Engineering Calculus Bridge Program Success: Comparing Variation Results

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Abstract

The need for a diverse engineering workforce requires the recruitment and retention of university students from all ethnicities and both genders. Engineering calculus proficiency is critical to success in most engineering majors. The Department of Mathematics at Texas A&M University created a bridge program to support incoming freshmen by improving their mathematics understanding and skills. The prerequisite for enrolling in the first engineering calculus course was to answer correctly at least 22 of 33 questions on the Mathematics Placement Exam (MPE). In addition to the online practice problems, there was a synchronous online portion of 36 hours with a tutor. The goal of the Personalized Precalculus Program (PPP) was to improve a student's mathematics understanding and skills sufficiently to meet the cut score on the MPE, allowing him or her to enroll in the first engineering calculus course during the first semester. A requirement for enrolling in the first engineering course was successful completion or concurrent enrollment in the first engineering calculus course. The program has been successful in improving student scores on the Mathematics Placement Exam (MPE). Convincing students who were weak in mathematics to enroll and participate fully in the program has been an ongoing challenge. It was hypothesized that more students might participate fully if the duration of the bridge program were reduced. Therefore, after four years of providing the course over a 6-week period in the summer, a change in the format was implemented. The purpose of this study was to investigate whether participants in the 6-week program or the 3-week program improved MPE scores more and which group fared better in the first engineering calculus course.

I. Introduction

A variety of bridge programs to support engineering majors have been utilized for over 20 years. In particular, many have focused on mathematics interventions because of the importance of mathematics knowledge and skills in science and engineering courses required for successfully completing the coursework leading to a degree in engineering. Recruitment and retention of engineering students is vital to the progress of American economy and ability to solve problems to address the needs of an ever-changing technological world[1, 2]. College calculus success is highly correlated to engineering retention[3]. Bridge programs designed to increase success for engineering majors were popular in the 1990's but then waned to some degree. A thorough classification of programs in use was conducted in 2002, but insufficient data was reported for researchers to conduct a meta-analysis[4]. Several common characteristics of programs were noted: 1) bridge programs generally improve assessment scores, 2) most program are not compulsory and have difficulty recruiting students who need the intervention, and 3) mathematics is the most commonly addressed subject area. In 208 a meta-analysis of bridge programs focused on mathematics instruction was conducted[5]. Only 12 summer bridge programs for incoming engineering freshmen were identified for the study. Of those programs, 8 lasted 4-6 weeks, while one program was only one week. The one-week program involved approximately 8 hours a day of solving mathematics problems. The total time spent was comparable to the longer programs[6]. A high percentage of those completing the program increased their mathematics scores, although small percentages of eligible students actually participated in the programs[5, 6]. The first program located in the literature that incorporated an online format focused on precalculus instruction for four weeks, although other programs included computer-based instruction in a face-to-face format. The online format of the program was discontinued after two years because of low completion rates and minimal scores increases. In addition, students spent less time working on the mathematics. All but one of the programs was residential. Table 1 summarizes information about the bridge programs in the meta-analysis[5].

Table 1. Bridge program results.

Program Location: Name	**% Placed into Calculus (% of Control)**	**Duration**
Arizona State University: Women in Science & Engineering	Not reported	Not reported
Borough of Manhattan Community College/CUNY: STEM Talent Expansion Program	Not reported	Not reported
California State Polytechnic Institute, Pomona: Quest	Not reported	4 weeks
Clemson University: Math Excellence Workshop	78% (70%) N = 131	6 weeks
Morgan State University: Pre-Freshman Accelerated Curriculum in Engineering	70% (17%) N = 91	6 weeks
Old Dominion University: Engineering Learning Center	70% N = 25	Not reported
Pennsylvania State University: Pre-First Year Engineering & Science Program	Not reported	6 weeks
Purdue University: Mathematics Summer Bridge Program	87% (59%) N = 129	1 week
University of Alabama: Engineering Math Advancement Program	90% Not reported	5 weeks
University of Michigan-Dearborn: Summer Bridge	Not reported N = 68	4 weeks

Program		
University of Wisconsin-Milwaukee: Summer Bridge Program	25% N = 32	4 weeks
Virginia Polytechnic Institute and State University: ASPIRE	Not reported	5 weeks

