identification, race, first-generation status ($p = 0.095$), or household income ($p = 0.08$); mathematics level prior to enrollment; or treatment/control group status.

One student in the corequisite course who participated in the Fall 2020 focus group demonstrated that their placement in precalculus was the right fit. Although the student took calculus in high school, a refresher course in precalculus was helpful, as was a different style of teaching. The student said,

> I thought it was a very good course. I took calculus in high school, but I did not do very well. My instructor was not very good. It really helped me to be able to go through it again and refresh on some of the precalculus concepts while also getting a different style of teaching on the calculus.

Excluding neutral responses to the item, “I found the [current semester] mathematics course to be very challenging,” 3 of 10 students (33.3%) in the traditional precalculus and corequisite courses in Fall 2020 responded “agree” or “strongly agree”; seven responded, “disagree” or “strongly disagree.” In Spring 2021, nine of 11 students (81.8%) responded “agree” or “strongly agree,” and two responded “disagree” or “strongly disagree.” While the numbers of responses available to address these questions are low, note that the Spring 2021 responses closely mirror student responses across *all* math classes (81.1% “agree” or “strongly agree,” 18.9% “disagree” or “strongly disagree;” $n = 37$).

Students in the corequisite course who participated in the Fall 2020 focus group frequently mentioned the conceptual knowledge they gained that they believed prepared them for a second semester of calculus. One student said, “I know there are some concepts that I learned in high school, but I did not remember them at all when I came to this course. Now I feel I really grasped them. That helps a lot.” Another said:

> While I took calculus in high school, I felt my teacher pushed a lot of work on us there. We had a lot of problems. I just survived and got it done. I didn't feel I actually learned the concepts, whereas when I took this calculus course, I really understood the concepts. I feel like that better prepared me for going to Calculus II.

In response to the Fall 2020 item, “The mathematics course I took this semester adequately prepared me for the next mathematics course,” 14 of 15 students (93.3%) in the treatment and control groups responded “agree” or “strongly agree;” one student responded, “strongly disagree.” When including those students who responded only to the Spring 2021 survey (treatment/control students reporting their preparedness for Fall 2021), 30 of 34 students (88.2%) responded “agree” or “strongly agree,” four responded “disagree” or “strongly disagree.” No statistically significant differences in perceived preparedness were found between the treatment and control groups.

Despite the two additional credits added to the corequisite course, students also felt that the workload was manageable. One student said “The workload was the perfect amount”. Two other students noted:

> Student 1: I also thought the course was structured really well. Meeting four times a week was very beneficial because you always had those concepts solidified. The way that we have to take a quiz every week based off the homework is a really good way to measure your understanding of the concepts.

> Student 2: I definitely thought it was manageable. It was enough that you would get enough exposure to the concepts to understand it, but it wasn't so much that you were struggling to finish it, or at least I wasn't struggling to finish it.

Attitudes

Excluding neutral responses, 12 of 14 students (87.5%) in the traditional precalculus or corequisite courses responded “agree” or “strongly agree” to the Fall 2020 item, “The mathematics course I took improved my confidence in my mathematics ability. Two responded “disagree” or “strongly disagree.” No statistically significant differences were found in students’ confidence between the treatment and control groups.

One student in the Fall 2020 focus group described how the corequisite course improved confidence in their mathematical abilities. They said,

> I've been exposed to these concepts before. I had a surface level understanding of them. After taking this course, I feel like I understand them at a much deeper level. I feel much more confident in my abilities to do them.

Similarly, in response to the item, “How do you feel about the [Fall 2020] mathematics course compared to the other courses you are taking this semester?” 14 of 15 students (93.3%) reported “positive” or “very positive.” One reported “very negative.” No statistically significant differences in attitudes were found between the treatment and control groups.

Finally, in responding to the item, “How strong, if at all, is your identity as a STEM major?” all of the students surveyed in Fall 2020 and Spring 2021, excluding those not majoring in STEM, answered, “slightly strong” to “extremely strong.” No statistically significant differences were found in level of identification between the treatment and control groups.

