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Implementation and Effects of a Bridge Program to Increase Student Learning and Retention in Engineering Programs

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Abstract

An engineering bridge program was implemented and utilized to assist pre-engineering students at Texas Tech University (TTU) by offering an optional one week course to strengthen their math and problem solving skills, while also providing mentoring and academic support opportunities to the students throughout the academic year following the course. The program has been in effect for over six years, and has had an approximate total enrollment of over 700 students during that time. Enrollment in the bridge program is offered to incoming students that have scored in the range of four to seven on the math placement exam (MPE), and the course is specifically designed to strengthen the student's understanding of trigonometry and related problem solving. The goal of the research is to determine whether the bridge program has an immediate effect on improving grades in math and engineering classes, and to determine whether the program has a long-term effect on the students by retaining them within the engineering program. The results of the research, based as a comparison between students that did and did not enroll in the bridge program, showed that the students enrolled in the bridge program brought their performance levels up to approximately the same level as the entire engineering college itself, indicating that the program was successful in increasing performance of the target students. Additionally the program showed that students enrolled in the bridge program stayed within an engineering major after their first year at approximately the same rate as the entire engineering college.

Introduction

There is a critical need for qualified engineering graduates to join the workforce. The most recent U.S. Bureau of Labor projections through 2020 show significant growth of jobs in the science, technology, engineering, and math (STEM) disciplines. Marra[1] et al states that engineering and science fields will grow at more than 3 times the rate of other disciplines. However, in the midst of the demand, institutions of higher education are faced with the challenge of retaining students within their engineering programs[1-5]. Student attrition has been attributed to several factors including: student attitudes and a sense of belonging in discipline, preparation for the course material, and quality of teaching and compatibility with student learning styles[1,6-10]. Although, the literature differs on which factor or combination of factors is the most important in addressing the issue, it is clear that retention is a complex and multi-faceted issue. One of the factors that has been pinpointed is a deficiency in students' mathematic skills[11-18]. Australian researchers highlight this "inadequate competence in mathematics" as a fundamental contributor to attrition[13]. Researchers at Montana State University also saw early mathematics courses as a "barrier to student success"[8]. Students without the necessary

mathematics skills struggle in initial coursework and often make the choice to transfer to a different discipline.

In light of these concerns about incoming students mathematics abilities, Many institutions have adopted diagnostic exams and avenues of remediation and support for incoming students. The university requires incoming students to take a Math Placement Exam (MPE), however, incoming students can opt out if they scored sufficiently well on the math portion of the ACT/SAT exam. Students that do not meet these requirements, and score below a 7 on the MPE are then provided the opportunity to enroll in the ConocoPhillips Academic Success Bridge Program within the Whitacre College of Engineering at TTU. The bridge program provides study skills training, academic preparation training, tutoring, mentoring, and other academic support services to incoming students. The focal point of the program is a concentrated math review course that occurs one week before the fall semester begins. This math review course covers fundamental concepts in algebra, trigonometry, and analytical geometry. The purpose of the math review course is to provide the academic foundation, and the confidence necessary to succeed in an engineering program. The program provides basic math concepts review combined with hands-on learning experiences, to show how math is fun and a critical component of all aspects of engineering. Craig[14] illustrated the importance of these types of learning experiences to assist students in properly conceptualizing the use of mathematics within engineering. The use of peer mentors both in the review course and throughout the semester helps to provide the additional support and sense of the belonging and identification with the field of engineering[1,14,18].

The goal of the research is to determine whether the bridge program has an immediate effect on improving grades, and a long-term effect on student retention.

Data Collected and Methods

Data was collected for students in the bridge program, as well as all other undergraduate students enrolled in the college of engineering. The data range analyzed starts with the Bridge program in 2010, and runs through the fall semester of 2013, corresponding to 3.5 years of overall data. The first set of data collected for all students consisted of the following: SAT math score, overall SAT score, ACT math score, composite ACT score, and score on the MPE. This data represents the preparedness of the student coming into the engineering program, and will be correlated to performance and retention throughout the paper. SAT scores were reported for approximately 82% of incoming students, while ACT scores were only reported for 53% of incoming students. SAT and ACT scores were only evaluated based on the math portion of each exam, and the overall score for the purposes of this paper. Historically, standardized test scores have been used as a predictive indicator of college performance, and have been shown to correlate with a statistically significant level of success[10,19,20] . MPE scores were available for approximately 71% of all incoming students, and were reported for 100% of the Bridge students because it is a requirement of the Bridge program to take the exam.

