Impacts of a Summer Bridge Program in Engineering on Student Retention and Graduation

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Abstract

A summer bridge program was developed in an engineering program to advance the preparation of incoming freshmen students, particularly with respect to their math course placement. The program was intended to raise the initial math course placement of students who otherwise would begin their engineering studies in courses below Calculus I. One reason given for low retention rates in this particular engineering program was that students needed to spend too much time taking math courses in college just to be ready to take the Calculus I course expected of incoming freshmen in the program; this extended their total time in college and delayed their ability to take the engineering courses that interested them. The program was successful at meeting its immediate goal of raising the math course placement of these students. However, the program's success with regards to improving math course placement did not lead to significantly improved odds of the students being retained in engineering or graduating from engineering in comparison to students of similar abilities who did not participate in this bridge program.

Introduction

Over the past two decades, there have been calls for the United States to increase the number of students completing studies in the disciplines of Science, Technology, Engineering, and Mathematics (STEM). [1,2] To do this, it is necessary to attract more students to pursue college studies in STEM. Then, once those students have decided to start their STEM studies, universities need to provide an environment that is conducive to student success while still providing a rigorous and comprehensive technical education.

A particular engineering college, which houses programs in both engineering and computer science, (students in both engineering and computer science will be referred to as "engineering" students in this paper) at an urban research university in the Midwestern region of the United States generally had been able to attract a fairly high number of students into their programs. However, the graduation and retention rates in this college were quite low. For example, the 6-year engineering graduation rate for incoming freshmen in the fall 2004 semester was only 26.3%, leaving much room for improvement. An analysis of student retention rates indicated that many students were leaving the engineering program during the first two years, with two-year retention rates less than 60%. In addition, results indicated that these rates may have even been inflated because of an unintended consequence of a university policy. Specifically, students at this university who were on academic probation in a college were not allowed to transfer to another college within the university. Therefore, a sizeable fraction of these "retained" students had already ceased their engineering studies and were taking non-engineering classes in an attempt to raise their grade point average (GPA) to no longer be on academic probation and thus be allowed to continue their studies elsewhere in the university. While the percentage of incoming freshmen falling into this group varied somewhat each year, approximately 10% of the incoming freshmen would fit the description of students who were on academic probation and intending to transfer out of the college while staying at the university during their first two years.

Further analysis indicated that, after taking the university's math placement exam, many students were beginning their studies with math courses that are prerequisites to Calculus I (e.g. College Algebra, Intermediate Algebra, and even Basic Algebra). Since the curricula of all programs in the college were based on the assumption that students take Calculus I in their first semester of study, these students were required to add one or more semesters to their program of study. Moreover, these students were also delayed in taking the engineering courses to which they were initially attracted. Therefore, taking these additional math courses was likely an impediment to retention and eventual graduation.

To overcome these impediments, an intervention was implemented prior to students' first year in the program, when these students were expected to take Calculus I. Beginning in the summer of 2009, for the fall 2009 cohort, a summer bridge program for incoming freshmen students who had placed into a pre-requisite course below Calculus I, based on the results of a math placement exam, was implemented. While this program met its immediate goal of improving math placement test scores for most students in the program, allowing students to register for a more advanced math course in the fall semester, it is important to evaluate whether this program had an impact on retention and graduation rates, due to the expense of such a program.

In this paper, the summer bridge program intervention is briefly described, its short-term impacts are summarized, and the results on the effect of the bridge program intervention on student retention and graduation rates are presented.

Summer Bridge Program Format

In a summer bridge program, incoming freshmen students spend a portion of the summer, prior to the fall semester, at their future university to help them become acclimated to the setting and become more prepared academically for their coursework in the fall.[3,7] The bridge program used as an intervention in this project was a four-week residential program. All students lived in the on-campus dormitory and participated in supervised and structured programs during the day.

