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Transforming a Freshman Electrical Engineering Lab Course to Improve Access to Place Bound Students

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Abstract

This paper discusses the transformation of an introductory electrical engineering lab course into an interactive hybrid teaching model, a combination of face-to-face and online instruction, to expand access to Electrical and Computer Engineering to place-bound students. The modified course will include inter-campus collaborative hands-on laboratory and team project experiences. This has the potential to transform the educational experience of the often isolated place-bound students in rural communities, building their social capital and connecting them to a larger learning community. The project addresses the needs of three very different populations of students: (i) traditional engineering students enrolled at the main engineering campus; (ii) students enrolled in a pre-engineering program at a separate campus; and (iii) place-bound students attending a minority serving community campus with no engineering curriculum. Delivery of an exemplary, financially responsible, engineering education in each of these communities has unique challenges, including cost and availability of an instructor, cost and availability of laboratory facilities, diversity of students' prior knowledge and cultural experiences, and variety of students' learning styles. In this formative year of the project we will assess (i) student content learning gains, (ii) the impact of the collaborative model on the development of social capital, and (iii) student perceptions of and engagement with the hybrid format in a freshman engineering lab course.

Introduction

One of the recommendations in the National Academy of Science (NAS) report *Educating the Engineer of 2020* [2005] is for "four year engineering schools … to work with their local community colleges to ensure effective articulation … with their two-year programs." This is essential considering that about half of all students pursuing STEM degrees start at community colleges [Starobin and Laanan, 2010]. In Alaska, the role of the "community college" is mostly served by satellite campuses administratively attached to one of the three main universities. For the University of Alaska Fairbanks (UAF) system, enrollment data shows that 47% of the student population is actually enrolled through one of its satellite campuses [Institutional Research, 2010]. Five of the six UAF satellite campuses are Alaska Native serving institutions. There is currently no engineering curriculum offered at these campuses.

Minorities, and particularly American Indians including Alaska Natives, are underrepresented in the field of engineering [NSF 2000, Bordonaro et al 2000]. Studies have shown that students who attend a 2-year college or a Pre-Engineering program are not likely to actually transfer to a 4-year college and complete their degree [Adelman 1998]. Alaska natives many times face the same impediments to choosing a career in engineering, academic success, and retention in college as other rural students as described in Felder et al's Longitudinal Study [1994]. These reasons include a lack of role models, less social pressure to attend college, and less access to rigorous high school courses.

In 2001, Etcheverry, et. al. showed that social capital has a positive effect on the retention and academic achievement of students. Etcheverry defines social capital as consisting of exchanges that arise through the interactions between students and professors and among students as they cooperate in learning the material. Research in social capital in engineering education is still mostly unknown. Brown, et. al. [2009] investigated social capital in a sophomore electrical engineering lab and found that need and lack of resources were key aspects that helped develop social capital. He then asks the questions, "… should engineering curriculum and laboratories be designed to encourage the development of social capital?" A more recent study by Martin et. al. [2013] explored the role of social capital on four Hispanic women pursuing engineering degrees. Martin's study concludes that "facilitating opportunities for students to develop sustained social capital may have potential to attract and retain underrepresented students in engineering".

This paper describes the transformation of an introductory electrical engineering lab course into an interactive hybrid teaching model, a combination of face-to-face and online instruction. The modified course addresses the needs of three very different populations of students: (i) traditional engineering students enrolled at the main engineering campus; (ii) students enrolled in a pre-engineering program at a separate campus; and (iii) place-bound students attending a minority serving community campus with no engineering curriculum. The lab component of the class includes inter-campus collaboration between the students through data sharing and discussions in the hands-on laboratories and team projects. This has the potential to transform the educational experience of the often isolated place-bound students in rural communities, building their social capital and connecting them to a larger learning community.

The goals of the first year of this study are:

1. Quantify student content learning gains in the restructured course,
2. Evaluate the impact of the collaborative model on the development of social capital, and to
3. Assess student perceptions of and engagement with the hybrid format in a freshman engineering lab course.

Background

EE102: Introduction to Electrical and Computer Engineering was originally taught, as a lecture only, pre-calculus circuits course. In recognition of modern instructional pedagogy, "learning by doing" [Bransford, et. al., 2000], this course was transformed in 2005 to include a laboratory experience, creating a project-based course which introduces students to the design process and common test/simulation/manufacturing tools available in the Electrical and Computer Engineering (ECE) department. Additionally the course content was augmented to provide an introductory overview of the core areas of electrical engineering taught at UAF: communications, power and control, and computer engineering. Teaching the "essence of engineering" during a student's first year is one of the recommendations of NAS *Educating the Engineer of 2020* [2005].

