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# **AC 2012-4214: LEVELING THE PLAYING FIELD: PREPARING STUDENTS FOR CALCULUS**

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# Leveling the Playing Field: Preparing Students for Calculus

## Abstract

This paper presents an on-line bridge program for incoming engineering freshmen. The program is implemented by a residential research institution in the Midwest that is a leader in distance education. The objective of the bridge program is to prepare students that grasp most, but not all the material required to enter calculus, to successfully complete calculus. The program consists of four weeks of lectures, assignments and exams. Students that successfully complete the course during an eight week period were permitted to register for calculus. The program was evaluated in three areas: student learning, engineering retention rates, and instructional tools. While the study is ongoing the initial results indicate that the program has had a positive impact, although the benefits have not been universally realized. Based on the initial results, suggestions are provided as to how the program can be improved.

## Introduction

Students entering university systems have a diverse set of mathematical backgrounds, creating anything but a level playing field at the outset of postsecondary study. Mathematically underprepared engineering students face the greatest difficulty because the standard engineering curriculum assumes students are ready to enter calculus in their first semester. The threat of an additional year of school forces students to enter calculus even if unprepared. This can be a big mistake because students that leave in their first year most commonly cite calculus as the reason<sup>1,2</sup>. It should be of no surprise that students become disenfranchised with engineering after struggling in calculus only to face the depressing reality of an additional year of instruction and all the associated costs.

The difficulties caused by requiring students to enter calculus in their first semester have led to the creation of several programs aimed at alleviating the hardship. One method presented by Klingbeil et al.<sup>3</sup> reworks the curriculum to eliminate the need for calculus until the sophomore year through the addition of an engineering mathematics course. This solution does little to address the disparity among students and requires a multi-department, multi-college initiative to implement. Thus, the implementation of this solution would be difficult at best. Another popular method for addressing this issue is implementing a summer bridge program to eliminate deficiencies in mathematical preparedness among incoming first-year students. These programs are a particularly popular for improving recruitment and retention of students from under-represented minorities<sup>4</sup>.

This work presents a bridge program created to address deficiencies in mathematical preparation in incoming first-year students at a residential research institution in the Midwest. This institution leverages their position as a leader in distance education to facilitate an introduction to engineering mathematics course. The online calculus preparatory course was offered to students entering engineering as an academic major prior to their arrival on campus. It provides students the opportunity to address deficiencies in their mathematics backgrounds and – in a sense – to level the academic playing field prior to their enrollment in engineering courses. In addition, the cost of the program is relatively small because participants do not need to relocate to campus. The program is also unique because students can complete it at their own place. This minimizes the program's effect on summer commitments and travel.

## Background

Bridge programs have been in existence for some time and have been employed by a large number of institutions<sup>5,6</sup>. The goal of these programs can range from recruitment to strengthening students mathematical abilities for improved student persistence. Additionally, the length of these programs can vary from one to ten weeks. The growth in the popularity of these programs is due to the recognition that many students entering engineering have deficiencies in their mathematical preparedness. Moreover, this lack of preparedness has a significant effect on student persistence. Bridge programs are one method for addressing the lack of preparedness and increasing persistence among incoming first-year students.

One of the earliest bridge programs is described by Hudspeth *et al.*<sup>7</sup>. The program recruits underrepresented minority students and immerses them in a residential program structured to simulate the university experience. The primary objective of the course is to improve students' mathematics background while providing them with the study and time management skills needed to be successful. The program helped students make the transition to university and improved student performance as measured through GPA. A similar program was adopted at Arizona State University<sup>4</sup>. Students in this program were recruited with the offer of a \$600 scholarship. The primary objective was to provide students with an experience to whet their appetite for engineering and science.

The bridge program that shares the most in common with the one presented in the work was implemented at University of Wisconsin-Milwaukee. The program was offered in both an on-line and residential format<sup>8</sup>. The primary objective of the program was to increase participants math placement scores. This program, open to all students, began by assessing the participants' mathematical preparedness with a math placement exam. Each participant's score was then used to assign them a customized, computer-based curriculum. The result of the program was a moderate improvement in student placement scores, but this benefit was not universally realized. Due to the poor performance of the on-line program with respect to a similar residential program, the on-line component was terminated. The authors concluded the inability of an on-line program to force students to adhere to a highly structured schedule makes achieving the success of a residential program unlikely.

