General Engineering Course for Freshman Students at Risk in Electrical Engineering

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***Abstract* - This paper describes the implementation of an academic success program in the 2015-16 academic year for the incoming freshman students in the Electrical and Computer Engineering (ECE) department of the University of Texas at Austin who have been identified by the university as at-risk students. At-risk status is assigned based on factors related to previous academic performance and demonstrated financial need. The purpose of this program is to provide these students with resources needed to ensure a successful transition from high school to college, to equip them with study skills and a problem-solving mindset necessary for rigorous engineering coursework, and to keep them enthused about the engineering discipline. The merits of the program are determined using quantitative data such as exam scores and course grades, as well as qualitative data such as mid-semester and end-of-semester surveys.**

Index Terms – at-risk students, summer bridge, general engineering

INTRODUCTION

Efforts to improve the academic success of students in engineering programs have been ongoing in many institutions [1, 2]. This growing awareness has resulted in the development of various supplementary courses (termed "bridge programs") to ease the transition from high school to college level coursework with a focus on at-risk students [3, 4]. Emphasis on math-readiness courses for these incoming engineering students have helped in closing gaps in their mathematical knowledge. Engineering study is difficult for many students, especially in institutions with large class sizes for freshman courses. Varied student backgrounds in introductory engineering classrooms results in a large spread in student skill levels, resulting in greater student isolation, especially for the at-risk student population. One of the objectives of summer bridge programs is to create a sense of community among these students. However, unless there is a concerted effort to continue building these communities and to monitor student progress, many of the at-risk students have a higher chance of failing engineering courses in their freshman year.

In the Electrical and Computer Engineering (ECE) department at the University of Texas at Austin, the General Engineering (GE) course was primarily created to help engineering students make a strong start to their studies. The Introduction to Electrical Engineering (EE302) course is routinely regarded by students as being very difficult and demanding, resulting in one of the highest rates of D's, failures, drops and withdraws ("DFQW" rate) in the department. This academic success program sought to address the following questions:

1. Does the General Engineering course affect the performance of the at-risk students in the Introduction to Electrical Engineering course?
2. How does the performance of these students compare with that of other at-risk students not in this program?
3. Do these students feel they are equipped to handle the rigors of future engineering coursework after their first semester?

DESIGN AND IMPLEMENTATION OF THE GE COURSE

I. Structure of the General Engineering course

General Engineering (GE) courses in the Cockrell School of Engineering at UT Austin are generally structured as two-hour-long sessions held twice weekly, and are associated with core courses such as Engineering Mechanics, Calculus, or Physics. These courses are led by graduate assistants who are carefully selected based on their ability to communicate course content. The graduate assistants are required to attend teaching workshops, and are also observed by program supervisors from the school. These sessions are offered by the Cockrell School of Engineering for courses that are notable for their high DFQW rates. The GE sessions emphasize collaborative learning. Problems are selected based on the concepts they demonstrate, and their applications to engineering principles.

The GE course for Introduction to Electrical Engineering (EE302) was first offered in the fall semester of the 2014-15 academic year. This pilot program was offered as an optional course to all ~400 freshman students enrolled in EE302. Due to schedule conflicts and the four-hour per week time commitment, very few EE302 students enrolled in the GE course. Additionally, both academically strong and at-risk students chose to participate in the pilot program. Based on exam scores and the overall structure of the program, it was decided that the course was the most beneficial to the at-risk

student population. Thus, in the fall semester of the 2015-16 academic year, the GE course for EE302 was offered to only those incoming freshman students identified as being at-risk.

At-risk status is assigned to incoming students by the university based on factors related to academic background and demonstrated financial need. All identified students are invited to participate in a bridge program in the summer prior to their freshman fall semester. The engineering students in this bridge program are enrolled in a rigorous calculus course with the objective of making them "math-ready" for engineering course-work. The 16 Electrical and Computer Engineering (ECE) students who participated in this summer program were also enrolled in an intensive 5-week long "Enhance Success in Engineering" workshop based on the teachings of Landis [5]. All of these students were enrolled in the same section of two required ECE courses in the fall semester, one of which was EE302.