During the first half of the semester, students are introduced to design tools and the design cycle (plan, simulate, prototype, build, test, deploy, and evaluate) through a set of seven guided hands-on labs. In the second half of the semester, students practice the design cycle and teamwork through team projects of their own choosing. Each guided lab contains elements from four different areas of learning: technical – theoretical understanding of electrical engineering concepts; tools – practical understanding of the tools used in electrical engineering such as test equipment, simulation, and software design tools; communications – experience in communicating the results of experiments, tests, and designs; and design – experience in design through the development of a specific product. The course is specifically designed to provide "skill development" in (i) professional skills via application of test/simulation/manufacturing tools to design projects; (ii) communications skills via writing lab reports and oral project presentations, including the presentation of data and design choices; and (iii) team skills via a modified BESTEAMS [Schmidt, et. al 1999] curriculum; all are skills used in subsequent courses.

In 2006, we obtained the Circuit Concept Inventory from Helgeland and Rancor [personal communication, 2006]. This test was modified to reflect the content of the course and administered to 15 students as a pre/post-test in 2007. The blue marker in Figure 1 indicates the average gain achieved by those students. Figure 1 was created in the manner of Hake [1998] who compared learning gains obtained in introductory physics courses that used interactive-engagement and traditional lecture methods as measured through pre/post-test data using Halloun-Hestenes Mechanics Diagnostic test and Force Concept Inventory. Hake determined that courses that used some form of interactive-engagement obtained learning gains typically in the medium gain region while traditional lecture courses obtain learning gains in the low gain region. Hake's data included 62 courses enrolling 6542 students. Although my statistics are not nearly as robust as those presented by Hake, the gains obtained in 2007 are consistent with that expected from a course using interactive-engagement methods.

EE102 is a critical course for students entering the Electrical and Computer Engineering curriculum at UAF. It is also a bottleneck course since it is typically taken in the second semester of the freshman year. Transfer students who have not taken *EE102* have been shown to be at a disadvantage as the course is specifically designed to set students up for success in subsequent courses. In addition, *EE102* is a great recruitment tool as evidenced by enrollments which routinely includes students who are either undeclared or have declared non-engineering majors (such as music). In 2012, 10% of the students enrolled were not declared majors. Pre-Calculus is the only prerequisite for the course, making it accessible to a relatively broad student population. The course content and laboratory exercises are designed to both spark interest in the field, to give students an understanding of the vast career opportunities in electrical engineering, and to prepare students academically for success in future electrical engineering courses.

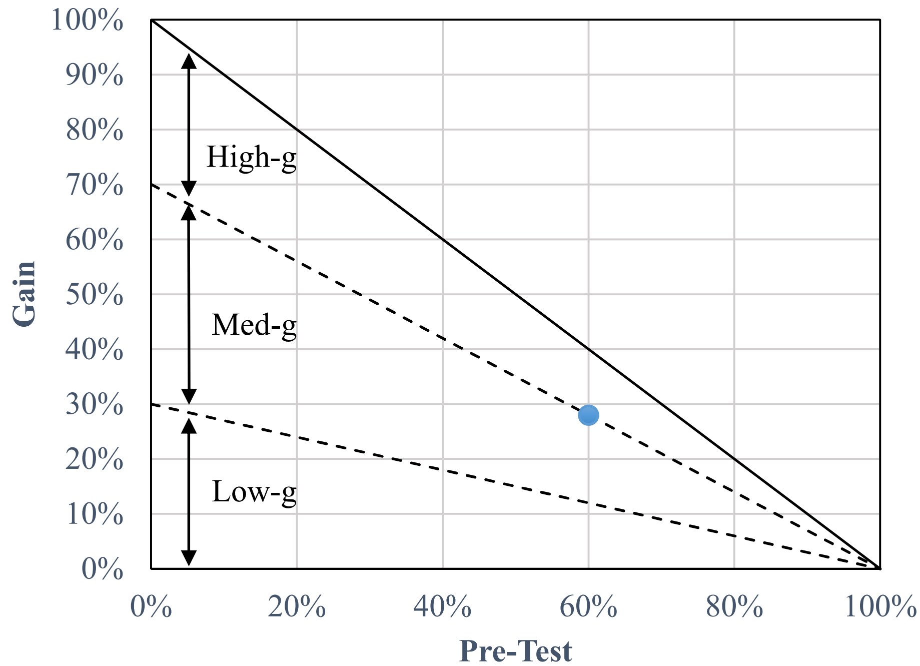

Figure 1: %Gain versus %pre-test score on concept test inventory test conducted in 2007 (blue marker). Lines indicate maximum possible gain (solid line) and transitions (dashed lines) between low gain, medium gain, and high gain as per Hake [1998]