A meta-analysis of similar, math focused, bridge programs was presented by Papadopoulos and Reisel<sup>6</sup>. They find that these programs vary in duration, content, and target population. Common measures of improvement are math placement of students, subsequent success in mathematics, persistence, and graduation rates. The programs were found to have similar levels of success. The most limiting aspects of the studies presented in the meta-analysis were small sample sizes, a lack of longitudinal data, and a lack of a proper control group (students self-select for the bridge program).

## Description of Program

The ability to offer an on-line bridge program is important because it reduces the resources required to implement the program. Additionally, on-line programs reach more students because moving to campus is no longer a requirement. Hosting the lectures on-line also allows students to re-watch lectures as needed. This is important because incoming first-year students often lack the ability to take quality notes.

*Recruitment:* The content of the bridge program was limited to that of a four week course. This limitation dictated that participants only include students that have a good grasp of most topics required for calculus, but could benefit from additional instruction. Students that have a very limited understanding of algebra and trigonometry are not ideal candidates for bridge programs<sup>9</sup>. It is impossible to properly cover the topics needed to prepare these students for entry into calculus. A similar bridge program open to all students found that most students only experienced a small improvement in preparedness<sup>8</sup>. Moreover, when this resulted in students being placed in a more advanced math course a small decrease in student performance was found. This can be detrimental because it has also been found that students entering algebra or trigonometry are more likely to persist in engineering if they receive a C or better<sup>10</sup>.

To identify candidates for the program all incoming engineering students were asked to take an on-line math placement exam in May. Students with a placement score at or near the threshold score needed to enter calculus were contacted and asked to participate in the bridge program. They were told that the program would better prepare them for the rigors of calculus and, in the case of students not qualified for calculus, allow them to avoid an extra semester of mathematics (Pre-calculus). Moreover, students were told that successful completion of calculus in their first semester is an important factor in completing an engineering degree in four years. Failure to complete the bridge program with a passing grade resulted in the student being placed in the mathematics course dictated by their original placement exam score. Thus, there was little risk to the participants. The only cost to the participants was the fees associated with the course.

*Program Description:* The primary objective of the course was to prepare students to successfully complete calculus in their first semester. This was accomplished by focusing on topics that calculus instructors indicated were the primary obstacles to student success. These topics included algebraic manipulation and the application of trigonometric identities.

The course consisted of four weeks of lecture (16 one hour lectures) covering the following topics:

- Functions
- New functions from old
- Algebraic functions
- Trigonometric functions
- Exponential and logarithmic functions
- Conic sections, polar coordinates, and parametric equations

Students viewed the lectures on-line at their convenience. This allowed them to quickly move through lectures on material they were comfortable with and spend more time on those they were struggling to grasp. The only constraint was that students had to complete the course by the end of an eight week period. Student progress was assessed through nine homework assignments and three exams. Students that completed the course and received a passing grade were allowed to register for calculus even if their original placement score would have prohibited them from doing so.

## Methods of Assessment

The evaluation plan for the bridge program in this study centers on implementing assessment models in three impact areas: student learning, engineering retention rates, and instructional tools. Table 1 summarizes evaluation goals for each impact area, assessment method, or vehicle used, and performance indicators or markers for success of the participants.

Table 1:  
Summer Bridge Course Assessment and Evaluation Plan

	<b>Evaluation Goals</b>	<b>Assessment Vehicles</b>	<b>Performance Indicators</b>
<b>Student Learning</b>	<ol style="list-style-type: none"> <li>1. Assess student learning of engineering-specific mathematical concepts.</li> <li>2. Assess student confidence levels in command of engineering-specific mathematical concepts.</li> </ol>	<ol style="list-style-type: none"> <li>1. Structured record review of homework assignment grades</li> <li>2. Student feedback on confidence levels at end of course</li> </ol>	<ol style="list-style-type: none"> <li>1. Change in mathematical knowledge as measured through performance on homework assignments.</li> <li>2. Changes in self-reported confidence levels of engineering-related mathematical concepts.</li> </ol>
<b>Engineering Retention Rates</b>	<ol style="list-style-type: none"> <li>3. Determine enrollment patterns in math and engineering courses and academic major selection following bridge course completion.</li> <li>4. Assess student comfort levels with engineering-specific mathematical concepts.</li> </ol>	<ol style="list-style-type: none"> <li>3a. Student feedback on intended course enrollment and major selection.</li> <li>3b. Structured record review of engineering student enrollment records (post-course).</li> <li>4. Student feedback on comfort levels at end of course.</li> </ol>	<ol style="list-style-type: none"> <li>3. Positive impact on engineering retention rates as measured by students' continued enrollment in math and engineering courses and maintaining engineering as their selection for an academic major.</li> <li>4. Changes in self-reported comfort levels of engineering-related mathematical concepts.</li> </ol>
<b>Instructional Methods</b>	<ol style="list-style-type: none"> <li>5. Determine impact of video lectures, practice problems, and homework assignments on teaching engineering-specific mathematical concepts online.</li> </ol>	<ol style="list-style-type: none"> <li>5. Student feedback on video lectures, practice problems, and homework assignments.</li> </ol>	<ol style="list-style-type: none"> <li>5. Positive self-reported student reaction to use of instructional tools (video lectures, practice problems, and homework assignments) to master math concepts.</li> </ol>