Most incoming freshmen did not participate in the bridge program. Students were invited to participate in the program via two routes. Some students were admitted to the college on the condition that they attend the bridge program; this was the "required" route. Generally, these students had high school academic credentials that would typically result in an initial math course placement at the level of Intermediate Algebra or below; the historical graduation rate of such students from the college was very low. The bridge program intervention was designed to strengthen these students' math abilities and place them in a better position to succeed in the college. The second route, or "optional" route, was for students who were admitted into the college, but who did not place into Calculus I after taking the math placement exam. By participating in the bridge program, these students had the opportunity to improve their math placement, ideally to

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Year (Summer)	Number of Participants	Number Improving Math Placement	Percentage Improving Placement
2009	37	25	68%
2010	47	39	83%
2011	64	56	88%
2012	42	37	88%
2013	36	32	89%
2014	40	36	90%

Table 1: Number of bridge program participants and the number of students improving their math placement through the program.

the Calculus I level, and thereby reduce the number of semesters they would need to spend in college. In addition, some students who were offered academic scholarships that were contingent on placing into Calculus I would participate in the bridge program through this optional route so that they could start their college studies in Calculus I and receive their scholarship. The bridge program students were approximately evenly divided between those who were required to attend to be admitted to the college, and those for whom the bridge program was optional. It can also be noted that nearly all students in the bridge program were serious about studying engineering as it made little sense to participate in the program without the intention of entering the engineering college.

Weekday mornings were devoted to 2.5 hours of supervised online mathematics instruction using the ALEKS software package.[8] ALEKS is a web-based assessment and teaching system that uses adaptive questioning to gauge the depth of a student's understanding of a subject, and then designs the student's lessons to address areas in which the student may lack understanding. While ALEKS is not specifically designed to work with engineering students, the math being studied in the bridge program were of a general, secondary-school nature and there was no need for specialized engineering math instruction. As will be seen below, use of the ALEKS software clearly allowed students to meet the short-term goals of this program with regards to math improvement. In addition to simply using the software, instructors were available to provide more hands-on explanations and assistance, as needed.

Prior to beginning the bridge program, students had taken the university's math placement exam. Based on the results of this exam, individualized programs were designed for each student to help him or her master the content needed to be placed into a higher course. Students would begin with topics either from typical Intermediate Algebra (i.e., polynomials, equations and inequalities, exponential and logarithmic functions, conic sections, and systems of linear equations), or College Algebra (i.e., more advanced functions, matrices and determinants, series, and analytic geometry) and Trigonometry, although a few students would have had to work on some Basic Algebra topics as well. Students would then continue to advance through more complex topics as they mastered simpler material. Student progress was continually monitored; students were encouraged to spend more time learning the content during their free time in the evenings and on weekends. Occasionally, additional work was provided to students to be worked on outside of class. The students retook the math placement exam on the second-to-last day of the bridge program. If they improved their math placement as a result of the program, the students received a $1,000 scholarship. The format of the program was developed based on experiences from previously conducting non-residential programs.[9,10] More details of the format of the program and the use of ALEKS are available in Reisel, et al.[11]

Weekday afternoons in the program were spent having students work as teams on engineering projects. These projects were designed to give students an experience with several different fields of engineering, allow them to practice teamwork, obtain design experience, and compete in friendly competitions with other teams in order to build bonds between students. Beginning in 2010, additional scholarship money was available for the students who excelled in these afternoon engineering activities.

With respect to improving the initial math placement of participants, the immediate success of the program was very good.[12] As depicted in Table 1, with the exception of the first year, between 83% and 90% of the students improved their math placement level each year. In fact, some students (~20%) improved their math placement by two levels (e.g., from Intermediate Algebra to Calculus I). Therefore, a large majority of students who participated in the bridge program were able to begin their college mathematics studies at a more advanced level than they would have been able to do without participating in the bridge program. Furthermore, an analysis of the early years of the program indicated that students who participated in the bridge program and took Calculus I in their first semester received grades of C or better at a very similar rate when compared to other students in the course that did not participate in the bridge program.[12] It should be noted that a grade of C or better is necessary to advance to the next course in the math sequence at the university. Students who participated in the bridge program and began their math studies in College Algebra did not perform as well as other students in the course, although this analysis is hampered by the low number of bridge students who were began their studies in College Algebra, in comparison to the total number of students in the course.

These results indicate that, overall, the bridge program met its immediate goal of improving the math placement of students. Furthermore, as bridge program students received grades of C or better at similar rates as students who did not participate in the bridge program, it would seem that participation in the bridge program should result in a reduced number of semesters in college prior to taking engineering courses for the students. Therefore, it might be hypothesized that the bridge program would lead to higher retention and graduation rates for students that participated in the program.