The MPE is a tool used by the university to test the math readiness level of incoming students, and to determine from their score what level of math class that student should be placed in. Students taking the exam can receive a score between one and seven, with seven being the highest score a student can achieve and one being the lowest. The university recommends that all incoming freshmen take the math placement exam, regardless of their standardized test scores, to indicate their readiness or preparedness for college math courses. In some cases, a student can use their standardized test scores to satisfy prerequisites for incoming math courses, but 71% of incoming students still took the MPE. For the engineering program, the typical entry level math course is Calculus I. For a student to qualify for entrance to Calculus I, they must obtain a score of 7 on the MPE, or have an ACT math score of 29 or a SAT math score of 660. If the student has taken a lower level math course such as pre-cal or trig, they can enter calculus I with a MPE score of 5 if they attained a grade of C or better in their prior math course.

Additionally, the first two semesters GPA and retention of students in the engineering college throughout the data range was also collected for all students. GPA for the first two semesters of attendance is typically cited as a strong indicator of whether the student will persist through the program[21,22]. Also, the first two semesters of classes within the engineering college are typically the same across all engineering disciplines, which allows for a stronger comparison between all students based on pure GPA. Retention data was monitored for all students in the data set, with the exception of the 2013 incoming class. For the purposes of this paper, 'retention' will be defined as staying enrolled within the college of engineering only. The following data does not differentiate between students that changed majors and were still enrolled within the university, and students that left the university completely. Furthermore, all prior mentioned data will be evaluated based on all students, and will also be evaluated to separately gauge the performance of female and racial minority students.

The bridge program is conducted over a week-long period prior to the start of the fall semester each year. The program is outlined in Figure 1. In addition to the program sections mentioned in Figure 1, tutoring sessions were made available for all students at the end of each day, and the afternoons of each day were used to work practice problems to further prepare the students in the program. Upon completion of the program, the students will have taken the MPE three times, and are allowed to use their best score of the three exams as their final score, to be used for admission into the appropriate math course.

Statistical Analysis

Data sets were evaluated within Excel to find averages and standard deviations, while a t-test was used to determine the statistical significance or insignificance between compared sets of data. Data averages and standard deviations are listed for each data range as (Average ± SD). P-values are also reported for each compared data set. A p-value of less than 0.001 indicates a high degree of statistical significance. For p-values that do not correspond to any statistical

significance, the value will be reported and a mention of the statistical significance will be made with the reporting of the p-value.

Day 1
- Basic Trig Review
- Trig Functions and Identities
- Polynomials, Exponential, and Log Functions

Day 2
- Roots and Radicals
- Factoring
- Rational Expressions

Day 3
- Solving Equations
- Composites of Functions
- Piecewise Functions, Graphs, and Conics
- Practice MPE Exam

Day 4
- MPE Review
- Trig Review
- Final MPE Exam

Figure 1. Bridge Program Curriculum

Results

Performance

One of the main goals of the engineering bridge program is to increase the performance of students that enroll within the program, based on their performance on the MPE. Prior studies have used standardized test scores as an indicator of performance within a university program, this study seeks to correlate standardized test scores from the math sections of each exam to performance on the MPE.

Over the course of the four incoming classes of students analyzed, there were approximately 2865 students that produce data. Of these incoming students, 71% took the MPE and had an average score on the exam of 6.12 ± 1.88 ($n = 2034$). Of the 2034 students that took the exam, 71% of the students achieved a score of 7 on the MPE, while the remaining 29% achieved scores ranging between 1 and 6, with the average score excluding all scores of 7 being 3.93 ± 0.66 ($n = 654$). During the same time period, there were 318 students that made it through the bridge program and continued in the engineering school through their first year of studies. These students had an average MPE score of 6.63 ± 0.68 ($n = 318$), which is approximately 8% higher

($p < 0.001$) than the average score for all incoming freshman students in the same year. Within the group of bridge students, 82% scored a 7 on the MPE, while the remaining students averaged a score of 4.93 ± 1.43 (n = 57). This correlates to a 25% higher ($p < 0.001$) score on the MPE for bridge students that do not achieve a score of 7 versus students that do not achieve a score of 7 on the MPE that were not part of the bridge program. This evaluation alone indicates that the bridge program is effective in sharpening student math skills, shows a higher rate of advancing students to calculus I, and results in higher scores on the MPE for students that do not achieve a 7 on their initial MPE.