Bridge programs continue to be introduced, with the aim of increasing retention in engineering by strengthening mathematics skills. More recent programs individualized mathematics instruction and practice through technology[7, 8]. Bridge programs have struggled with recruiting and retaining the students who most need their services. They often did not realize their need until after they were unsuccessful in college calculus. They tended to make just enough effort to hopefully be able to retake the placement exam and reach the cut score without completing the program[8]. Challenges to recruitment and retention include overcoming students' beliefs of understanding the material because they previously had it in high school. Additionally, they are advised by calculus students who downplay the importance of strengthening the precalculus background. Students also need to recognize that the probability of success in the calculus sequence is very low if they do not earn an A or B in Precalculus[8]. Another barrier to student success in college calculus is their lack of experience with appropriate learning strategies. Student surveys from the summer 2013 program showed that students overwhelmingly learned to solve mathematics problems in high school by imitating the teacher's solutions to specific types of problems; however, they believed they needed a different approach for college calculus[9]. Recent bridge programs at Texas A&M University have one significant difference from most online programs. They require sessions with a live, online tutor. Students meet with the tutor online and communicate through headphones. They work in groups or individually with an electronic whiteboard. They are then gathered back in the main room online so that the tutor can review the material.

II. Background and Description of Program

A large tier-one research university in the southwest United States, with an extensive, strong engineering program designed and implemented a program to retain prospective engineering majors through a summer bridge program that strengthened algebra and precalculus skills. Students were placed into Precalculus or Engineering Calculus I based on a mathematics placement exam (MPE). This exam was substantially on precalculus topics, including for example, trigonometry, a *gate*-keeper type topic in Engineering Calculus I. Students who were placed into Precalculus were given the opportunity to participate in the summer bridge program, Personalized Precalculus Program (PPP). If participants raised the MPE score to at least 22 out of 33 correct, they were allowed to enroll in engineering calculus I.

The PPP consisted of several components: four online categories of quizzes and practice problems, videos, PowerPoint documents, and live, online tutoring sessions. The online categories with their subcategories were as follows:

1. Graphs and Functions
   1.1 Foundations of Functions, Parent Functions, and Piecewise Functions
   1.2 Inverses of Functions
   1.3 1.3 Logarithms and Exponents
   1.4 Transformations and Composite Functions
   1.5 Basic Trigonometry
2. Factoring and Solving Equations and Inequalities
   2.1 Factoring
   2.2 Solving Equations and Inequalities
   2.3 Basic Trigonometry
3. Algebraic Fractions, Exponents, and Radicals
   3.1 Algebraic Fractions
   3.2 Exponents and Radicals
   3.3 Basic Trigonometry
4. Trigonometry
   4.1 The Unit Circle
   4.2 Right Triangle Trigonometry
   4.3 Trigonometric Identities
   4.4 Solving Trigonometric Equations

Regular online tutoring sessions were required for all students. This feature is unique to online bridge programs[10]. In cohorts of about 20 students each, they were assigned a tutor with whom they met for 36 hours during the program. Hiring capable tutors, preferable with high school and college teaching experience, was key to outcomes and retention in the program. For the years 2010-2013, they met 3 times a week for 2 hours each, (total of 6 hours per week) for 6 weeks. In 2014 and 2015, the program was changed to meet 12 hours a week for 3 weeks. The impetus for the change was that students tended to decline in attendance the last weeks of the program. Often, they would try to go ahead and retake the MPE with the hope of reaching the cut score and then dropping out of the PPP.

III. Purpose and Research Questions

The purpose of this study was to analyze results and impact of the 6-week program in 2011-2013 and the 3-week program in 2014-2015 and to compare the results of the two variations. The research questions were:
1) Did the 6-week or the 3-week program increase MPE scores more substantially?
2) Did participants of the 6-week or 3-week program perform better in their first college mathematics course?

IV. Methodology

Participants were all students who participated in the PPP during the summers of 2010 through 2015. The means and standard deviations of MPE scores before and after the program were computed, along with the average change in MPE scores for the students in the 6-week program (n = 226) and the students in the 3-week program (n = 288). Hedge's *g* effect sizes for the change in MPE scores were calculated and confidence intervals constructed. Then the difference in MPE scores gain for the two groups was tested to see if there was a statistically significant difference between the two groups.

V. Results

The results for the means and standard deviations for the MPE scores each year are shown in Table 2.