II. Course content of Introduction to Electrical Engineering

The objectives of this requisite course are to introduce the incoming ECE freshman students to the basics of electrical engineering through a solid foundation in electric circuits. Due to the varied high school backgrounds and lack of preparedness of these approximately 400 freshmen, the course focuses on only DC circuits and circuit analysis, with AC circuits covered in the subsequent Circuit Theory course taken in the sophomore year. Prior knowledge in high school physics and algebra is expected. There are usually six sections taught by five different instructors with about 65 students per section. Each lecture section is divided into three lab sections, each led by graduate teaching assistants.

The course material is divided into three units, with weekly two-hour-long labs designed to reinforce the theory covered in lectures. Circuit terminology, basic circuit elements, and fundamental laws such as Ohm's law and Kirchhoff's laws in resistive circuits are covered in Unit 1. Analysis techniques such as Node-Voltage, Mesh-Current, and source transformations are introduced in Unit 2. Unit 3 covers circuit equivalents such as Thévenin's and Norton's equivalents, maximum power transfer theorem and superposition theorem, and finally an introduction to operational amplifiers. Following each unit is a uniform midterm exam taken by all enrolled students regardless of lecture section. The discussion in the next section examines the average exam scores of several groups: the overall class, at-risk students enrolled in the summer bridge program and GE course, and at-risk students not enrolled in (but invited to) the summer bridge program or GE course. All the GE students were in the same lecture section, but the at-risk non-GE students were scattered throughout the class.

III. Highlights of the GE for Introduction to Electrical Engineering course

The GE course in Fall 2015 followed the described overall format with some exceptions. The sessions were led by a graduate assistant with a faculty member (an experienced EE302 instructor) on the sidelines, and the two-hour sessions were held only once weekly. A basic session would begin with 30-45 minutes of lecture and review of the topics covered in class that week. Questions were encouraged throughout the lecture, with breaks explicitly for that purpose at the end of each major topic. This period included practice problems led by the teaching assistant using the input of the entire group. This was followed by 20-45 minutes of student-driven practice problems, performed either individually or (more commonly) in small groups. The grade for this 1 credit hour course was based entirely on attendance. No homework was assigned and no exams administered.

Hands-on circuit building exercises and circuit programming using the Raspberry Pi computer was an important component of these sessions. Studies have shown that instructional intervention strategies that provide more real-world examples and opportunities for experiential learning, targeted to the at-risk student population, help these students see the benefits of maintaining their commitment to this degree program [6]. For the sessions that took place in the weeks leading up to a midterm, the time was entirely dedicated to working through practice exams to reinforce the concepts that would be on the exam and identify key types of problems that had appeared on previous exams. The weeks following exams were similarly dedicated solely to the Raspberry Pi labs.

The Raspberry Pi labs were intended to build on each other, introducing a new programming concept each week. This included a series of introductory lectures on programming and the essentials of the Python language, chosen for its naturalistic syntax and general ease of use. The target programs focused on producing tangible results from user input in the form of lights on a breadboard or console output. The goals of each project are listed below.

- Provide power to an LED.
- Take input from the command line to make an LED blink a specified number of times.
- Implement a 2-digit binary display using command line input and LED output.
- Implement a 2:4 decoder using push button input and LED output.
- Implement a calculator using push button and command line input and LED output.

IV. GE course Teaching Assistant Training and Development

General Engineering Teaching Assistants in all departments were required to attend a half-day workshop before the start of the semester detailing the format, expectations, and unique challenges of a GE session. This training emphasized fostering student connections and study habits through peer-driven learning and teamwork. The university's General Engineering Coordinator observed each TA midway through the semester, and a pursuant one-on-one discussion was held soon afterward. The Coordinator also discussed with the TA the results of an anonymous course instructor survey given to the students administered around the same time. Two

additional GE workshops were held during the course of the semester. These sessions focused on pedagogical discourse and discussion of techniques and technologies that could be used to improve communication with the students, student engagement, and the GE sessions themselves. These workshops were hosted and led by the GE department and featured hands-on tutorials consisting of lessons and activities in simulated classroom environments and work with new classroom technologies in addition to conceptual discussions.

V. Control group: At-risk students not in Summer Bridge nor GE

In order to make a fair evaluation of the merit of this academic success program, we considered the performance of students enrolled in EE302 who were invited to the Summer Bridge program but who declined the invitation. Since these students were also designated as being at-risk, but did not participate in the Summer Bridge nor the GE course for EE302, we selected this group as our control group for this experiment.

