ON-CAMPUS AND OFF-CAMPUS FIRST-YEAR ELECTRICAL ENGINEERING STUDENTS ENGAGE IN INTERACTIVE LEARNING ENVIRONMENTS

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Abstract. *Universally available Internet and Web technologies support interactive learning environments for both on-campus and off-campus students in an introductory course in electrical engineering. This paper describes the rationale for the course and reports the results of scaling up online discussions from a 15-student on-campus honors section of the course taught during the fall semester of 1999 to a class of approximately 50 on-campus and off-campus students taught during the spring semester of 2000. The off-campus students comprised high-achieving high school students who enrolled in the course under a pilot offering of the Texas Tech University Early Admissions Program (EAP). An overview of the EAP and initial results of this pilot offering are discussed in the paper.*

INTRODUCTION

An introductory course in electrical engineering introduces students to object oriented programming, basic electronics, and the pleasures and pains of engineering practice through an interactive learning environment built with universally available Internet and Web technologies. The interactive learning environment of the course, by design, supports learning outside the classroom and, therefore, serves on-campus and off-campus students, alike [1, 2, 3]. A major design objective is to promote learning outside the classroom without demanding undue expenditures of time by faculty and teaching assistants. In addition to the use of Internet and Web technology, the design relies on peer mentors——students who have completed the course and who act as guides and trainers for students in synchronous MOO (MultiUser Object Oriented environment) discussions and in an asynchronous threaded discussion list forum. The mentors also act as moderators for discussing faculty posed questions, although they do not evaluate the participants in the discussion. Mandatory participation by every student in the synchronous and asynchronous discussions provides a practical way of requiring contemporary students, whose schedules seem increasingly fragmented, to collaborate on course projects.

Because the interactive learning environment allows off-campus learners to actively participate in this introductory (i.e., first-year) course, the course was selected for the pilot offering of the Texas Tech University Engineering Early Admissions Program, which allows high-achieving high school students to take university courses during their junior or senior years. A math or science teacher from each of the five area high schools that participated in this pilot offering were paid stipends to consult with the program developers and the professor teaching the course to help resolve issues and understand constraints endemic to secondary education. These teachers also acted as mentors to students at the high school campus to help the high school students matriculate into a university-level course.

Although on-campus students meet in class to accomplish the usual classroom functions [1, 2, 3], all students access essentially all course materials on a Website [4]. The site includes Lotus ScreenCam [5] tutorials, 5-minute videos that introduce each week's work, notes and homework assignments with hyperlinks to relevant sites, access to the synchronous and asynchronous discussions for the course, as well as a syllabus and a detailed weekly course schedule that contains links to the notes, tutorials, videos, and homework assignments for that week.

The following sections discuss the rationale for the course and report results of scaling up the MOO and forum discussions from a 15-student honors section of the course taught during the fall semester of 1999 to a class of approximately 60-70 on-campus and off-campus students taught during the spring semester of 2000. A detailed overview of the EAP and a discussion of the initial results of the pilot offering of this course in this program are also provided.

THE PLEASURES AND PAIN OF ENGINEERING PRACTICE

Reading about engineers at work is one of the few opportunities available to first year engineering students for learning about engineering practice. In this course, all students read *The Soul of the New Machine* [6], a book that describes an actual engineering effort, albeit somewhat chaotic, by a group of engineers at Data General to save the company after archrival Digital Equipment beat them to the market with a 32-bit minicomputer. Students enjoy reading

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the book, a good read for which Tracy Kidder, a journalist, received a Pulitzer Prize in 1982. Chapter-by-chapter notes, developed by the instructor, identify issues in the workplace for practicing engineers. The notes discuss people and events that relate to such issues as the inevitability and practicality of lifelong learning, the vital importance of interpersonal skills, the intrigues of corporate politics, the centrality of teamwork in engineering, the existential pleasures of completed projects, the varieties of motivation for engineering practitioners, the frequent career path transition of engineers from focusing primarily on technical work to focusing on management, and the unrelenting pressures on personal life. On the basis of more than two decades engineering practice after the events in the book, some of the engineers mentioned by Kidder have been willing to offer advice, answer questions and participate in discussions with students in the class. This contact affords students an unusual opportunity to benefit from decades of engineering practice gained by practitioners whose personalities and early engineering careers the students have come to know something about.

