Full Paper

Introduction

The need for engineers world-wide can only be met if sufficient numbers of students of diverse ethnicity, both male and female, are successfully recruited and retained in engineering fields. Engineering majors understand that calculus skills are essential for success. Various types of bridge programs have played a major part in this effort for more than 20 years. Common features of bridge programs in the 1990's included a) increased scores on assessments, b) challenges convincing students who needed the intervention to take advantage of the opportunity, and c) skills training, especially mathematics because of its critical role in college matriculation (Ohland & Crockett, 2002). Bridge programs for mathematics have had success in improving the mathematics background of incoming freshmen, improving grades in the first mathematics course taken in college (Basitere & Ivala, 2015; Doerr, Ärlebäck, & Staniec, 2014; Raines, 2012). Although small percentages of students targeted for bridge programs in the 12 programs examined in a meta-analysis of bridge programs participated, high percentages of those who completed the program increased their mathematics scores (Diefes-Dux, 2002; Papadopoulos & Reisel, 2008).

The earliest bridge program identified that used an online format focused on precalculus, was free, and lasted four weeks. The online format was discontinued after two years because of low completion rates and minimal score increases, with students spending less time, on average, working on the mathematics (Papadopoulos & Reisel, 2008). The lack of mathematics proficiency continues to be problematic for engineering students; therefore, bridge programs designed to address that deficiency continue to be used. Programs began to include technology to provide individualized instruction and practice (Boykin, Raju, & Bonner, 2010; Reisel, Jablonski, Hosseini, & Munson, 2012). One program that offered an online or face-to-face option discontinued the online portion because of its ineffectiveness (Reisel et al., 2012). However, research about bridge programs that use live tutors online was not located in the literature search.

Although bridge programs have enjoyed some success, challenges have continued to plague them. Students who most need to strengthen their mathematics backgrounds often do not recognize their need, especially those with borderline passing scores on placement exams. Therefore, considerable effort, time, and money is necessary to entice those students to participate. Even after students are recruited, they often drop out before the end of the program, thinking they have completed enough to review and retake the placement test and score high enough to register for the course they are aiming to take. They failed to understand the seriousness of their situation (Reisel et al., 2012).

Bridge Program Development

The Department of Mathematics at Texas A&M University implemented bridge programs to support students in their engineering calculus sequence. The new bridge programs were developed to support at-risk students throughout the engineering calculus sequence. They were off•shoots of a summer precalculus review program, the Personalized Precalculus Program (PPP) for incoming freshmen. Initially, discussions included the fact that there was a need for support throughout the engineering calculus sequence, not just for incoming freshmen. There have been many supports available for students over a number of years. There are past exams with answer keys available on the department website. In addition, there is a "week-in-review" session that students can attend during the semester to review concepts and practice problems from the past week. However, a more intensive review of underlying concepts and skills was needed to additionally support students. When that type of support was offered during the semester, it was not well attended; at-risk students had so many other pressing study needs that they did not persist throughout the semester. The decision was made to provide that support just before the beginning of the semester with the expectation that 1) students would be fresh and ready to prepare for the upcoming course, and 2) the practice would be close enough to the semester that students would retain what they learned long enough to apply and solidify their knowledge and skills. Results were encouraging in the first three years of the PPP, so it was determined that plans for the mini-bridge programs to support students throughout the calculus sequence would be initiated. The program was directed toward students who earned a B or C in precalculus or the first or second engineering calculus course to strengthen their mathematical understanding and skills before they progressed to the next course. The bridge programs were one week in length, occurred just before the fall and spring semesters, and consisted of 15 hours of instruction with an online tutor.

Students who earned a D or F in a calculus course were not allowed to take the next course. However, students who earned B or C were still considered at• risk for the subsequent course. These particular students were invited to participate in the bridge program schedule just prior to the next fall or spring semester. The one-week bridge programs were designed for courses in the engineering calculus sequence to better prepare students at risk for success in the next course in the sequence by addressing insufficient knowledge and skills in mathematics. As a result of surveying instructors of engineering calculus courses, each bridge program's curriculum had a dual purpose 1) strengthening prior knowledge and skills, and 2) providing a head start on new topics for the upcoming course.

Topics that were important in calculus applications were selected for each bridge program. The bridge to calculus I focused on three main areas: trigonometry, vectors, and parametric equations. Students coming from precalculus courses at high schools, community colleges, or universities were expected to have covered these topics because they are generally included in precalculus courses, and are components of the state standards for precalculus. However, it is common knowledge that these topics, especially vectors and parametric equations, get the short shrift because they are more difficult for teachers and are left to the end of the school year when time usually runs out.