Table 2. Means and Standard Deviations for MPE Scores

	Mean of Pre-MPE (S.D.)	Mean of Post-MPE (S.D.)
6-week program (n = 305)	18.25 (2.79)	22.61 (5.06)
3-week program (n = 141)	18.03 (2.95)	24.02 (5.24)

Hedge's *g* effect size for change in MPE scores for the 6-week program was 1.067, which was statistically significant ($p < .01$) [0.90, 1.24]. For the 3-week program, the Hedge's *g* effect size was 1.405, which was also statistically significant ($p < .01$) with confidence interval [1.15, 1.67] indicating that students who participated into the 3-week program increased their MPE scores. Figure 1 gives a visual representation of the 95% confidence intervals for the MPE scores before the intervention (MPE_1) and after the intervention (MPE).

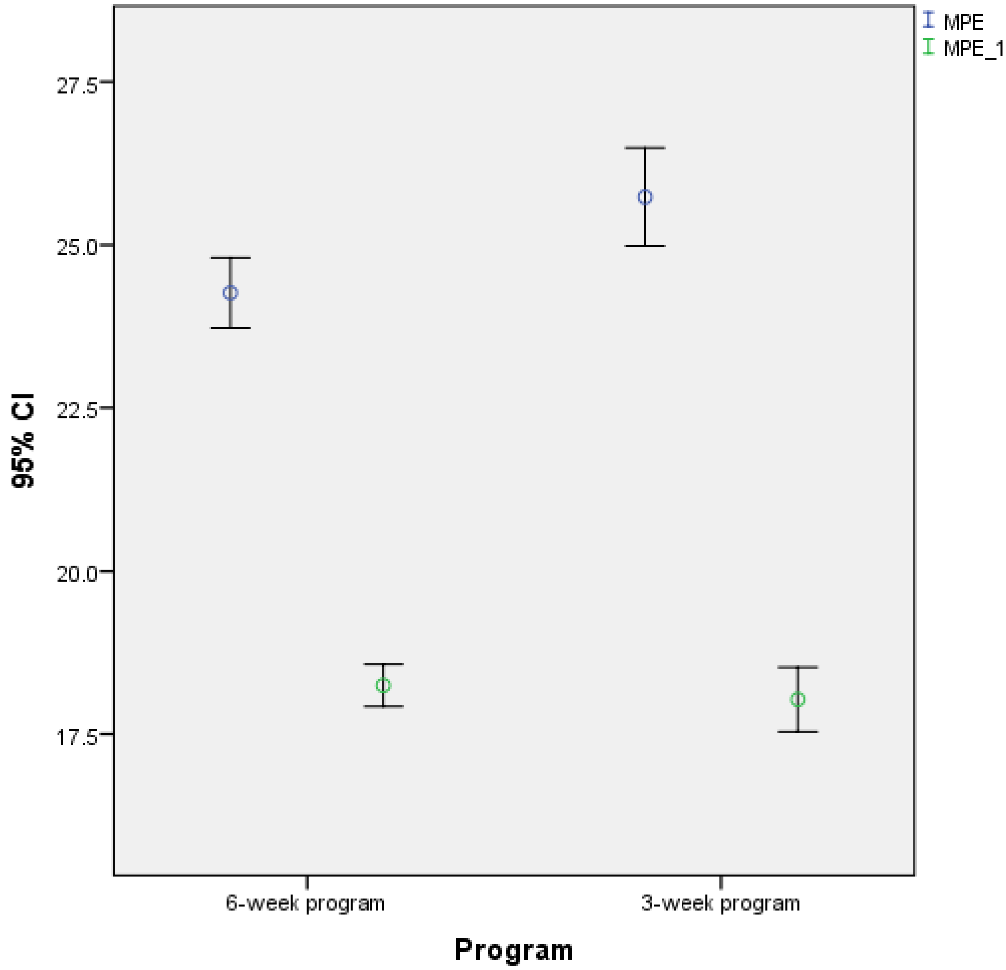

Figure 1. Confidence Interval for students' MPE and MPE-1 test scores.

Means and standard deviations for course grades are given in Table 3.

Table 3. Means and Standard Deviations for Engineering Calculus I Grades

	Mean of Course Grade (S.D.)
6-week program (n = 335)	1.97 (1.24)
3-week program (n = 117)	1.21 (1.24)

A *t*-test showed that the mean course grade difference was statistically significant ($p < .01$) between students who participated into 6-week program and students who participated into 3-week program. The confidence interval is shown in Figure 2. Hedges *g* effect size for the differences in the two programs was 0.610 with confidence interval [0.40, 0.83].