Description of Analysis Method

To determine if the bridge program was successful at improving retention and graduation rates, the rates associated with students who participated in the bridge program must be compared to students who did not participate in the bridge program, of comparable academic ability and achievement. In this study, we predicted the ratio between odds of retention after 1, 2, and 3 years, and when possible the odds of graduation from engineering and computer science, for students who participated in the bridge program versus comparable students from the 2007 and 2008 cohorts who did not participate in the program. Logistic regression models [13,14] were used to predict the logits of the binomial response variable of interest (e.g. retention or graduation) based on a set of predictors. In this study, we describe the results in terms of odds ratios. Because the odds ratio is a ratio of probabilities, what is actually modeled is the logarithm of the odds. It is important to understand that odds and probabilities, although sometimes used synonymously, are not the same. Probability is a ratio between the number of events favorable to some outcome and the total number of events. On the other hand, odds are the ratio between probabilities: the ratio of the probability of an event favorable to an outcome and the probability of an event unfavorable to the same outcome. Probability is constrained between zero and one while odds are constrained between zero and infinity. The odds ratio is the ratio between odds from two groups.

Logistic regression was used in this study to predict the change in the odds of success of retention or graduation with respect to the explanatory variables of interest. This procedure is quite similar to multiple linear regression, with the exception that the response variable is binomial. The results indicate the impact of each explanatory variable on the odds ratio of the observed event of interest.

In this study, we compared the odds of successful retention or graduation for engineering students who participated in the bridge program to students who did not participate in the bridge program, controlling for ACT mathematics test scores. This is an odds ratio which is derived from two odds (odds for bridge program students and odds for non-bridge students), and its natural logarithm is a logit. The regression coefficients of the categorical predictors in the logistic regression model reflect the logit of retention or graduation rates and their exponentiated value is the odds ratio, or the factor by which the odds of success increases compared to a given reference category.

For all logistic regression models considered in this study, we controlled for math ACT scores by coding scores into three categories:

- Math ACT between 17 and 23: Low (1L)
- Math ACT between 24 and 27: Moderate (2M)
- Math ACT at or above 28: High (3H)

We estimated the odds of success using Equation (1):

$$\left(\frac{\pi}{1-\pi}\right) = \exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2) \quad (1)$$

where π is the probability of success (graduating in engineering, or being retained in the engineering program after 1, 2 and 3 years in engineering), is the odds of success (dependent variable (DV) =Yes/1), χ_1 is the dummy variable for participating in the bridge program intervention (χ_1=1), compared against a control group (χ_1=0), and χ_2 is the categorized Math ACT scores as described above. The reference category for the intervention indicator variable is χ_1=1; i.e., the student participated in the intervention. Students who participated in the bridge program between 2010 and 2014 have χ_1=1, while students in the control group from the 2007 and 2008 cohorts have χ_1=0. The reference category for the Math ACT variable is MACT=1L, or the low Math ACT level. With these, Eq. (1) can be rewritten as

$$\ln\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1(Bridge) + \beta_2(MACT) \quad (2)$$

The corresponding probabilities can be obtained by transforming back the estimated logit equation to the following probability form:

$$\pi = \frac{e^{\beta_0 + \beta_1(Bridge) + \beta_2(MACT)}}{1 + e^{\beta_0 + \beta_1(Bridge) + \beta_2(MACT)}} \quad (3)$$

In summary, the logistic model predicts the logit of Y from X. The logit is the natural logarithm (ln) of odds of Y, and odds are ratios of probabilities (π) of Y happening (e.g., a student graduates in Engineering) to probabilities ($1-\pi$) of Y not happening (e.g., a student does not graduate in Engineering). The null hypothesis underlying the overall model states that all regression coefficients (βi) equal zero. A rejection of this null hypothesis implies that at least one β does not equal zero in the population, which means that the logistic regression equation predicts the probability of the outcome better than the mean of the dependent variable Y.

