AC 2007-851: DEVELOPMENT AND BETA-TESTING OF A DISTANCE-LEARNING FRESHMAN ENGINEERING COURSE SERIES

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Development and Beta-Testing of a Distance-Learning Freshman Engineering Course Series

Abstract

The projected shortage of engineers in the United States and the need to attract a more diverse engineering workforce remains a challenge for engineering programs across the nation. Recent court rulings prohibit our university from considering gender, race, or ethnicity in all activities of the university. However, one method for increasing diversity of the technical workforce is to focus on first-generation college students because underrepresented minority students make up a large percentage of first-generation college students.

Many such students attend local community colleges because their limited financial resources override their choice of academic major. These students are confronted with limited academic choices, especially in the engineering disciplines. Over the last four years, our university's engineering program has developed several strategies for recruiting highly qualified students and increasing retention rates. Additionally, one of the authors has been awarded two competitive Texas Workforce Development Grants targeted at providing career-forming introductory engineering courses in a distance-learning, web-based format to regional community colleges and 3+2 partner institutions (i.e., 4-year universities without engineering programs).

The first course in our freshmen engineering series is a hands-on laboratory/lecture course that students in all engineering majors take. The course is designed to let students experience what it is that engineers do in each of the majors offered. PowerPoint lectures, based on the on-campus lectures were modified to add recordings of the spoken lectures and animated sample problems to lead the students through problems that ordinarily would be written on the board in the lecture hall. All lectures and assignments were posted on Blackboard. The greatest challenge in converting this course into a successful distance-learning web-based course was the development of portable laboratory modules that could be shipped to the community colleges and partner institutions while delivering a quality, hands-on laboratory experience similar to that experienced by the freshmen engineering students on our campus. To enhance this experience, these students are required to visit our campus for a 4 hour multi-lab session. The secondary intent of this on-campus requirement is to encourage the students to consider transferring to our university.

The first-semester course underwent beta-testing at a nearby four-year partner institution campus in Fall 2006, and the students responded positively and provided constructive feedback for improvement of this course in preparation for rolling it out to multiple regional campuses.

The second course in our freshmen engineering series is a math-skills course with a computer tools laboratory component. This course was also developed using animated PowerPoint presentations with recorded lectures. The lectures, homework, and computer assignments are posted for the students on Blackboard as well. CDs with PowerPoint and audio lectures are also provided to facilitate portability. This course has undergone beta-testing on our campus utilizing students with diverse schedules and abilities. Several lessons learned resulted in redefining the

role of the mentor, and in the manner of presentation. This course is now "in the can" and awaiting launch to multiple regional campuses.

Introduction

According to Chubin *et al* [1], "Women and underrepresented minorities are not entering undergraduate programs in engineering in the same proportions that they did several years ago." In addition, engineering has not just a diversity problem but also a bigger problem with "cultural competence [1]." The issue of a homogeneous workforce's ability, or lack of ability, to provide goods and services to an increasingly diverse population as well as its ability to compete in a global marketplace requires that these disciplines attract and retain a more diversified student body and mentor them through the completion of their baccalaureate degree. Attracting students from community colleges into programs with specific mentoring objectives will contribute to the diversity of the engineering workforce. Recent court rulings prohibit our university from considering gender, race, or ethnicity in all activities of the university. However, one method for increasing diversity of the science, technology, engineering, and mathematics (STEM) workforce is to focus on first-generation college students because underrepresented minority students make up a large percentage of first-generation college students.

According to Peterson *et al*, "Factors that negatively impact minority students' success in engineering include finances, academic preparation, difficulty envisioning themselves as engineers, and lack of community on campus[2]." This project will help well qualified students with limited financial means to overcome a significant personal barrier to their academic success. Brown *et al* [3] studied the perceptions of campus climate on the graduation rates of African American engineering students and concluded that "institutional commitment was found to play a favorable role in influencing graduation rate among African American students." The authors further concluded that universities should look for opportunities to reinforce the students' perception that they made the best choice regarding which university to attend.