The first impact area, student learning, was determined by a two-pronged process. First, we completed a structured record review of course records. More specifically, we collected student scores on the homework assignments that they completed during the course so as to track their

academic progress and command of the course material. We also collected student feedback on the course concerning confidence levels in performing well in math related to engineering concepts.

The second impact area, engineering retention rates, can also be determined by structured review of students' academic records, not related to performance, but by identifying the courses in which students enroll in semesters following completion of the bridge course. A data request has been made to the institution to receive aggregate data concerning student enrollment in engineering and math courses in the Fall 2011 semester. In addition, we asked for the current selected major (or intended major) of the bridge course completers. Once received, this information will enable us to determine the students' level of commitment to engineering as a viable field of study. We were also interested in ascertaining students' comfort levels with mathematical concepts that are central to the study of engineering. It is believed that awareness of changes in self-reported comfort levels with the course content will better inform our understanding of the likelihood of student commitment to engineering as a major.

The third impact area, instructional tools, was assessed following completion of the calculus preparatory course in summer 2011. Students were asked for feedback on their experiences in the course related to the video lectures, practice problems, and homework assignments. We also gathered participants' opinions on how the course prepared them for university study, particularly as it related to studying calculus.

## **Results**

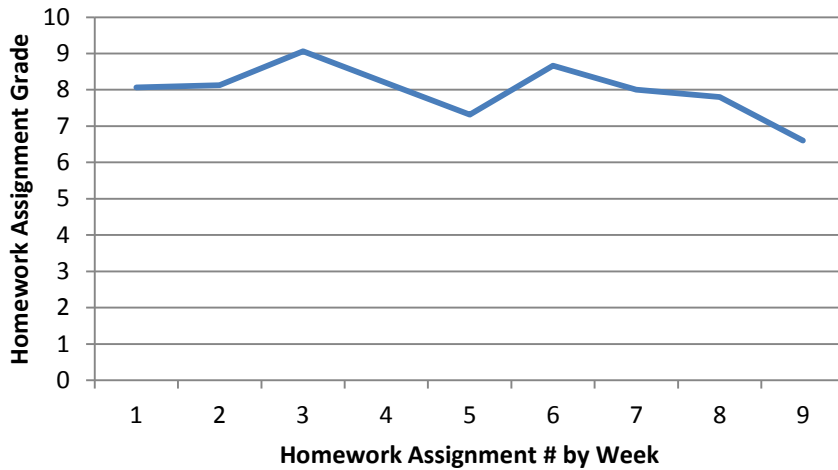
Although the number of students who participated in the bridge program is low ( $n=8$ ), we qualitatively explored student records to establish a baseline of performance and intent to study engineering in college. The response rate to the optional student feedback opportunities was also low (37.5%), thus limiting the analytical capabilities of the data collected. However, we found value in qualitatively evaluating student feedback concerning comfort levels and confidence levels with the mathematical concepts covered in the course. Student feedback on the use of the instructional tools in the online bridge course was also qualitatively evaluated.

### *Student learning*

In the first analysis of results concerning assessment of student learning, we sought evidence of changes in mathematical knowledge as measured through student performance on homework assignments. General trend lines of the completing students' homework assignment grades present an overall downward trend in performance (see Figure 1).

Figure 1

Average Homework Assignment Grade for Students in Bridge to Calculus Course



Student feedback on three specific questions was used to determine student confidence levels in the command of engineering-specific mathematical concepts:

- 1) After taking this course, how confident are you in your mathematical abilities?
- 2) After taking this course, how prepared do you think you are to take calculus?
- 3) Overall, how confident do you feel in your ability to succeed in engineering?