We also compared the performance of the EE302 students enrolled in the 2015 Summer Bridge program with those in the 2014 Summer Bridge program. Since the GE course in Fall 2014 was not targeted towards the at-risk student population, but instead offered to all EE302 students including those classified as academically advanced, comparing the performance and retention of these two student groups can also be considered to be a measure of the success of the 2015 GE course.

RESULTS AND DISCUSSION

This section examines the aggregate midterm exam scores of several groups: the overall class, at-risk students enrolled in the summer bridge program and GE course, and at-risk students not enrolled in (but invited to) the summer bridge program or GE course. All the GE students were in the same lecture section, but the at-risk non-GE students were scattered throughout all lecture sections.

I. Student performance in assessments

Although the course material is based in basic principles of electrical engineering, specifically circuit analysis, one of the course goals is to apply those principles to difficult engineering problems. Exam problems are designed to engage higher levels of thinking than the usual homework or textbook problems. Figure 1 provides a comparison of average exam scores for four different exams (three midterms, and one final exam) of the four different groups of students to evaluate the effect of the GE course on student performance. The first group (All) is the entire ECE freshmen class of 387 students enrolled in EE302 (and who completed the course) across the six lecture sections. The second (GE) is the group of 16 students who participated in Summer Bridge and enrolled in the GE course. The third group (No-GE) is the group of 13 students who were categorized as being at-risk but attended neither the Summer Bridge nor the GE course. Finally, the fourth group (No-GE same section) consists of the 4 students who were not in GE but in the same lecture section as the GE students. As such they received the same instruction as the GE students, and hence we believe had the same exposure to the subject as the GE students. These mean scores along with the standard deviations for each exam are also listed in Table 1.

As is evidenced by these data, the GE students consistently performed better than the non-GE (at-risk) students. The improvement ranged from 4.2 – 24.6 %, with the largest improvement shown in the end-of-semester cumulative final exam. Even more dramatic is the difference in performance between the GE students and the non-GE students in the same section. In this case the improvement ranged from 14.7 – 49%, with the largest improvement shown in the cumulative final exam.

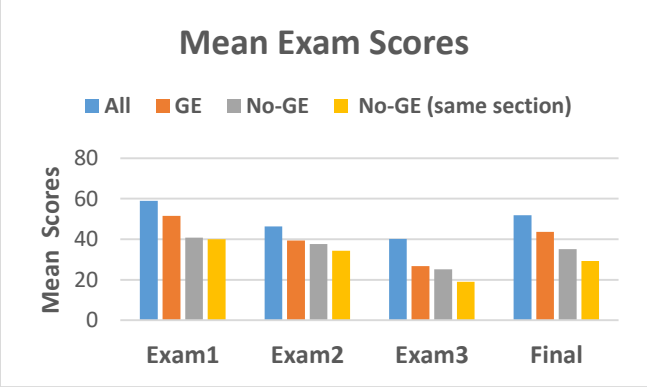

FIGURE 1
COMPARISON OF EXAM SCORES

TABLE I
MEAN EXAM SCORE COMPARISON

	N	Exam1 (σ=18.6)	Exam2 (σ=13.1)	Exam3 (σ=15.5)	Final (σ=17.5)
All	387	59	46.3	40.2	51.8
GE	16	51.47	39.27	26.7	43.7
No GE	13	40.77	37.69	25.23	35.07
No GE (same lecture section)	4	40.0	34.25	19.0	29.25

Listed in Table 2 are the mean course GPAs (out of 4.0) for EE302 for the four groups. The course grade was determined based on homework (10%), labs (15%), project (5%), and exams (70%). The mean GPA indicates that the average letter grade over all EE302 sections was close to B-, while the average letter grade for the GE student group was roughly C+ compared to an average C grade for the non-GE at-risk students.

TABLE 2
MEAN COURSE GPA COMPARISON

	N	Mean Course GPA (out of 4.0)
All	387	2.72
GE	16	2.21
No GE	13	1.95
No GE (same lecture section)	4	2.00

The average course GPA of the Fall 2015 GE students was also compared with that of the 17 Summer Bridge (at-risk) students from 2014. Most of the 2014 at-risk students did not participate in the GE course offered in Fall 2014 due to the previously mentioned schedule conflicts. As a result, the 2014 Fall GE course was not targeted at these students. The purpose of this comparison is to show the effect of the changes implemented in our 2015 GE course, offered only to the at-risk students. The 2015 cohort of at-risk students showed a 13% improvement in course GPA over the 2014 cohort.