A number of universities have instituted special programs in STEM disciplines to increase recruitment of women and underrepresented minorities and to improve retention to graduation. In many cases, the students are awarded with scholarships providing they meet program requirements, which include full-time enrollment in the university, financial need, the ability to maintain a minimum GPA per semester, and to meet additional program requirements that are set forth in a contract that the student must sign [4]. In the case of one university, the funds provided to the student are not called a scholarship but rather a stipend that replaces the income from a part-time job and effectively pays the students to study during the time that they otherwise would spend working to support themselves through school [4].

The goals of these programs are to provide students with the skills, support, encouragement, and guidance that will allow them to develop a passion for their field, which, in turn, will allow them to make and keep their focus on long-term career goals and short-term academic goals. In the case of women and underrepresented minorities, building connections to peers, faculty, industry representatives, and to the university community [5] are vitally important themes in how these students learn and incorporate themselves into a culture. Due to the lack of minority role models in engineering, women and minority students often have trouble seeing themselves as engineers[2]. Providing tools to help students develop a vision of themselves in their future career will help them to stay focused on long-term and short-term goals when coursework becomes discouragingly difficult.

In order to help these students envision themselves as future engineers, it is important to provide opportunities for the students to interact with and to be mentored by peers, faculty, and industry professionals [1]. Since engineering is not commonly taught in K-12 programs, many college students have trouble developing a passion for the field without being made aware of what it is exactly that people working in these fields actually do with their education on the job. Students who require a connection to their field in order to remain committed to a difficult course of study can benefit from learning from industry professionals how they work as problem-solvers who use creativity and artistic abilities to have a "direct impact on improving the lives of others[6]."

A number of reports on intervention programs designed to increase student retention reveal that those programs that succeed are those that:

- work to improve student study skills[1], including
  - critical reading skills [6, 7],
  - note-taking [4],
  - time management [6, 8],
  - stress management, especially with test anxiety [4],
  - tutoring [9].
- work to improve life skills, including
  - dealing with family interaction issues [10],
  - the transition from high school or community college to university life [10],
  - conflict resolution [7],
  - money management with the focus on obtaining financial aid and avoiding student debt [6, 8],
  - dealing with issues of social life within the university community [6].
- work to improve career skills, including
  - resume writing [6, 8],
  - interviewing skills [6],
  - business etiquette [10].
- increase participation in student organizations [1].
- encourage undergraduate participation in research programs [1].
- seek feedback from students and faculty [1].
- increase student interaction/mentoring by peers, faculty, and industry professionals [1].

Participants in these programs tended to achieve better grades and graduation rates among underrepresented minorities.

Felder and Brent [11], in a review article about levels of intellectual development described, among others, the Baxter Magolda model that involves four levels of intellectual development: 1) absolute knowing, 2) transitional knowing, 3) independent knowing, and 4) contextual knowing. Factors that encourage a student's progression of intellectual development include social and emotional influences, such as "interpersonal interactions among students and between students and instructors, cultural predispositions, and students' emotional states [11]." An educational experience that "encourages and facilitates independent, critical, and creative thinking" and provides an accepting and supportive environment inside and out of the classroom helps to lead the student to successfully progress to more advanced levels of intellectual development. Progression to higher intellectual developmental levels also correlates with growth in the areas of "moral reasoning, multicultural awareness, and tolerance for diversity [11]."

Thus, the task of engineering educators is the promotion of intellectual growth so that graduates view science and engineering as "processes of inquiry" rather than the blind application of facts and formulas [11]. Felder and Brent describe the attitudes of a student who has achieved the highest level of intellectual development, contextual knowing, as one with "the intellectual curiosity, openness to alternative ideas, and acceptance of responsibility for one's own learning[12]." The authors also offered this description as a definition of the thinking processes of expert scientists and engineers.