All students in the course also read *The Civilized Engineer* [7], a collection of essays by Samuel Florman, a practicing engineer (with a Masters degree in literature) and principal partner in a construction management firm. In these essays, written for non-engineers, Florman explores the origins of engineering, engineering ethics, conflicting loyalties, women in engineering, engineering curricula, the existential pleasures of engineering, engineers and management, and technology and societal decisions. These issues, though complex, are accessible to first year students. Encountering them early in the curriculum builds a base for effective consideration of them in later years.

Although simple questions on the weekly computer-graded 10-minute tests encourage at least a casual reading of the assignment from *The Soul of the New Machine* and *The Civilized Engineer*, mandatory participation in both synchronous and asynchronous discussions in subsequent weeks promotes in-depth reading of the texts and consideration of the issues far beyond what can be achieved with simple testing. This online approach to teaching habits of critical reading and critical thinking has been pioneered over the last decade by teachers of introductory courses in English composition and literature [8, 9]. The rudimentary coordination and cooperation required for the synchronous discussion groups to agree on times to meet online is a sometimes painful first step by the students in the first course in electrical engineering toward learning about teamwork. Although the interactive discussions encourage students to examine political, ethical, and other issues that shape the professional roles of engineers, once they take that mandatory first step toward teamwork, some students learn, to our delight, to work collaboratively on other course projects, such as homework. The peer mentors, having already completed the course, sometimes act not only as moderators for discussing faculty posed questions about the texts, but also offer suggestions to the members of their discussion group about homework projects as well.

Detailed tutorials about the mechanics of accessing and participating in the online discussions are available on the course Website, to both on-campus and off-campus students, as Lotus ScreenCam files [5]. ScreenCam allows the tutorials to be developed by recording both audio and video during demonstrations of software.

Students enrolled in the Honors Section of the course participate in the synchronous and asynchronous discussions of *The Soul of the New Machine* and *The Civilized Engineer* [6,7,] with students who are not enrolled in that special section. Students in the Honors Section, however, read and discuss an additional book, *Dealers of Lightning: Xerox PARC and the Dawn of the Computer Age* [10], by journalist Michael A. Hiltzik.

This book tells us about the remarkable group of people at the famed Xerox Palo Alto Research Center (Xerox PARC) who, in the 1970's, pioneered networks and personal computing (including the use of bit-mapped graphics, icons, the mouse, WYSIWYG word processors, and laser printers) and yet were largely unsuccessful in convincing Xerox to bring products based on these developments to market. Apart from the laser printer, other companies, such as Apple and Microsoft commercialized the other developments only later. By understanding something about what went right and what went wrong at Xerox PARC, students in the Honors Section gain additional insights into how both engineering and business happen in the real world.

BASIC ELECTRONICS AND HARDWARE HOMEWORK

A second focus of the course is electronics and hardware. Students are supplied a list of parts, available at Radio Shack and other local stores for less then $40, needed to assemble and test 1) a simple two-loop circuit and make measurements to verify Kirchhoff's Voltage Law, 2) a simple bipolar junction transistor amplifier, and 3) an RS flip-flop. Students submit their circuits, built on a small breadboard, in protective plastic VHS videocassette cases. Because the students build and test the circuits at home and the teaching assistants grade these assignments much as they grade the programming assignments, we term these projects hardware homework [11]. The hardware homework projects not only help the students become familiar with concepts of voltage and current, they also acquaint students with basic circuit components and the measurement of voltage and resistance with a multimeter. In addition, students learn to document their work in word-processing files that include embedded bit graphics that display circuit schematics as well as embedded spreadsheets that tabulate and plot measurement data. The students acquire the background for the hardware homework, and survey a number of other aspects of electronics, by studying the book *Basic Electronics* available from Radio Shack [12]. Only certain key concepts from the readings are addressed during the class meetings. A few questions on several of the weekly ten-minute computer-graded quizzes pertain to electronics. Most of these quizzes, however, primarily are devoted to the non-technical portion of the course.

OBJECT ORIENTED PROGRAMMING

Visual Basic Version 6 allows user-defined classes and hence provides a practical means of introducing the rudiments of object-oriented programming. During the course, for example, students construct a word processor that can open multiple documents and perform a word or phrase search through all of them by defining a suitable document class.