The bridge to calculus II also focused on strengthening topics from the previous course and looking forward to calculus II. Topics included antiderivative and definite integrals, the area between curves, U-substitutions, partial fractions, integration by parts, volumes by slicing, integrals with trigonometric functions, and sequences and series. This bridge program was the first one established, and its initial implementation and results were the focus of this paper because grades from the course became available after students completed the semester. Analysis will continue for the first bridge (to calculus II) and the subsequent bridge programs as each semester concludes.

Technology in the Bridge Program

The bridge programs were designed as shorter, more focused programs than the larger PPP for incoming freshmen (see Nite, Capraro, Morgan, Peterson, & Capraro, 2014, October; Nite, Morgan, Allen, Capraro, & Capraro, 2014, December). They did not contain the online practice problems or videos. However, they included the component that students in the PPP most often commented about and rated as very beneficial to their success – the live, online tutor.

Students were provided the link to join with the tutor and other students, in class sizes of about 20 in WebMeeting. The online venue provided opportunities for oral communication through headsets with microphones. Students logged on to the system at the time assigned for their 3- hour sessions each day. Tutors answered questions in a whole-class setting. The topics to be addressed and corresponding PowerPoint presentations with example problems were prepared for the tutors to ensure consistency throughout the program. The tutor reviewed the concepts and skills for the session, using the PowerPoint presentations and the ability to write on the whiteboard as he/she discussed concepts and worked sample problems. Then students were divided into small groups or individually into their own virtual rooms, where they worked additional problems. They discussed the problems and used the whiteboard to write their solutions. The tutor circulated throughout the rooms, observing the work on the whiteboard and the conversation between students, asking and answering questions to facilitate the learning in each room. Students were then returned to the whole class setting, where they were able to share their thinking and results with each other and receive feedback from the tutor. The tutor was able to save each group or individual's work, discuss misconceptions and gaps in knowledge, and answer questions about the work. Students could then be given additional practice problems for the topic of the day. The technology used allowed students to remain in their hometowns, hold down jobs, and participate through the capabilities of the program to bring education directly into their homes.

Methodology

Participants were students entering engineering calculus II. Students who passed precalculus or engineering calculus I with a grade of B or C were targeted, but other students could also enroll. Because grades tended to drift down as students progressed through the engineering calculus sequence, these students were considered at risk for not successfully completing the sequence and remaining as engineering majors. They were invited to participate in the bridge program designed to strengthen their skills so that they would be better prepared for the next course.

There were 41 students who participated in the bridge from the first to second engineering calculus course the first time it was offered, just before the Spring 2014 semester. Data were examined from both student responses to a survey about their perceptions of improved skills, and grades in subsequent calculus courses. Questions from the survey addressed the follow:

- Whether they felt better prepared for engineering calculus II after the bridge
- Whether they felt they understood the material in engineering calculus I
- How often they participated in class discussions or asked questions
- Whether the large class size was intimidating
- Which available resources they used (instructor office hours, commercial tutoring, help sessions, week-in-review sessions)
- Whether they believed the online environment was as effective as face-to-face sessions
- Whether they thought 15 hours (3 hours a day for 5 days) was a good length for the program

Results

There were several interesting results during the first implementation of the bridge program for engineering calculus II. Reasons students chose to participate included preparing ahead of time, improving chances of a good grade in the course, and because they heard it was hard. Of particular interest were 1) the student reactions to the online format, and 2) the participating students' grades in the engineering calculus II course.

The online format

Survey results showed that students felt the bridge program strengthened their skills and probability of success in engineering calculus II, and they believed the online format to be effective. As shown in Figure 1, 15 (36.6%) of the students believed the online format was just as effective, and 19 (46.3%) of the students believed the online format was almost as effective as face-to-face sessions. Only 17.1% of the students did not believe the online sessions were at least as effective as face-to-face sessions.