Course Modifications

In order to provide access to identical instructional material for each student population and to facilitate collaborations, we have adopted, for spring 2014, an "inverted classroom" paradigm where students work through self-paced online instructional material out of class and participate in related labs and small group activities in class. During the previous two years, we have included students in a pre-engineering program at a separate campus primarily through video conferencing. Although this was moderately successful, video conference requires a special classroom which restricts the size of the students attending at the main campus, was not available for the laboratory portion of the class, and would not be available for the pace-bound students at our satellite campuses. Because of the limitations of video conferencing, the laboratory lectures were pre-recorded.

Mason et al. [2013] compared an inverted and traditional lecture classrooms in an upper-division engineering course and found that in the inverted classroom (i) more material was covered and (ii) students learning outcomes were as good as or better than the traditional classroom. Mason et al. also indicated that students "initially struggled with the new format" and that the students felt that "freshman did not have the academic maturity needed to succeed in an IC setting". In 2013 we created online instructional materials for one topic module. These were created using Adobe Captivate, an electronic learning tool that allows for embedding questions in the lecture material, which is reflective of the manner in which the course was originally taught. Feedback from students was very positive. In fact, they asked if there would be more online modules for the rest of the class. The 2014 course will have all of the lecture material online leaving classroom time for small group activities.

In 2013, anecdotal evidence showed that the students who most benefited from the online materials were those students who were least academically prepared for the class as measured by the level of math obtained at the beginning of the semester. As previously stated the only pre-requisite to *EE102* is pre-calculus, however math placement for students enrolled in the class range from pre-calculus to beyond Differential Equations. The distribution for the 2014 students is 5% pre-calculus; 23% Calc I, 28% Calc II, 13% Calc III, and 31% beyond Calc III. The assumption is that those students who were least academically prepared benefited the most because they were able to review the material multiple times something that they are not able to do in a traditional lecture setting.

Replacing what would traditionally be lecture material with interactive online lessons, allows for more interactive engagement during class. We have designed two types of activities, both created to provide the students with a collaborative learning environment with the hope of increasing the student's social capital. The first type of activity includes open-ended design problems that require the use of that week's electrical engineering concepts. The student's will work on these problems in small groups and compare their design choices with those of the rest of the class. The second type of activity is collaborative laboratories. In previous years, lab measurements were taken by groups of two or three students and individually written up in lab reports. This year all the data taken by the students will be compiled into a single data set. Again, working in small groups during class time, the students will analyze the compiled data. This has the potential to lead to more in depth discussion and understanding of the lab material, something that was previously not possible.

Planned Assessment

The spring 2014 offering of *EE102* is the formative year for the redesigned course and does not include any distance students. The plan is to obtain formative assessment of the changes with a highly controlled classroom environment and then add distance student in 2015. Although the creation of the online instructional materials will help to facilitate the inclusion of distance students in year two, the in-class small group activities will have some technological challenges to overcome.

As previously stated we have three assessment goals for this year:
1. Quantify student content learning gains in the restructured course,
2. Evaluate the impact of the collaborative model on the development of social capital, and to
3. Assess student perceptions of and engagement with the hybrid format in a freshman engineering lab course.

To accomplish these goals, students will be administered the pre/post concept inventory test. Learning gains will be calculated and compared with results from this course in 2007, and will be evaluated with respect to Hake's model. In addition, we will track access to the online lecture materials and math placement for individual students to look for correlations between learning gains, student preparation, and access of the online instructional materials.

Student perceptions and engagement with the course will be measured using a mid-course focus group (primarily for early formative assessment) and end of the year student survey. The survey will include questions regarding student social interactions during the course in an attempt to measure social capital development among students and with the instructor.

Conclusion

This paper outlines the transformation of an introductory electrical engineering lab course to expand access to Electrical and Computer Engineering to place-bound students. The modified course will be delivered for the first time in spring 2014 to students on the main engineering campus. Formative assessment will be conducted and will guide additional modifications in preparation for the inclusion of distance students in 2015. The ultimate goal is to deliver the course simultaneously to three very different populations of students: (i) traditional engineering students enrolled at the main engineering campus; (ii) students enrolled in a pre-engineering program at a separate campus; and (iii) place-bound students attending a minority serving community campus with no engineering curriculum. We believe that the pedagogy used to facilitate inclusion of distance students can enhance the educational experience of each student population.

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