Long-Range Plan

In 2002 a consortium of eleven Texas public and private institutions of higher learning was awarded a competitive grant, *Launching the Texas Engineering Education Pipeline: Deploying the Infinity Project Statewide*, from the Texas Technology Workforce Development (TWD) Grant Program. The collaborative project focused on strategies to increase enrollment and retention of electrical engineering and computer science students. This grant was part of a collaborative effort by the eleven Texas institutions to generate freshman-level curricula (course and lab) specifically targeted at increasing the freshman and sophomore retention rates at the respective institutions [13]. In 2005, a second competitive grant, *Attracting Engineering Majors from Community and Small Private Colleges*, was awarded by the TWD program to support the development of two distance-learning, web-based freshman engineering courses and to develop administrative and educational structures for delivering these courses to potential engineering students enrolled in regional community colleges and 3+2 private schools. The project's goal is to reintroduce freshman engineering courses into educational settings that have dropped support for engineering education as the result of budget cuts and program restructuring. The first year of the grant focused on course development and testing. The second-semester course, which leant itself more readily to a distance-learning format, was developed first and beta-tested on our campus. The first-semester course was developed over the last year and underwent beta testing at a nearby four-year institution that does not offer engineering in Fall 2006. Fundamentally, the distance-learning project is designed to provide students, who attend local community colleges because of limited financial resources, with an opportunity to explore the engineering profession and to build course credits that would transfer to four-year engineering programs. Without freshman and sophomore engineering credits, transfer students are typically forced to extend their undergraduate tenure three or more years.

Our School of Engineering and Computer Science has embarked on several recent initiatives that promise to increase student retention. Beginning in 2002, curriculum changes were instituted in the first-semester EGR 1301 - *Introduction to Engineering* course that added more hands-on experiments to the course and introduced the students to what engineers do in the workplace. These curriculum changes, presented previously, resulted in increases in retention from the first semester to the second-semester freshman engineering sequence [14].

The next initiative involved the creation of the Engineering and Computer Science (ECS) Living-Learning Center, a new residential complex built in close proximity to the ECS academic building. The Center's operation is designed to attract exceptional students and promote retention and success initiatives supportive of all ECS students. One of the Center's goals is to strengthen the student chapters of IEEE (*Institute of Electrical and Electronics Engineers*), ACM (*Association of Computing Machinery*), ASME (*American Society of Mechanical Engineers*), and SWE (*Society of Women Engineers*) which, in turn, leads to more upper-level/lower-level student interaction, professional exposure, and leadership initiatives.

Student retention has been a major concern within the School for many years. In 2003, the School hired a Student Success Specialist to develop and coordinate the School's recruitment and retention efforts. In the fall of 2004, the university embarked on an aggressive student retention study led by educational consultants from Noel-Levitz. This study generated a number of recommendations that have been or are in the process of being implemented. One particular initiative that has positively impacted the School is an "Early Alert" system deployed during the Fall 2005 term. This system is a web-based application that provides a mechanism for faculty to identify students who are having academic problems, usually manifested by multiple absences, missed assignments, or low exam grades. The system forwards an "Early Alert" notice to the University's Office of Student Success, the ECS Student Success Specialist, and the ECS Associate Dean. The ECS Student Success Specialist serves as the first responder by meeting with students who are referred by faculty to determine the cause of the student's academic stress, to identify needed academic services and to help the student develop an action plan. Although a formal evaluation of the Early Alert program has yet to be completed, results within the School have indicated a positive influence on retention rates within engineering and computer science as well as increased University retention rates for students that leave ECS.

Other activities within the School that are targeted at improving student retention and success include a new approach in the freshman computer science sequence, making the Success4Students program (www.success4students.com) available to all entering ECS freshmen, and continuing efforts to improve the freshmen engineering sequence.

The impact of retention efforts that began in 2002 with the TWD grants and continue through 2005 for Baylor's engineering and computer science programs are readily discernable from table 3. The two-year freshman retention rate increase of 46% for engineering and 38% for computer science is evidence that the School's retention efforts have been particularly effective.

Recently, two of the authors received a 5-year NSF S-STEM grant to fund scholarships and mentoring activities for transfer students. These funds will provide scholarships for up to fourteen transfer students per year and mentoring activities to increase the probability that they will graduate with a degree in engineering or computer science.

Development of Second-Semester Distance-Learning Course

The second-semester EGR1302 – *Fundamentals of Engineering Analysis* course is essentially a problem-solving mathematics course, which also teaches the use of computer tools for problem solving. Because of the easy portability of this course, it was developed and tested first. Lectures were recorded using a portable digital audio recorder during live classroom presentations and then edited for content using Audacity 1.2.3 (audacity.sourceforge.net), free audio recording and editing software. PowerPoint slides were constructed based on this content, the audio recording was embedded in the slide, and the slide was animated to correspond with the lecture. CDs were created using the "Package for CD" function in PowerPoint, which allows the creation of a standalone disk. This disk includes a slide viewer, which allows the student to port the presentation to any Windows-based PC (i.e., running Windows 98 or later), even if the PC does not have PowerPoint installed. These files were also made available on the Univversity's Blackboard site, so students had multiple options for access to the lectures.