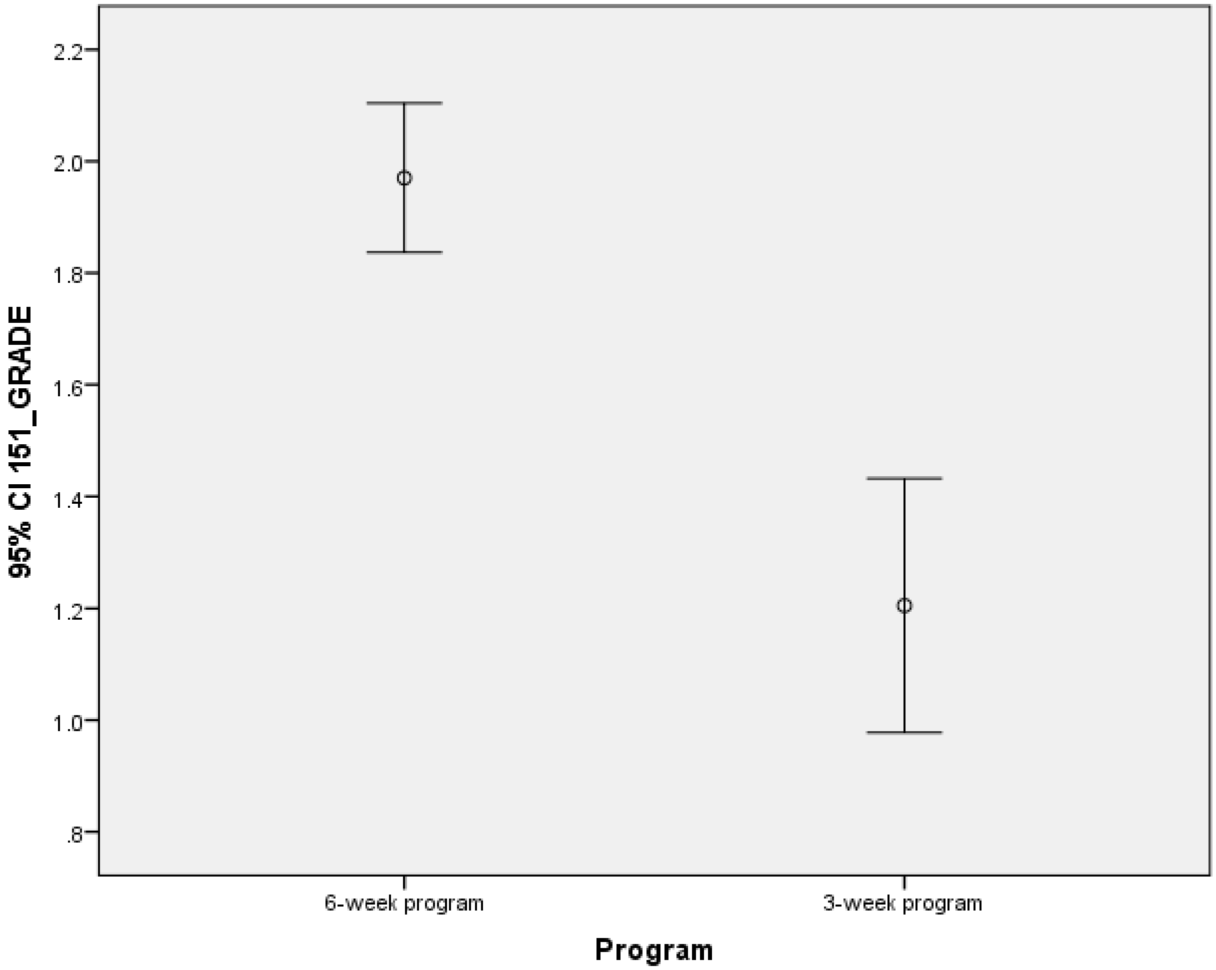

Figure 2. Confidence interval for students' 151 grade.

One interest of the present study was to understand the interaction effects of gender and the bridge programs on students' grades in their calculus courses. The results (see Figure 3) showed that both female and male students who attended 6-weeks long program achieved statistically significantly ($p < .01$) higher grades in calculus than their counterparts who attended the 3-week long program.