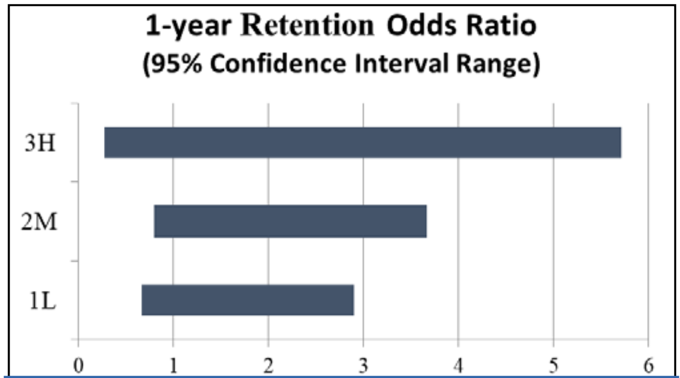

Figure 1: The 95% confidence interval range for the 1-year retention odds ratio for the bridge program students vs. the 2007-08 cohorts, divided into the three Math ACT score level categories. As a portion of all the interval ranges fall below 1, none of the results are statistically significant.

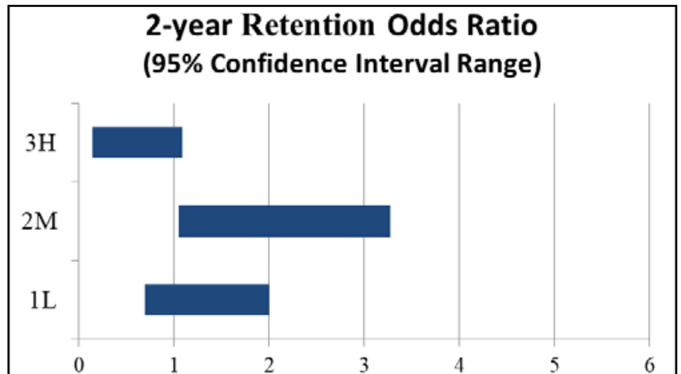

Figure 2: The 95% confidence interval range for the 2-year retention odds ratio for the bridge program students vs. the 2007-08 cohorts, divided into the three Math ACT score level categories. As the range exceeds 1 for the 2M group, the bridge program intervention's improvement in the likelihood of 2-year retention for this group is statistically significant.

Description of Cohorts

In this study, the control group of students who received no intervention consisted of the college's 2007 and 2008 incoming freshmen cohorts. Table 2 contains a breakdown of the math ACT category for these two cohorts. Table 2 also contains a breakdown of the portion of the 2010-14 cohorts who participated in the summer bridge program and who subsequently enrolled in the college (as a few students listed in Table 1 who participated in the bridge program chose to enroll in a different academic unit before the fall semester began). The 2009 bridge program cohort was not included in this study as the program was in a formative stage in 2009 and modifications that were made to the program after 2009 affected the 2010-14 cohorts, but not the 2009 cohort. Finally, Table 2 also contains the number of students in the 2010-14 cohorts who did not participate in the bridge program for each Math ACT score category. This information is provided to demonstrate an unintended consequence of admitting some lower-achieving students, based on the condition that they participate in the bridge program – that is, many students who may have attended the engineering program prior to the initiation of this conditional acceptance opted to self-select out of the engineering program prior to enrolling. The percentage of the cohorts that were in category 1L fell from 28% in the 2007-2008 control group cohorts to 20% in the 2010-14 cohorts. Such a potential impact should be considered by a school considering the development of a summer bridge program.

Math ACT Category	2007 and 2008 Cohorts	2010-14 Cohorts Bridge Participants	2010-14 Cohorts Non-Bridge Participants
1L (17-23)	139	109	86
2M (24-27)	176	87	312
3H (28 and higher)	181	19	365

Table 2: Cohort profiles, based on Math ACT scores

Results and Discussion of Logistic Regression Analysis

Comparisons were made using the logistic regression analysis method described above between the 2010-14 bridge participant cohort and the 2007-08 control group cohort. The odds ratio of the students in each group being retained through 1 year, 2 years (for 2010-13 cohorts), and 3 years (2010-12 cohorts) in comparison to the control group were determined. In addition, an analysis of the odds of graduation for students through the spring 2016 semester was performed. For a result to be statistically significant, the entire uncertainty range of the odds ratio needs to be greater than 1. The 1-year, 2-year, and 3-year retention odds ratios (bridge program students versus control group), with their 95% Wald confidence limit intervals are presented in Table 3, and the 95% confidence interval range is shown graphically in Figures 1-3.