From within the same data set, females within the bridge program were shown to score 3% higher ($p = 0.30$) than females not in the bridge program, which is not statistically significant. Females not in the bridge program had an average MPE score of 6.28 ± 1.31 (n = 319), while females within the bridge program had an average score of 6.50 ± 0.61 (n = 40). Minorities within the bridge program were shown to score 10% higher ($p < 0.001$) than those not in the program, with an average score of 6.60 ± 0.74 (n = 112) versus 6.01 ± 1.54 (n = 997) for non-bridge minority students. All data collected in regards to the MPE is reported in Figure 2.

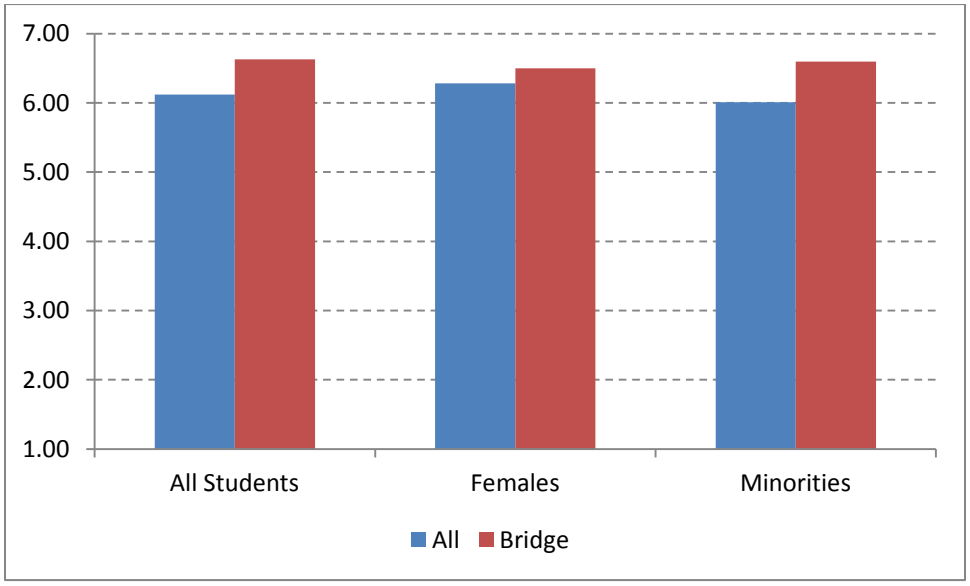

Figure 2. MPE scores for all students versus students in the bridge program

SAT and ACT math scores were also collected for all students and bridge students, but will not be correlated to MPE performance, because MPE scores were taken for the bridge students after completion of the program. However, incoming students to the bridge program have shown a lower average math score on the SAT and ACT alike compared to all other incoming students, indicating that the bridge program is targeting the correct group of students for enrollment. The average bridge student reported a SAT math score of 588 ± 52 (n = 276), and an average ACT math score of 25.3 ± 2.5 (n = 168), while the overall group of incoming students had an average SAT math score of 609 ± 67 (n = 2416), and an average ACT math score of 26.7 ± 3.4 (n =

1522). This corresponds to 4% ($p < 0.001$) lower scores for bridge students on the SAT math section, and 5% lower ($p < 0.001$) scores on the ACT math section.

Females enrolled in the bridge program scored an average of 569 ± 52 (n = 32) on the SAT math section and an average of 24.4 ± 2.6 (n = 27) on the ACT math section, while all incoming females scored an average of 598 ± 71 (n = 339) on the SAT math section, corresponding to a 5% lower score ($p = 0.025$), and 26.6 ± 3.7 (n = 229) on the ACT math section, corresponding to a 8% lower score ($p = 0.003$). Along the same lines, incoming minorities into the bridge program scored an average of 455 ± 43 (n = 105) on the SAT math section and an average of 24.8 ± 2.9 (n = 49) on the ACT math section, while all incoming minorities scored an average of 594 ± 70 (n = 848) on the SAT math section, corresponding to a 23% lower score ($p < 0.001$), and 25.6 ± 3.5 (n = 530) on the ACT math score, corresponding to a 3% lower score ($p = 0.121$, not significant). Data for the ACT and SAT math score comparisons can be found in figures 2 and 3, respectively.