Students learn Visual Basic 6 mainly outside the class meetings by utilizing one of the interactive courses on computer languages offered by the Sams Publishing [13]. The purchaser of an interactive course, sold at bookstores for a list price of $49.95, receives a textbook, an ancillary CD-ROM and password admittance to a Website that provides access to a threaded e-mail peer discussion group of people working through the course. ScreenCam tutorials specifically related to each homework assignment supplement the text as a means of learning Visual Basic. During the course, students work through approximately the first half of the Visual Basic 6 book.

Although programming is an interactive learning activity by its nature, the inherent interactivity is supplemented by the opportunities offered in the Website maintained by the publisher, which requires no direct participation by faculty or teaching assistants. Each teaching assistant grades the weekly homework projects, usually programming projects, for up to 60 students. The word processor mentioned above is developed progressively in homework assignments HW9 and HW11. In homework assignment HW10 and the Final Project, students learn the rudiments of digital signal processing. With the free evaluation version of CoolEdit [14], a digital sound file editor, students generate sound files, save them in text files, develop a Visual Basic application that low pass filters them and saves the filtered files in text format, and then display the filtered files with CoolEdit.

ONLINE COURSE ACCESS BY EARLY ADMISSION HIGH SCHOOL STUDENTS

The Early Admissions Program (EAP) allows students (primarily seniors) who are still in high school to apply to Texas Tech University under the undergraduate guidelines of *Special Enrollment for Students Still in High School*, and if admitted, they can register for the introductory course in electrical engineering. This program is quite different from a dual-credit program because university faculty develop and teach each course, and evaluate and grade student work and participation; in addition, credits earned are transferable to other universities. Participating high schools determine if the course will count for credit toward the high school diploma. One purpose of the course is to inform students of the diverse career opportunities in science, math, engineering, and technology (SMET) and about various disciplines participating in these areas.

Another purpose of the EAP is to provide high-achieving high school students access to university courses while still attending classes on their own campuses. The minimum SAT score requirement for admission is 1180 (or a minimum ACT score of 27). In addition, EAP students typically take Advanced Placement courses and frequently participate in extracurricular academic activities such as the Academic Decathlon. Generally, the program allows students the opportunity to investigate areas of interest and gives them a leg up toward completing a college degree.

EAP courses do not differentiate much between on-campus and off-campus students. All students are expected to complete course work by due dates and to participate in course discussions. The high school student has a high school math or science teacher who acts as mentor, proctors tests, and is available for questions regarding homework—which the teacher may or may not be able to answer, but is able to guide the student toward appropriate resources. The high school instructor also provides human contact to encourage, advise, and facilitate the student's out-of-class learning. The high school teacher, in the role of mentor/facilitator, meets with the students face-to-face on an average of twice a week, but is readily available to students throughout the week. While contact with a mentor does not provide exactly the same experience as that of on-campus students who have direct contact with the university professor in the classroom, both on-campus and off-campus students have access to the university professor by email, telephone, or on-site visits during the professor's office hours. Although it is often difficult for students at a great distance to come to campus for a visit, we have found that most students, both on-campus and off-campus, prefer email as a means for interacting with the professor. By-and-large, both student populations have a remarkably similar experience.

The high school teachers also collaborate with the university professor, helping in the design and delivery of the course and making suggestions about how the course might better facilitate the needs of high-school students. This partnership is a significant factor that distinguishes the pedagogical model for this online course from numerous other online courses offered by universities to high school students. By developing this partnership, both institutions develop an understanding of the expectations and constraints of the other's academic environment, which can engender a more seamless model for SMET education between universities and K-12 institutions.

EAP students are teamed with on-campus students in collaborative assignments, providing opportunities to form peer-relationships that can ease the transition should they enroll in Texas Tech University after graduation from high school. In addition, both on-campus and off-campus students have student mentors to help them negotiate the electronic learning environments utilized in the course and with homework questions. Five students who successfully completed the honors section in the previous semester act as student mentors in this engineering course. Student mentors work closely with the professor and help to keep him abreast of concerns or problems the students may have. As the program grows, both with an increased number of courses and participating high schools, we plan to scale up the mentoring process by hiring experienced mentors to train new mentors. Similarly, we expect to use the same strategy for the high school teachers, with experienced mentor/teachers training teachers new to the program.