The presentations covered only the required lecture material. A significant portion of the course is an introduction to programming a hand-held calculator and to sophisticated computer applications (i.e., MS Excel, Mathcad, and Matlab) commonly used by upper division courses and by professional engineers for analysis and reporting. The laboratory tutorials and exercises had already been developed for the on-campus course and required no additional development. The advantage of these labs is that the material readily ports to any location as long as the appropriate applications and licenses are installed at the distant location. A mentor experienced in these applications, can easily review the exercises in order to tutor students with any questions or difficulties. The primary learning objectives are to acquaint students with the tool interface and to gain confidence in their ability to use the tools in subsequent course work.

Second-Semester Course: Beta-Testing and Lessons Learned

Initial feedback was obtained from a part-time student who was employed full-time as a university employee. This particular student, more mature and self-directed than the usual university freshman, was considered a good candidate for the first trial. This student took the course during a normal 16-week semester and learned the material entirely from the electronic presentations. It quickly became apparent that weekly mentoring was absolutely required in order to keep the student on track to complete the course on time. This mentoring session ensured that the student was interpreting the material correctly and allowed for assessment of skills and progress. This student completed the labs and exams with the resident students, and earned an A in the course.

The second trial was offered to a transfer student during an accelerated summer term. The administration of the highly compressed course proved challenging because several labs and an exam had to be completed each week. This student was not as self-motivated when engaged in independent work, yet he completed the course satisfactorily. From this experience, it was concluded that this course could be taken during a compressed summer schedule as long as this was the only course taken by the student, unless the student is exceptional.

Throughout both trials, the students were able to identify typographical errors in the slides and assignments. More importantly, they highlighted areas in the lectures that were confusing or weak and required clarification. The nature of the electronic content facilitated changes which could be redeployed and reevaluated without delaying the students' progress.

Development of First-Semester Distance-Learning Course

Because the majority of the development of the lecture modules occurred during the summer, there was no opportunity to record live lectures for the first-semester EGR1301 – *Introduction to Engineering* course, which is taught only during the fall semester. The team chose to modify and animate existing PowerPoint presentations from the on-campus course. Lectures were recorded and edited using Audacity 1.2.3. The recorded lectures were embedded within the PowerPoint slides, and the animated features of the slides were timed to match the recorded lectures. This was especially useful when presenting solutions to sample problems. PowerPoint handouts in pdf format with additional lecture handouts embedded in the file were developed for each lecture with the intent to bind them into a workbook for future use.

Reading assignment quizzes were previously developed using Blackboard's Test Manager feature for the on-campus course. Students were required to complete the quizzes prior to the lecture on that topic. The quizzes are automatically scored, and the scores are automatically recorded in the Blackboard Gradebook. These existing quizzes were used for the distance-learning version of the course.

As described previously in the Long-Range Plan section, a variety of innovative changes were made in the laboratory component of this course to increase the hands-on nature of the laboratory experience and to teach the iterative nature of the engineering design process. Those changes have been presented previously [14]. These hands-on laboratory exercises posed the greatest challenge in the development of a distance-learning version of EGR1301. The laboratory exercises needed to be portable and needed to fit into a small box for shipping and, at the same time, needed to deliver a quality learning experience similar to that which our students on campus were exposed to. Considerable development time was allotted to this task, and brainstorming sessions were held involving both faculty and undergraduate students. Undergraduate students tested new lab modules and provided suggestions for improvement prior to the beta-testing of these labs.