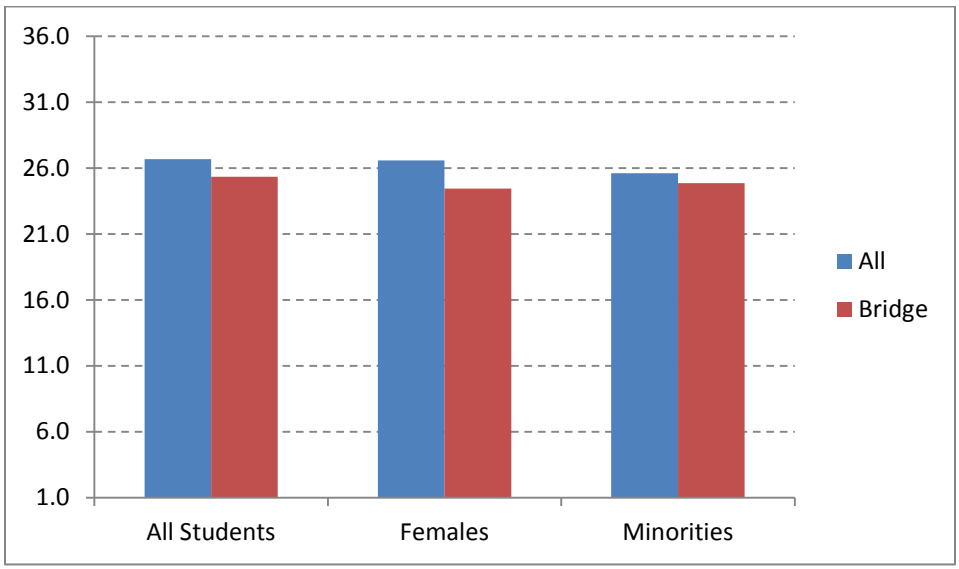

Figure 2. ACT math section scores for all incoming and bridge students

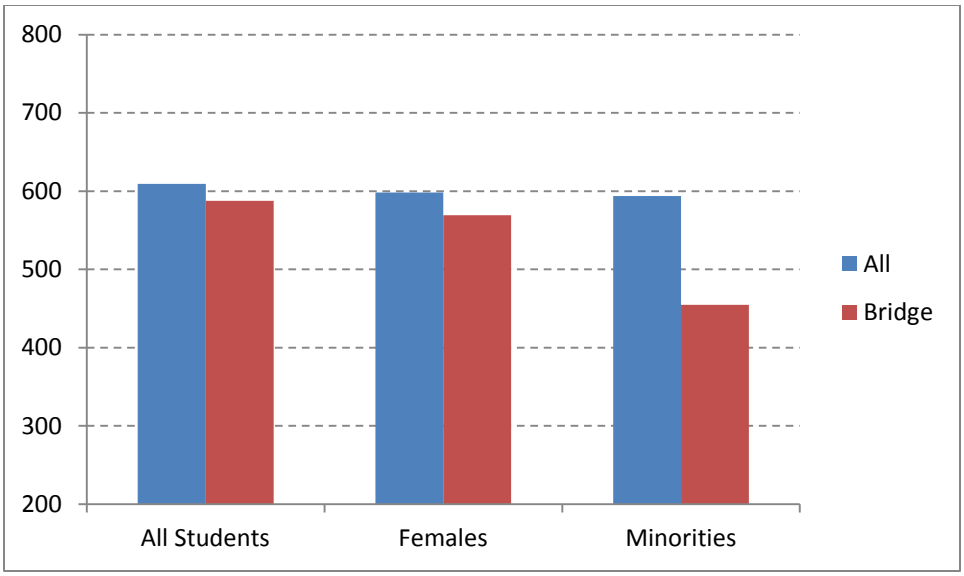

Figure 3. SAT math section scores for all incoming and bridge students

In addition to standardized test scores on the ACT and SAT, and performance on the MPE, the students were also evaluated based on their first two semesters GPA. Overall, freshman have an average GPA of 2.58 ± 0.91 (n = 2884) after two semesters of engineering curriculum, versus 2.54 ± 0.84 (n = 318) for students that went through the bridge program. This corresponds to less than 2% difference in GPA (p = 0.4537), and is not considered to be statistically significant. The lack of statistical significance between these two data sets indicates that the bridge program has brought the level of competence of the students in the bridge program up to a comparable level as the students that do not require or do not go through the bridge program, indicating program success. Additionally, all freshman females have an average GPA of 2.88 ± 0.78 (n = 397), while females in the bridge program have an average GPA of 2.87 ± 0.54 (n = 40). While all minorities after two semesters had an average GPA of 2.50 ± 0.94 (n = 1193), while minorities that went through the bridge program had an average GPA of 2.58 ± 0.78 (n = 112) after two semesters. These values correspond to a difference of less than 1% between female students (p = 0.937) and 3% between minority students (p = 0.383), which are both considered to be not statistically significant.

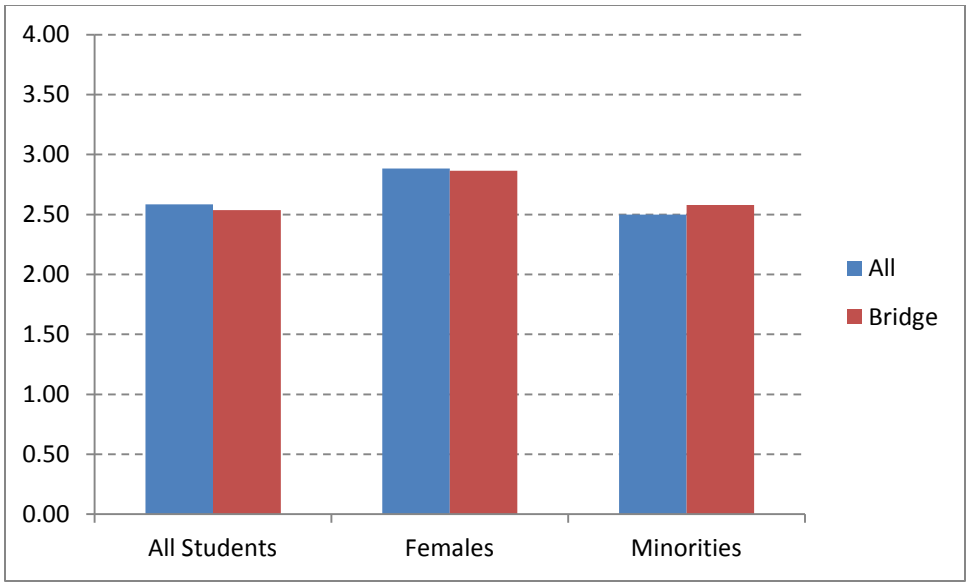

Figure 4. GPA data for all students through the first two semesters of the engineering program

Retention

The other primary objective of the bridge program was to increase retention of bridge students within the engineering program due to increased performance in initial classes. Throughout the first three years of the data period, students dropped out of the engineering program at an average rate of 17% in the first year of studies, while students from the bridge program dropped out of their respective engineering programs at a rate of 30% in the first year. Overall, between 2010 and 2012, 1722 students enrolled and 1437 students completed their first year of studies; the bridge program enrolled 284 students in the same time period, of which 198 students progressed to their second year of studies. These values are summarized in Figure 5.