Grades

Using the DFW rate in each of the courses, the students’ performance during the Fall 2020 semester was comparable (Figure 2). The DFW rate identifies the proportion of students receiving letter grades of D or F and those students who Withdraw from a course without earning a final letter grade. Recall that there were 36 students in the traditional precalculus courses and 36 students in the corequisite courses, but undecided, non-matriculated, and non-STEM students were removed from analysis. Furthermore, DFW rates were examined for students that major in engineering as well as STEM majors, those students in engineering, biochemistry, chemistry, neuroscience, mathematics, and physics. The DFW rate was slightly lower in the corequisite course (treatment) in comparison to the standard calculus class for the engineering students (all STEM majors as well). Recall, hybrid instruction and grade determination were similar for the experimental groups. The first semester calculus courses in Fall 2020 were taught by instructors not involved in the study.

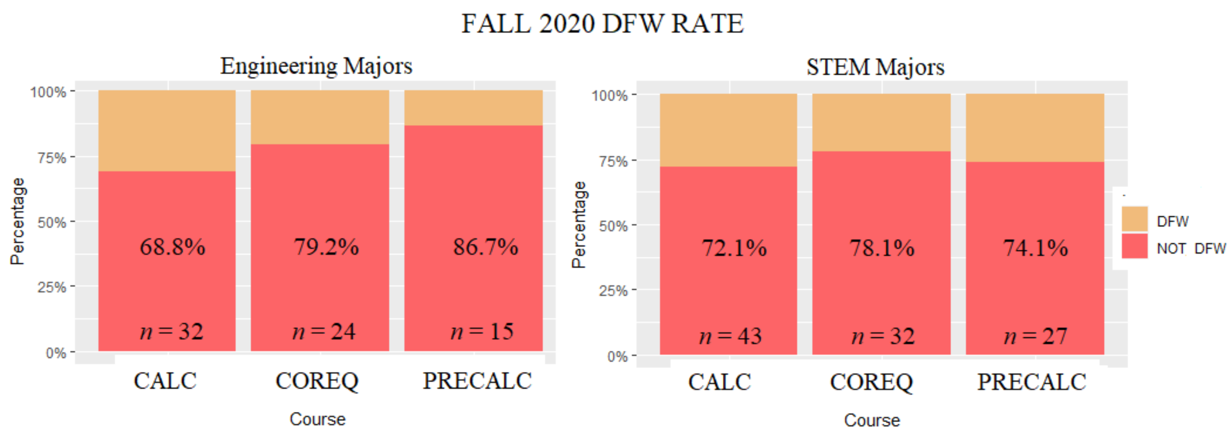

Figure 2: A comparison of the DFW rate for the two experimental groups (precalc as the control and coreq as the treatment group) and students in a first semester calculus course (calc). The graph on the left includes only engineering students; whereas, the graph on the right includes engineering and biochemistry, chemistry, neuroscience, mathematics, and physics majors.

Comparison of the performance of the two experimental groups in subsequent courses will require additional analysis in the future. The control and experimental groups have similar characteristics and mathematics background; however, the precalculus students (control) have not yet completed a second semester of calculus so a comparison of the success in Calculus II cannot be completed at this time. Currently, the DFW rate in the subsequent mathematics courses during the Spring 2021 semester for the students in three comparison groups among engineering and STEM majors are compared (Figure 3). For engineering majors, the students in calculus and the corequisite course had a comparable DFW rate in the subsequent mathematics course, namely the second semester of calculus. In contrast, for all STEM majors, the DFW rate is higher in the subsequent mathematics course for students who took the Fall 2020 corequisite course than those who took the Fall 2020 calculus course.

The percentage of students that enrolled in the subsequent mathematics course varied among the study groups (control – precalc and treatment – corequisite) and the first semester calculus course. This is due, in part, to the higher retention rate for the students in the first semester calculus course.