Two students responded that they felt “somewhat confident” in their mathematical abilities, “somewhat prepared” to take calculus, and “somewhat confident” in their ability to succeed in engineering after taking the summer bridge course. One student reflected a feeling of “very confident” in mathematical abilities, “very prepared” to take calculus, and “extremely confident” in ability to succeed in engineering after taking the summer bridge course.

#### *Engineering retention rates*

Although student records have not yet been received to determine enrollment patterns in math and engineering courses and academic major selection following bridge course completion, we reviewed student responses to questions about intent to take math and engineering courses, as well as identification of intended major. This line of inquiry revealed that two students expected to take a math class in Fall 2011 (pre-calculus and calculus). One student indicated uncertainty about plans to take math in the subsequent semesters. Three students said that they were “100% sure” they would take engineering classes in Fall 2011; mechanical engineering and electrical engineering courses were specifically mentioned.

Student responses to a question about their comfort levels with engineering-specific mathematical concepts were mixed – ranging from “somewhat comfortable, comfortable, to very comfortable”. Thus, it is difficult to determine a benchmark or change in self-reported comfort levels with math.

### *Instructional tools*

Three instructional tools were used in the summer bridge course: video lectures, practice problems, and homework assignments. Table 2 depicts the student-reported usefulness of each of these tools in helping them succeed in the course.

Table 2  
Helpfulness of Summer Bridge Course Instructional Tools in Learning Math



Several students elaborated on the most popular response, homework assignments as most helpful in learning math. They indicated that the homework assignments were helpful because it gave them a chance to practice what they learned in the problem sets/worksheets. To a lesser extent, students enjoyed the homework assignments because they provided an opportunity to practice what they learned by watching the video lectures. The only negative reaction to the homework assignments was reported by three students who stated that they did not feel connected to the material in the homework assignments.

Summer bridge student feedback revealed no consistent message concerning the video lectures. Some of the positive comments included:

- I was able to work at my own pace.
- I could start/pause them as often as I needed to.
- I could replay the lectures as often as I needed to.
- They are available whenever I want them.
- I am in control of the flow of information.

Negative feedback included:

- The quality of the video lectures (i.e., audio, video, graphics accompanying the video) was not optimal.
- I was not able to ask a question in real time if I did not understand something.
- The lectures were not personal enough.
- I did not feel connected to the material.
- I would rather learn alongside my peers (in a group setting).



The problem sets/worksheets were the least helpful in learning math, according to feedback from students in the summer bridge program. As with the video lectures, student comments on the problem sets/worksheets were mixed. Although there was no consensus, reasons that students liked the problem sets/worksheets included:

- I was able to work at my own pace.
- The problem sets helped me learn math.
- It was a good chance to practice what I learned from watching the video lectures.
- I could re-work the problems as often as I needed to.
- I liked working on the practice problems on my own.

Student comments concerning what they did not like about the problem sets/worksheets a bit more aligned around two themes: 1) students prefer to work on the problem sets with others (in a group setting; and 2) students did not understand the content in the problem sets/worksheets.

### **Lessons Learned**

In the online calculus preparatory course, the first iteration of which was offered in summer 2011, our main goal was to review the standard topics of pre-calculus, emphasizing algebra skills, in order to better prepare students for the study of engineering and engineering-related calculus. Specific outcomes of student enrollment and participation in the online calculus preparatory course were:

1. to increase student levels of proficiency in pre-calculus concepts and;
2. encourage students to persist in the study of engineering

Preliminary results related to student learning are troublesome in that student performance on the homework assignments actually reveals a decrease in proficiency of pre-calculus concepts. Moreover, individual student feedback does not reflect strong confidence levels in their abilities. Subsequent analysis will couple engineering retention rates, as determined through structured record review, with the student learning assessment results, to further explore the efficiency and capability of the summer bridge course in meeting the desired outcomes of the course.

In this same vein, we sought to determine the most effective vehicles for delivering calculus preparatory course instruction in an online format. In this study, all lectures were delivered in an asynchronous environment via recorded lectures. The instructor used additional methods for examining students' mastery of material, including practice problems and homework assignments.

Offering a distance bridge program has two major disadvantages over residential programs. First, there is a lack of structure. Simply placing students in a room and watching them complete the exercises has a positive effect<sup>8</sup>. Second, students do not feel that they had enough access to help. While they were encouraged to email the instructor with questions, this was not enough. These problems will be addressed by offering video chat sessions several times a week. Students will be required to attend a minimal number of these sessions. The video sessions will be used to answer student questions and force them to think about their assignments.

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