Math ACT Range	Odds Ratio Estimate	95% Confidence Limit - Lower	95% Confidence Limit – Upper
1 – Year Retention			
1L	1.389	0.665	2.901
2M	1.711	0.799	3.666
3H	1.237	0.268	5.709
2 – Year Retention			
1L	1.180	0.696	2.000
2M	1.854	1.050	3.272
3H	0.386	0.137	1.086
3 – Year Retention			
1L	1.086	0.616	1.914
2M	1.415	0.769	2.602
3H	0.454	0.158	1.304

Table 3: Odds ratio estimates and 95% Wald confidence interval limits for the retention rates of each Math ACT score range for comparisons between the bridge program students and the control group.

Some observations can be made from these results. First, while the odds ratio estimates generally indicate a positive impact on retention rates for the students in the 1L and 2M Math ACT ranges, the only truly statistically significant result is for the 2-year retention of students in the middle Math ACT (2M) range. While the other results should not be disregarded, with respect to the impact of the bridge program on the potential success of students in these groups in engineering, it should be noted that the impact of the bridge program on the retention of students likely is small overall.

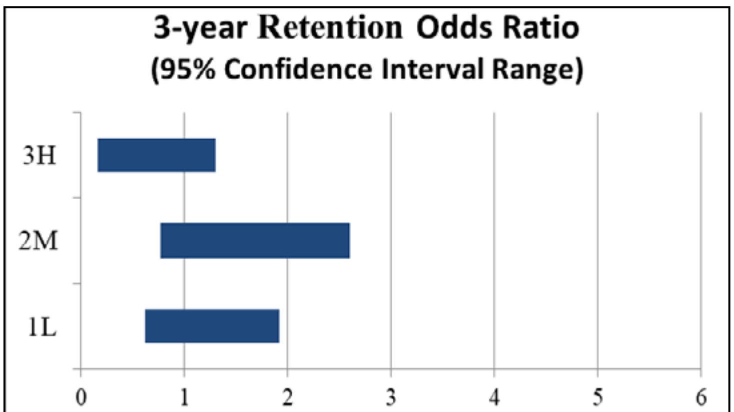

Figure 3: The 95% confidence interval range for the 3-year retention odds ratio for the bridge program students vs. the 2007-08 cohorts, divided into the three Math ACT score level categories. As a portion of all the interval ranges fall below 1, none of the results are statistically significant.

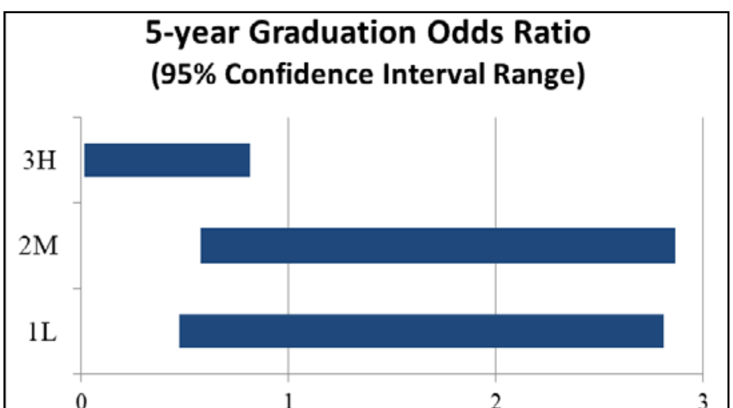

Figure 4: The 95% confidence interval range for the 5-year graduation odds ratio for the bridge program students vs. the 2007-08 cohorts, divided into the three Math ACT score level categories. While the result is technically statistically significant for the 3H level students, in the bridge program being harmful to the students, the number of 3H students in this category is very small making any conclusion questionable.

Second, the results for the 3H group of students appear to indicate that the students in this group are less likely to be retained after going through the bridge program. However, there may be extenuating factors impacting these results. Recall from Table 2 that the number of students in the bridge program in the 3H level is low. This is to be expected, as engineering students who score a 28 or higher on the math portion of their ACT typically place into Calculus I on the university's math placement exam; therefore, they would not be invited to the bridge program. The small number of students in the 3H level in the bridge program make the results more susceptible to individual student decisions (such as transferring to an engineering program at another university), and such decisions may have no relationship to participating in the bridge program. In addition, by not placing into Calculus when they first took the placement exam, as would ordinarily be expected from their ACT scores, there is the possibility that these 3H bridge program students may not have the same interest in engineering academic success as the other 3H students who did place into Calculus. Such an attribute may make it more likely for them to leave engineering than other high-achieving students.