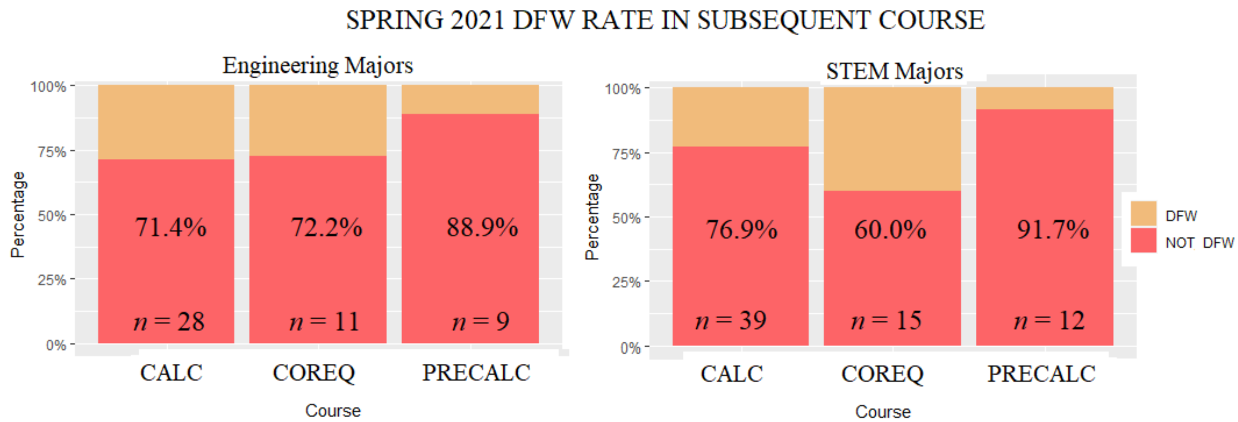

Figure 3: A comparison of the DFW rate in the subsequent mathematics course during the spring semester for the two experimental groups (precalc as the control and coreq as the treatment group) and students in a first semester calculus course (calc). The graph on the left includes only engineering students; whereas, the graph on the right includes engineering and biochemistry, chemistry, neuroscience, mathematics, and physics majors. Students that may have repeated a course are included in this analysis.

Retention

Retention measures, at this point of time, were limited to retention through the end of the spring semester. For the retention metric within majors, a student may change their major at any point during the academic year and these changes were captured as long as the change occurred prior to the end of the spring semester. Students who took the corequisite course had the lowest retention rate within a STEM major among the three groups. Again, only the control and experimental groups have similar characteristics and mathematics background. As with the DFW rate in the second semester of calculus, the comparison of the retention of the two experimental groups will be analyzed in the future after the precalculus students complete the second semester of calculus.