First-Semester Course: Beta-Testing and Lessons Learned

The lesson regarding the requirement for an on-site mentor at the distance-learning site was applied to the design of this version of EGR1301. The on-site mentor served as our point of contact for the beta-testing of this course with five students. Because our first beta-testing students were taking the course at a university less than an hour's drive away from our campus, we chose to require that one lab period be spent on our campus. This on-site visit served a variety of purposes. One of the laboratory exercises required the use of a large wind tunnel that the students use to measure the drag force on a brass cylinder. Another laboratory exercise included a tour of our campus power plant facilities and ended with calculations to determine the energy efficiency of the conversion of the energy in the natural gas to the energy contained in electricity, steam, and chilled water that were generated from the burning of the natural gas. We performed mechanical testing of their group prototype truss design so that the students could watch one of their designs as it underwent testing. Finally, we wanted an opportunity to provide a campus tour and to encourage the students to consider continuing their studies by transferring to our university. The visit ended with dinner and discussion time to solicit feedback from the students midway through the semester in order to make any necessary mid-course corrections.

One problem encountered by the authors was the result of them carrying a full teaching load on-campus, with one of the authors carrying a teaching overload. This made rapid turnaround of graded assignments problematic. All lectures were not completed prior to the beginning of the semester, and this caused problems in the latter half of the semester. Some lectures had to be presented out of order in order to work around lectures that were not ready for presentation on their designated date on the syllabus. In the future, it would be helpful for the on-campus course coordinator to have a reduced on-campus teaching load.

For the last scheduled lecture period of the semester, two of the authors visited with the students and the on-site mentor to discuss what worked and what requires improvement for the future. Only one of the five students was at an early enough stage in their academic career and had an interest in possibly pursuing engineering. The remainder were upper division computer science majors who were recruited by the course mentor and department chair to enroll in the course for technical elective credit toward their computer science degrees. The students provided objective and constructive feedback for improving the course for the future.

First, the students felt that the lectures were missing the “why” factor. They wanted to know why they should be motivated to learn a particular topic. This can be easily updated at the beginning of each lecture topic by modifying the lecture introduction. Some of the students had not taken math courses in the recent past and suggested a quick review of math, including angles, trigonometry, basic physics, and solutions of systems of equations. Although the students requested that the math be “taken down a notch”, this may or may not be incorporated into future versions of the courses, depending on the students who enroll in our next test phase. If the students are truly interested in pursuing an engineering degree, the math (all at the pre-calculus level) should be well within their capabilities.

The students requested more sample problems, better training of the on-site mentor, and quicker turnaround on graded assignments. They also requested that all the lectures be posted online at the beginning of the semester. This could not be done during the beta test because some of the lectures were still under development as the semester began. This will not be an issue in the future.

One of the more intriguing suggestions by the students was that they would prefer to view the PowerPoint lectures with recorded audio outside of the assigned lecture time. This would be the equivalent of a reading assignment that the students were required to complete outside of class. They preferred that the lecture time be devoted to discussion with the mentor and online discussion board time or live streaming video sessions with the authors to answer questions related to the lectures and sample problems. They felt that interaction between the instructor and students was critical for addressing any areas that the students felt needed clarification and for keeping the students motivated.

Plans for the Future

Now that the material has been prepared for use in independent study, an added benefit is that it can also be made available as supplemental material for the on-campus course. Audio files of the lectures can be used for review, and the PowerPoint files can be used as lecture presentation material or as notes during individual review. The material is ideal for an on-campus student to use in the event of a missed class. More importantly, students who had difficulty grasping the material in the classroom are now free to review the lecture material at their own pace.

As the authors continue to learn new techniques and approaches to enhance the student's learning experience, we will be able to easily incorporate revisions or updates to the existing recorded lectures. We can look forward to rolling these courses out to multiple sites in order the gain feedback from a larger population of distance-learning students.

EGR1302 is being offered in Spring 2007 at the same university that performed the beta test on EGR1301 in the Fall 2006 semester. Future plans include deploying these courses to additional regional community colleges and 4-year universities that do not have engineering programs. Further refining will be done to the EGR1301 lectures in order to emphasize the "why" factor and to clarify points that confused the beta-testing students. The availability of NSF-funded scholarships will serve as an incentive for students to enroll in these courses and to subsequently transfer to our university to complete their engineering degree. The authors will continue to seek additional funding to support the development of sophomore-level courses, such as Circuits and Statics, which can also be deployed to the distance-learning partner institutions.

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