II. Student survey

The students were surveyed at the middle and end of the semester to evaluate the perceived effectiveness of both the Summer Bridge and General Engineering programs. In the mid-semester survey (Table 3), the students were asked what they thought of Summer Bridge with the benefit of several weeks' worth of experience in a college environment. Eleven of the thirteen students who took the survey expressed appreciation for their experience in Summer Bridge, and nine endorsed the idea of including more students. Three quarters of the students cited that the most valuable part of Summer Bridge was the "connections" that they made during that time; keeping the students together through GE was generally viewed positively. Similarly, three quarters of the students characterized the amount of work they were being given as "heavy but manageable." The program seems to have instilled confidence in most participants. We conclude that while the Summer Bridge program was likely not a completely sufficient preparation for the demands of undergraduate engineering coursework, it is certainly a welcome step in the right direction.

A second survey (Table 4) was conducted at the end of the semester to evaluate the students' position on the GE program and its implementation in Intro to Electrical Engineering. More than half of the students referred to the GE sessions as "helpful" overall and only one had a generally negative view. Three quarters of the students also felt that a GE session would have been beneficial for their other major engineering class that semester (Introduction to Computing Systems) and that the single two-hour session was preferable to having two one-hour sessions. Opinions were also universally positive regarding GE's treatment of exam preparation. The students seemed to greatly appreciate the extra structure and focus provided by the GE format. Tellingly, only one student provided a concrete suggestion for improvements to the program. The others either indicated that everything was fine as-is or that the only changes they would make pertained to their personal study habits.

TABLE 3
SURVEY RESPONSES (MID-SEMESTER SURVEY ON SUMMER BRIDGE)

Questions	Responses
Did summer bridge adequately prepare you for the fall semester?	Yes (46%) Maybe (54%)
Do you feel confident in your ability to become an engineer?	Yes (54%) No (46%)
Does the college provide plenty of help outside of class?	Yes (100%)
Do you feel that summer bridge helped you develop good study habits?	Yes (33%) Somewhat (60%) No (7%)
What was the most valuable aspect of summer bridge?	Connections Community Study tips Networking Support system.
Comment on the main aspect of the GE course.	Group study and extra practice. More useful because it is a smaller class which leads to fewer answers blurted out by others. Working with breadboards and the Raspberry Pi. Approaching/solving engineering problems. Test taking skills and study habits.

TABLE 4
SURVEY RESPONSES (END-OF-SEMESTER SURVEY ON GENERAL ENGINEERING)

Questions	Responses
Overall, what are your thoughts on the GE course?	It was helpful. It was very beneficial. It has the effect of a group study with the help of a TA.
Did you find that the GE sessions helped adequately with exam preparation?	Yes (100%)
Do you have any suggestions on what we could have done to better help you?	I think everything is as good as it can get. I wish we could have done mock exams. No. I feel the only things I could have done additionally was just extra work.

CONCLUSIONS

The results of this study show the effectiveness of coupling the Summer Bridge and General Engineering programs. This

combination affected tangible improvement in the performance of at-risk students in the freshman level Introduction to Electrical Engineering course at UT Austin. Both quantitative as well as qualitative data demonstrate that students perceived these resources as essential to their comprehension of the course content, their level of preparation for exams, and their commitment to the engineering major. Except for one student who transferred out of the engineering major, and another student who is seeking transfer within the Cockrell School of Engineering, all other students who participated in GE are still within the ECE major.

From both student performance and student feedback, we conclude that the Summer Bridge and General Engineering programs were very effective in helping the students handle the transition into undergraduate-level academics. For many, the structure and sense of community fostered by the cohort seems to have provided a measure of reassurance that bolstered their confidence in their abilities.

FUTURE WORK

The progression of this cohort of students will continue to be monitored. More analysis is underway to answer other research questions, such as the lasting influence of this success program on student performance in other courses in future semesters. We hope to expand these programs in the future to provide more statistically significant results.

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