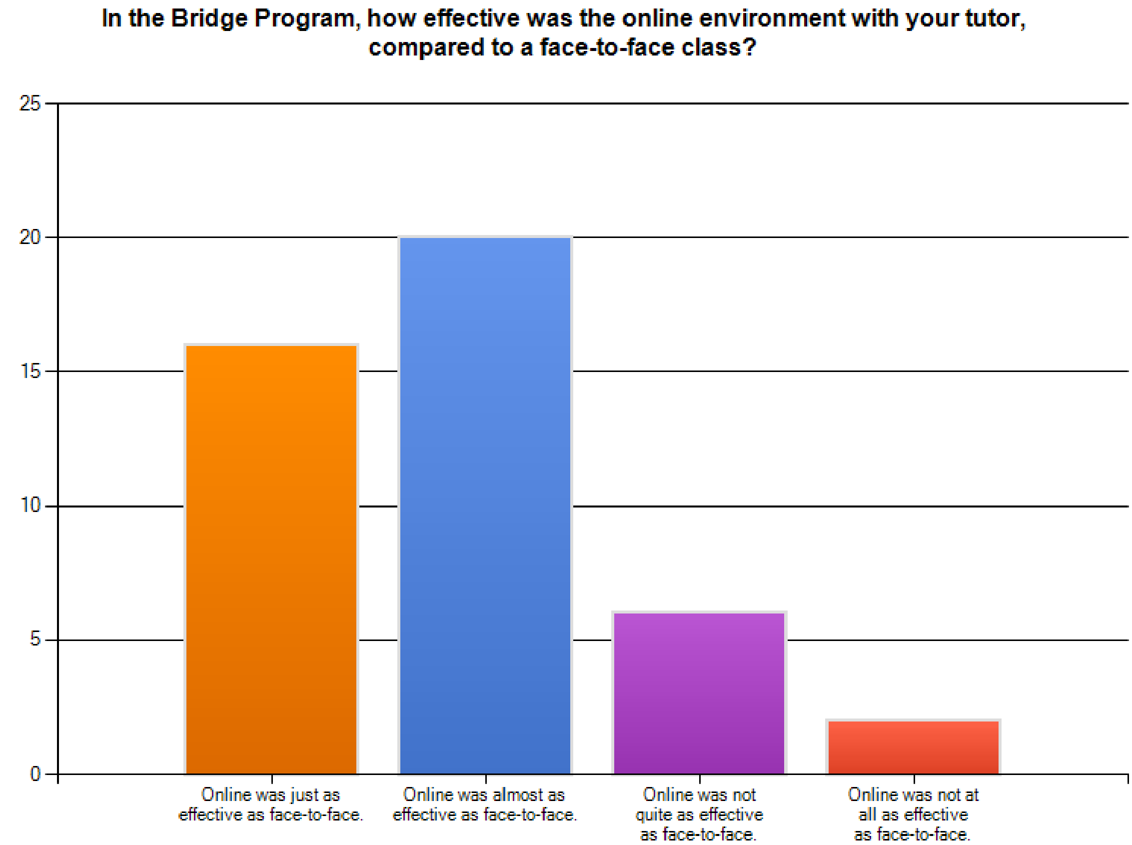

Figure 1: Student beliefs about effectiveness of the online environment.

In addition to the question specific to the online environment, students were asked why they enrolled in the bridge program. Some wanted to remediate skills they felt were missing, and some wanted to get a head start for the next course. This verified the assertion of the faculty team that the mix of topics chosen to include concepts and skills from engineering calculus I and new topics from engineering calculus II was a good choice. A few of the interesting, sometime humorous answers included:

“I wanted the best possible grades for the upcoming semester and I had nothing better to do so I thought I might as well learn something.”

“I heard calculus 2 was the hardest and I wanted an A.”

“I decided to sign up for the Bridge Program to get back into the routine of the next semester of Engineering Calculus, and to prepare for what the second semester of the class would be like, which I found to be a very helpful and pleasant way to use my time before starting back up for the spring semester.”

Grades in Engineering Calculus II

Besides the question about the effectiveness of the online format, students were also asked whether they believed the bridge program helped them become more successful in engineering calculus II. Overwhelmingly, they believed that it did. Seventy-eight percent responded that they believed the program definitely (26.8%) or somewhat (51.2%) enabled them to be more successful.

The participants in the bridge program earned B (42.5%) or C (57.5%) in the first engineering calculus course. Because concepts and skills in calculus build upon prior knowledge, grades, especially those below A or B, tend to drift down throughout the sequence of courses.