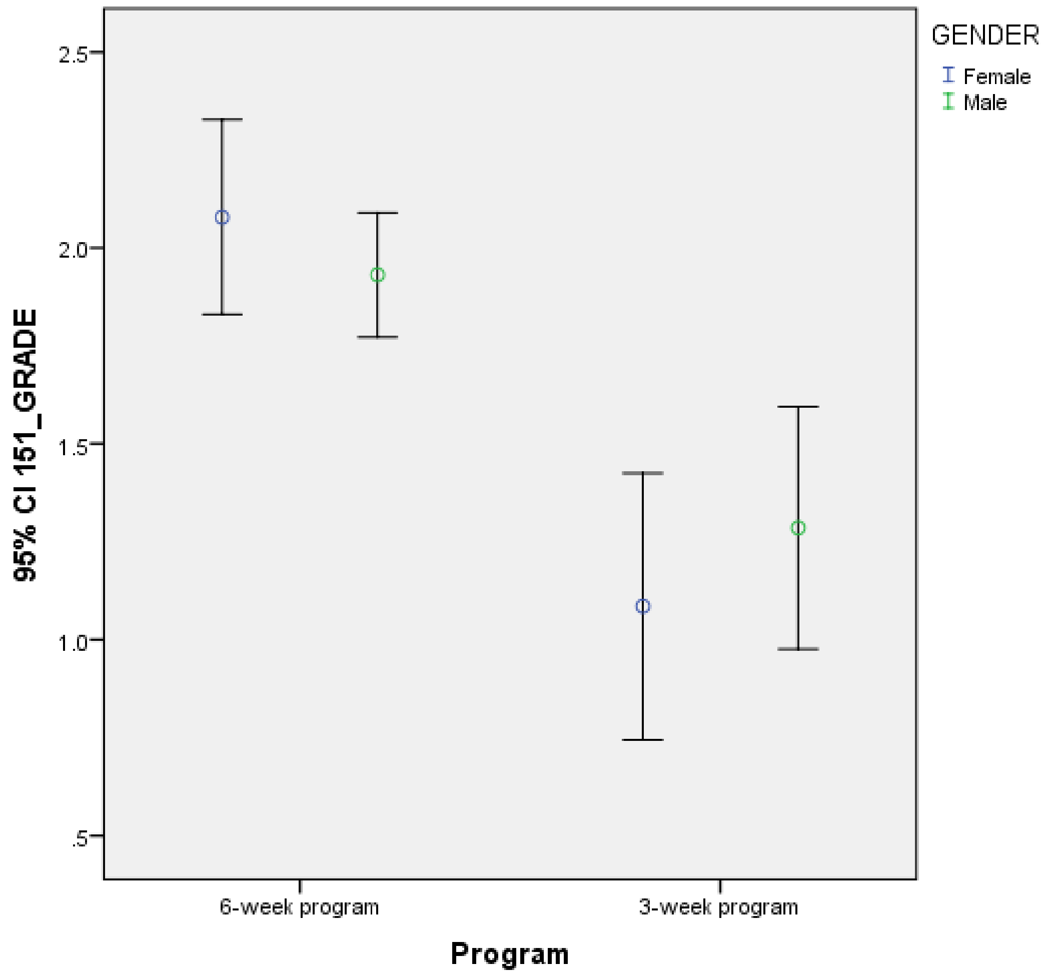

Figure 3. The interaction effect of gender and programs

The interaction effects of ethnicity and bridge programs on students' calculus grades was also investigated. Similarly, results revealed that all students (African American, Hispanic, White, and Others (e.g., Native Hawaiian, Native Alaskan, Mixed, Asian) who participated in the 6-week long bridge program earned statistically significantly higher grades than students who attended the 3-week long bridge program (see Figure 4). The confidence intervals for African American and Other are wider, particularly for the 3-week program. Wider confidence intervals can be expected when numbers are small.