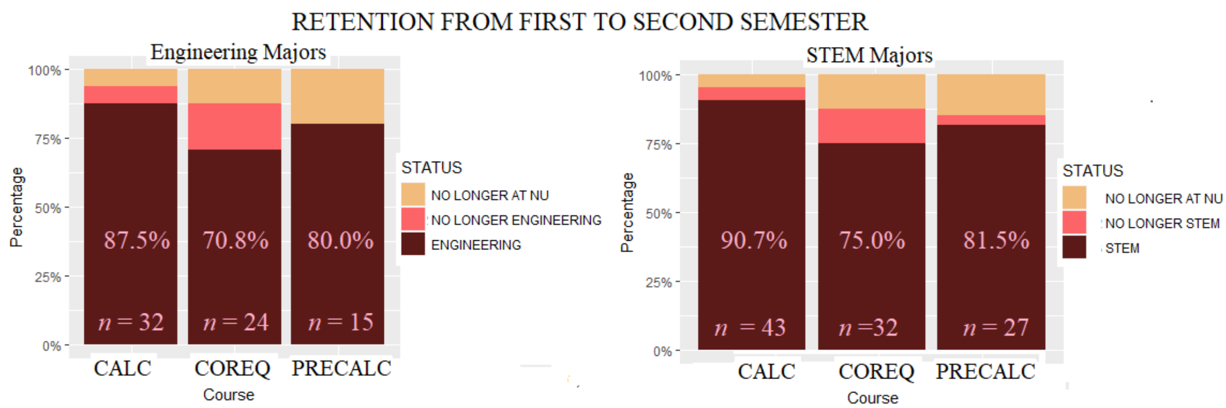

Figure 4: Retention rates for both the major and the institution for the two experimental groups (precalc as the control and coreq as the treatment group) and students in a first semester calculus course (calc). The graph on the left includes only engineering students; whereas, the graph on the right includes engineering and biochemistry, chemistry, neuroscience, mathematics, and physics majors. Students that changed majors within the broader grouping of engineering and STEM were included in the numerator of the retention rate.

Discussion

The biggest challenge in this study was the pandemic. COVID-19 limited in-person instruction and increased the academic workload for students and faculty alike. Student mental health issues were exacerbated by COVID-19. Additionally, social distancing restrictions limited coordination between instructors and course designers and required the use of hybrid and remote instruction.

The hypothesis is that this corequisite course could improve retention and graduation rates for low-income students. The plan was to rely heavily on survey data from student participants for socioeconomic information. Unfortunately, there was a low responses rate on our survey and focus groups. This made it a challenge to tie outcomes to income levels. This study will be replicated next semester with the intent to gather some pertinent data at the beginning of the semester and make a clearer connection of the results to socioeconomic status.

There is concern for the next implementation of the study that a 6-credit course has a large impact on the workload and GPA of students. The set-up of the corequisite course required assigning two course grades, a grade for both the 4-credit calculus course and for the 2-credit supplemental precalculus course. This past fall, survey results and focus groups suggest this was not an issue for the students; however, they may feel differently when classroom capacities are no longer an issue and students will attend 6 hours of face-to-face instruction.

Instructors noted that most students enrolled in the corequisite courses seemed to have previous knowledge of topics such as trigonometry and exponentials/logarithms. The course was designed and taught under the assumption that students may not have seen these topics rather than treating it as a review. Perhaps a more robust assessment of students' skills is needed and the course be redesigned to meet their needs. The course could potentially have less emphasis on teaching the precalculus topics and more of a focus on problem solving skills. This may also indicate the institution is not properly placing students into the first year mathematics courses and there is a need for improvements to our math placement test. Results from surveys and focus groups indicate that students believed that they were placed properly into mathematics courses, but further studies need to be done to assess students' perceived self-efficacy and the institutional placement test.

Survey and focus group results suggest students in general had a positive view of the precalculus/calculus corequisite course. Anecdotally, there seemed to be increased engagement in the corequisite courses in comparison to the precalculus courses. Due to the cyclic approach to teaching the corequisite courses, all exams were cumulative and demonstrated student mastery of the concepts of limits, differentiation, and integration. Based on the distribution of grades, preliminary outcome measures indicate that the corequisite course has not hindered the students' ability to learn calculus but has kept most students on track with respect to the curriculum maps.

Results are preliminary and further study is needed to fully assess the benefit of the corequisite course. Initial results suggest that the corequisite course did not significantly hinder students' progression through the calculus sequence. Tracking of these students is planned to understand the long term effects of the corequisite precalculus/calculus course. Additionally, this course is scheduled to run again the following fall semester. The plan is to increase the study group to include computer science majors to increase the sample size of students in each of the experimental groups. Additional surveys may be used as well, one at the start of the semester to determine students' math background, and another to assess students' experience at the end of the semester. Improving assessment by designing a specific tool to compare outcomes between the corequisite course and calculus course will strengthen the findings. Lastly, tying these findings to the income status of students will also increase the evidence of the benefits of the corequisite implementation of precalculus and calculus to low income students.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant Number 1930263. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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