Although the grades for the participants were not as high as their expectations about mid-semester when the survey was taken, they were encouraging. There were only 5 A's (12.2%), but 78.1% earned an A, B, or C and were able to move on to the next course, engineering calculus III. In the total of 9,993 students who took engineering calculus II over the years from 2010-2014, 86.8% earned an A, B, or C. In the group that took engineering calculus II the same semester as the bridge students (Spring 2014), 88.2% earned an A, B, or C. Thus this group of at-risk students performed reasonably well. Table 1 shows the percentages of A, B, C, D, and F (or drop) for each group. Although the bridge students had a smaller percentage of A's and B's, they had similar numbers of D's and F's. It was not possible to completely bring the at-risk students, none of whom earned an A in the first engineering calculus course, up to the standard of the non-bridge group, but the number passing and qualified to move to the next course were similar. That meant more of those students remained in the STEM pipeline with the opportunity to continue working towards their goals than would likely have been able to do so without the bridge program. Grades are reported on a 4-point scale, where A = 4, B = 3, C = 2, D = 1, and F = 0. There are no + or – designations to further differentiate. Generally A is assigned for 90-100%, B for 80-89%, C for 70-79%, D for 60-69%, and F for below 60%. Table 2 shows the means and standard deviations of the grades of the two groups, based on a 4-point scale with only integer values, 4 corresponding to an A, and 0 corresponding to F or dropped the course. There were no statistically significant differences between the mean grade averages of the two groups.

Table 1: Grade distribution in engineering calculus II

Grade	Bridge Students (n = 41)	Non-Bridge Students (n = 1758)
A	12.2%	22.0%
B	29.3%	33.8%
C	36.6%	22.4%
D	7.3%	6.9%
F or Drop	14.6%	15.0%

Table 2: Mean grades in engineering calculus II

	Mean	Standard Deviation
Bridge Students (n = 41)	2.17	1.202
Non-Bridge Students (n = 1758)	2.41	1.310

Whereas Tables 1 and 2 compare the grades of the students in Spring 2014 who participated in the bridge to engineering calculus II with the students who did not participate in the bridge program, Tables 3 and 4 compare the grades of only the students who earned B or C in engineering calculus I. All of the students who participated in the bridge to engineering calculus II had earned B or C in the previous course. They were then compared with the non-bridge students who earned B or C in the previous course. The students in the bridge program had a higher success rate (A, B, or C) and a higher percentage of A's in engineering calculus II. Although the mean grade was higher for the bridge students, it was not statistically significantly different.

Table 3: Grade distribution in engineering calculus II for B and C students in calculus I

Grade	Bridge Students (n = 41)	Non-Bridge Students (n = 1002)
A	12.2%	6.9%
B	29.3%	32.8%
C	36.6%	31.4%
D	7.3%	9.4%
F or Drop	14.6%	19.5%

Table 4: Mean grades in engineering calculus II for B and C students in calculus I

	Mean	Standard Deviation
Bridge Students (n = 41)	2.17	1.202
Non-Bridge Students (n = 1002)	1.98	1.215

Discussion

Even when offered over a short period of time, bridge programs can be very effective if explicitly focused on desired calculus foundations. Because this program focused on a few specific topics over the course of only one week, it was anticipated that students who participated in the bridge program would increase their knowledge and skills in mathematics and their confidence in their abilities to succeed in mathematics. In addition, it was expected that grades of students who earned a B or C in the engineering calculus course and participated in the bridge program for the subsequent course would earn higher grades than students who earned B or C and did not participate in the program.

Bridge programs have most typically involved either face•to•face instruction or asynchronous online instruction. However, an online bridge program with a live tutor can be successful in remediating mathematics skills in order to reduce attrition in engineering majors as a result of difficulties in mathematics. The grades for students in the bridge to calculus II for the 2014-2015 academic year will be analysed, along with grades in the third engineering calculus course with the expectation that results from the pilot will continue. In addition, the subsequent bridge to calculus I program that was created after the bridge to calculus II will provide additional data to determine the effectiveness of the sequence of bridge programs for the engineering calculus sequence. The Australian higher education system does not currently generally provide remediation for prospective engineering students. However, as the need for engineers increases, the ability to bolster mathematics skills through bridge programs (without university faculty needs to change engineering subjects) may be a consideration. Bridge programs for entering freshmen as well as support throughout the mathematics sequence can be a viable option. If results from mini-bridge programs such as this one continue to benefit at-risk students and retain them in the STEM pipeline, it seems likely not only that such support programs would be effective for other STEM course sequences such as those in chemistry and physics but that at least part of the instruction could be brought right into the students' homes through technology.

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