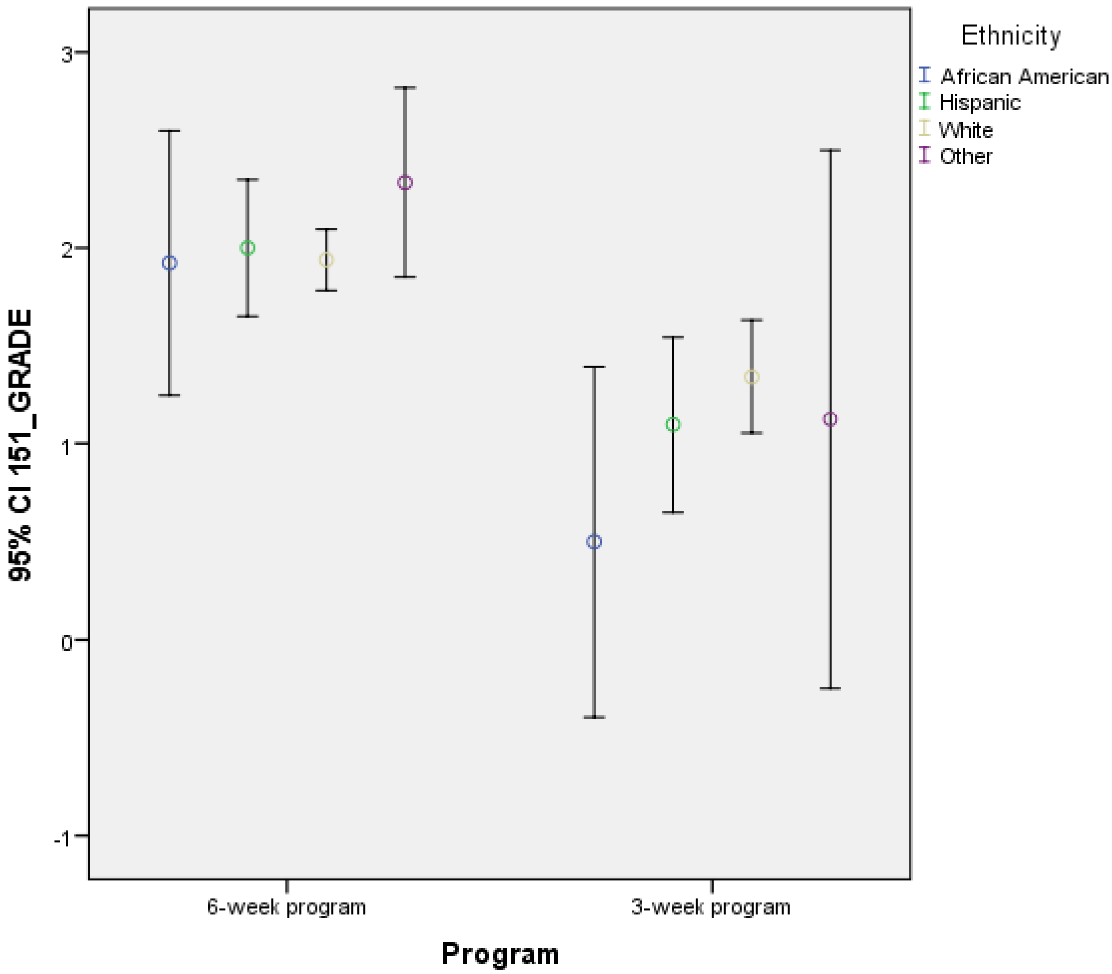

Figure 4. The interaction effect of ethnicity and programs

VI. Discussion and Recommendations

The difficulty with the decision about whether to run the program for 6 weeks or for 3 weeks is many-faceted. Changes in the scheduling of the new students conferences required students to know earlier whether they could enroll in engineering calculus I or needed to enroll in Precalculus first. This created pressure on the PPP to provide students with this information sooner. In addition, attendance tended to diminish toward the second half of the 6-week program. Students would often go ahead and take the MPE to see if they could raise scores enough to qualify for engineering calculus I, and would then drop out of the program. The emphasis seemed to be more on getting the score to enroll than strengthening skills they would need in the course. Part of this problem related to the issue of students who took AP Calculus believing they were well prepared for college calculus, whether or not that was truly the case[11]. On the other hand, the 3-week course left little outside time for students to review and practice concepts and skills during the program or to have more time to process information that might be new to them. The limited results currently available indicate that students in the 3-week course raise MPE scores more than the students in the 6-week course.

However, grades in engineering calculus I were statistically significantly higher for students in the 6-week course. It is possible that student improvement in mathematics skills over the short term increase more, but the effects are not as lasting as desired. This could be a result of student tendency to memorize what is needed to the moment, and during the 1-1.5 months between the PPP and the beginning of fall classes, their knowledge fades.

There are many colleges and universities whose engineering students struggle with their calculus requirements. Based on the results of this study, there are several recommendations to consider: 1) Institute a bridge program to support students and increase success. 2) Use tutors along with any technology intervention. 3) Ensure the program length provides sufficient hours for immersion in the content but also allows time to process material and engage in additional practice.

Results from this study, and subsequent studies of student success in the calculus sequence after the 3-week program has been effect longer, will add to the data that will affect future program planning. Additional student surveys will be created to learn more about student perspectives that affect their participation and success in the program. Studies will be expanded to include longitudinal results as the number of participants that continue through the calculus sequence increases. The search for the most effective program possible will likely be an unending process as we strive to support students in engineering calculus courses.

VII. Acknowledgement

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