Returning to the results for the 1L and 2M students, it is interesting to note that despite the overwhelming immediate success of the bridge program, there is relatively little impact on the retention rates of the bridge program students. Therefore, the basic hypothesis that advancing the students into engineering courses sooner and reducing the time to graduation (in addition to the other elements of the bridge program) would improve retention is not supported for this program.

This leads one to ask the question as to whether the academic skills and preparation of these students is insufficient for them to succeed in engineering studies at this university. It can be noted that the Math ACT scores of even the 2M group are rather low for what many engineering schools consider necessary for admission. Considering that the impact on the retention rates of the students in the 1L group was lower than in the 2M group, this does suggest that there is a point where students are too weak academically to be expected to succeed in engineering. However, some students with similar academic backgrounds do graduate with engineering degrees. So a likely conclusion is that the bridge program alone should not be seen as a means of improving the graduation rates of less talented students, but that it may play a role as one of a series of interventions that universities need to employ to increase graduation rates, particularly for less academically-prepared students, in terms of their mathematics preparation.

Graduation rates can also be compared between the cohorts, although it should be noted that it is unlikely that later cohorts of bridge program students will have had sufficient time to graduate. Therefore, the 5-year graduation rate was compared through the spring 2016 semester between the control group and the 2010 and 2011 summer bridge program participants. This reduces the number of students considered in the bridge program cohort to 1L-55, 2M-39, and 3H-12. The results of the logistic regression analysis odds ratio estimate are presented in Table 4, and the 95% confidence limit range are shown visually in Figure 4.

As with the retention rates, the improvement in the likelihood of graduating within 5 years appears greatest in the 2M math ACT group, although the results again fall short of being statistically significant. The 1L group also shows a statistically-insignificant improvement in their odds of graduating in 5 years. It should be noted that many students in the engineering program may not graduate until their 6th year – however, a purpose be-

Math ACT Range	Odds Ratio Estimate	95% Confidence Limit - Lower	95% Confidence Limit – Upper
5 – Year Graduation			
1L	1.151	0.471	2.809
2M	1.284	0.575	2.866
3H	0.102	0.013	0.812

Table 4: Odds ratio estimates and 95% Wald confidence interval limits for the 5-year graduation rates of each Math ACT score range for comparisons between the 2010-2011 bridge program students and the control group.

hind offering the bridge program is to reduce the time to graduation, making 5-year graduation rate comparisons reasonable. The results for the 3H group are statistically significant, but for reasons discussed earlier, the sample size is not large enough in the bridge program cohort to be able to make conclusions on the impact of the bridge program for these students.

Overall, the results indicate that the summer bridge program, as implemented in this engineering program, had a small impact on the likelihood of improving the retention and graduation of students with math ACT scores of 27 or lower. The odds ratios for retention and graduation are consistently higher for students with math ACT scores at or below 27 in the bridge program than those not in the bridge program. However, the majority of these results were not statistically significant. On the other hand, the program did result in a large majority of students placing into a higher initial mathematics class. This suggests that there is a positive trend towards the bridge program aiding the academic success in engineering of such students. But for this trend to result in increased graduation rates, there likely needs to additional interventions beyond the bridge program to continue to support the academic needs of particularly the less-prepared students.

Conclusions

A logistic regression analysis was performed to determine the odds ratio between students who participated in a summer bridge program and comparable students did not participate in such a program. The bridge program was designed to improve students' math placement levels (as determined by a university math placement exam) and familiarize students with engineering and the university before beginning formal classes. Students were grouped into three categories based upon their score on the math portion of the ACT. The results showed that for the middle and lower range students, there was a small increase in the odds of the students being retained and graduating, but the only statistically significant result was for the 2-year retention of the students with Math ACT scores in the middle range. There were too few students in the bridge program in the high score range to make any meaningful conclusions about how the bridge program may impact such students.

While the bridge program met its goal of improving the math placement level of most of the students in the program, that improvement and the increased familiarity of the students with campus and engineering do not appear to have had a great impact on the likelihood of students ultimately succeeding in engineering studies. This does not mean that the bridge program does not serve a useful purpose, but rather indicates that engineering colleges will likely need to provide additional, on-going support for students at these academic levels throughout their studies. The math ACT scores in the lower and even the middle groups are below what are often expected of incoming freshmen in engineering programs, and so universities should be prepared to provide such ongoing support for years in order to help such students graduate if they admit such students.

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