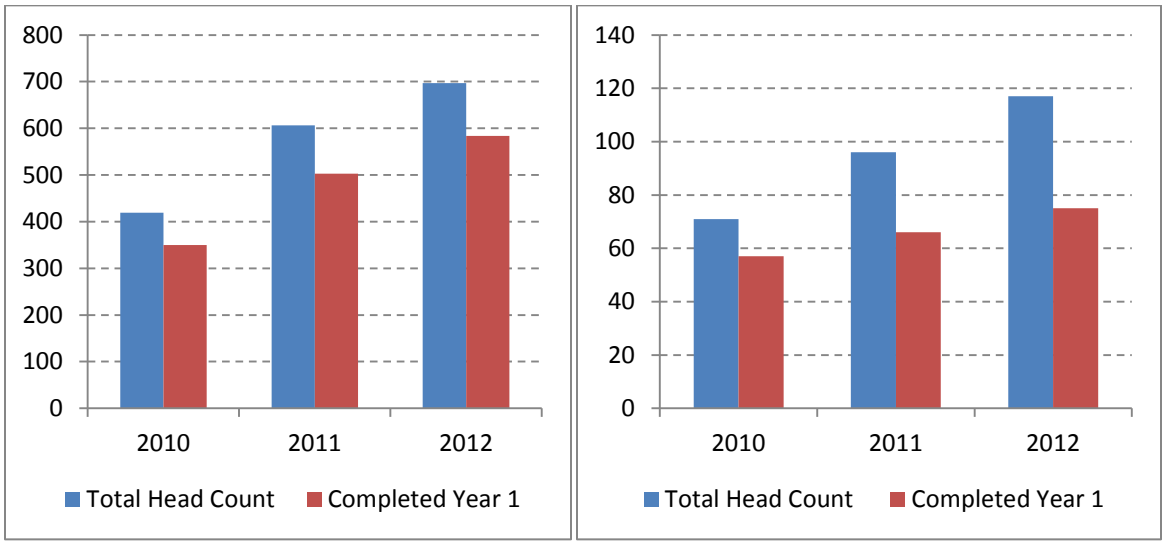

Figure 5. Retention of All Students (L) and Bridge Students (R)

However, to better understand the effects of the bridge program SAT and ACT math scores for the overall student group was brought down to the average of the bridge program student group, and then retention was re-evaluated. The average of the test scores was brought down by eliminating the highest scores, so that the lower scoring students would be looked at from the overall group. When this evaluation was complete, it was found that the overall drop rate for students was approximately 32% in the first year, compared to 17% when the higher scores were included. Overall, there were approximately 1028 students in the newly evaluated group, of which 699 completed the first year of studies, while the bridge group was evaluated on its original values of 284 students and 198 completing their first year of studies. The 32% drop rate for all students in this evaluation is higher than the approximately 30% drop rate seen for bridge students. While the bridge program does not have a significantly higher retention rate than the overall college, the evaluation shows that the bridge program does at least stay on par with the average drop rate for the college of engineering.

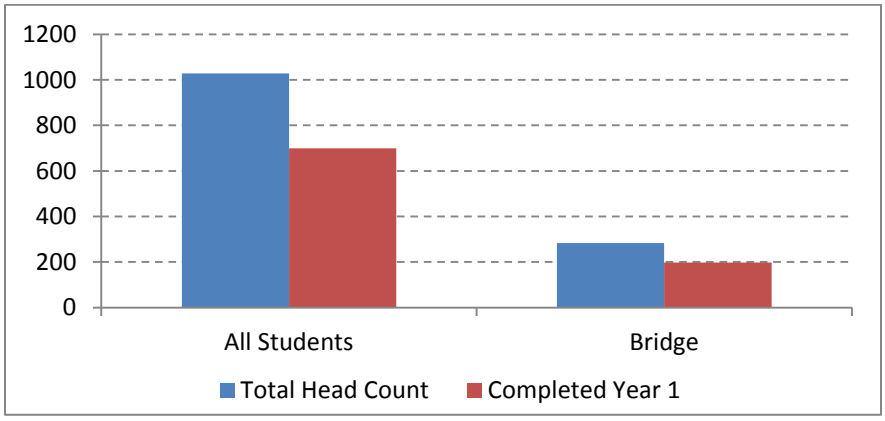

Figure 6. Retention of Students when Standardized Test Scores are Set Equal to Bridge Program

Conclusion

Based on the prior evaluations, the engineering bridge program can be viewed as an excellent tool for students that need to increase their math skills prior to entering an engineering program. The program results in bringing students in the bridge program up to average levels for performance within the entire college, and also brings students up to average retention levels when evaluated on a level plane. From this analysis, the bridge program meets its goals of improving the overall performance and retention among the incoming students to the program to similar levels of all incoming students. While the bridge program is primarily a tool to improve math skills prior to entry into the engineering program, the program could also be viewed as a tool to assist students in deciding for themselves if they are prepared for the rigors of math in engineering, and that they could decide for themselves if engineering is the right choice for them after they realize how much math they will be encountering in their academic careers as an engineering student.

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