As previously noted, students read two books that examine various professional and ethical issues in engineering practice. To promote team building and critical reading of the texts, students engage in both synchronous and asynchronous online discussion. Discussion teams of five to six students are randomly selected. Using email, team members schedule meetings to discuss reading assignments and to work through discussion prompts provided by the instructor. Synchronous discussions, conducted in a MOO environment, provide students an opportunity to informally discuss elements of the reading assignment and to expand upon issues suggested by the instructor's discussion prompts. MOO's have been used for a number of years in education to facilitate discussion and to afford meeting spaces for people who are separated by geographical space [15]. The MOO environment, similar to a chat room, is very conducive to group discussion because it is text-based, and the entire conversation can be logged. This logging feature allows the instructor to evaluate student participation in course discussions and to respond to their ideas and comments without having to be present during the discussion. Logs are converted to HTML and posted on the course website, so they are available to the other teams.

Students summarize their synchronous MOO sessions in an asynchronous, web-based, threaded-discussion list, in which students read and respond to the summaries of other teams. This exercise requires more considered written responses that underscore the importance of not only strong writing skills, but also critical reading of texts. Having students read, analyze, and critique each other's text not only helps develop their writing and reading skills, but also affords an opportunity to significantly refine topical discussions over the course of an entire semester.

Another dynamic use of online discussion environments is that instructors can invite subject matter experts, practitioners, and other "guests" to participate course discussions——the virtual guest lecturer, if you will.

Although some students find meeting and collaborating online cumbersome at first, we have found that once they become comfortable with working in electronic environments, they frequently prefer them to the more traditional proscenium classroom and often begin to use these tools to facilitate their personal and social interactions.

EVALUATION OF THE COURSE

In order to improve the course and to facilitate development of other EAP courses, we are developing evaluation metrics to examine performance in three critical areas: 1) the students, 2) the high school teachers, and 3) the student mentors. We are also looking at the effectiveness of the course as a recruitment tool for the College of Engineering and Texas Tech University.

Students: It is difficult to compare the fall course to the one in the spring, because in the fall semester only students enrolled in the honors section of the course used the electronic discussion environments. Assessing the effectiveness of the teaching strategies and the electronic environments as spaces conducive to student learning is impossible at this point, because we are still refining these elements of the course. Clearly, more classes need to be taught in order to develop any reliable qualitative information. We will conduct detailed exit surveys with the students this semester to get their reactions to the course in general, the delivery of the course, the teamwork, the reading, and the discussion techniques. However, there are a number of students enrolled this spring semester that had dropped the course the previous fall, so we expect the results of this survey to be somewhat skewed.

We are extremely interested in trying to gauge student reaction to a number of issues that we feel are critical to the success of courses and programs of this kind. One is comparing the quality of the learning experience of on-campus students to that of the off-campus, high school students. Our initial feeling is that the mentoring program will be a critical success factor in making the program sustainable in this regard. Another issue is student reaction to various different delivery techniques and software. A difficulty with this issue is that the technology is changing rapidly. Perhaps the best we can expect in this area is that student responses will inform our decisions in adopting new software and provide clues as to how to use the existing electronic environments more effectively.

Teacher mentors: Our initial reaction is that the mentoring role of the high school teachers is another critical success factor for this program. Their motivation for participating in the program is one area in which we are interested, because it is crucial in our efforts to expand the program. The $2,000 stipend that we pay the high school teachers ($1,000 for development and $1,000 for mentoring the course) certainly plays a part in their motivation; however, as a group, these teachers have been extremely enthusiastic about working on the course, and several have remarked that they will continue to participate in the program, with or without a stipend. Even though these teachers are not receiving a course reduction (because they are not officially teaching an additional class), acting as mentors and meeting with university faculty requires them to put in a significant amount of time every week for this program. We feel that it is imperative they be compensated for their time and effort. We are also seeking their input about what we can provide in way of documentation and training to make their roles as facilitators and mentors easier and more productive.

Student Mentors: Using student mentors as part of the program has worked out better than anticipated. Again, these students are being paid a small undergraduate salary for one semester, but most of them did not know they would be getting a salary when they agreed to be part of the program in the spring. What we want to learn from the student mentors is how much time they devoted to working with the students regarding the use of the technology, like the MOO and the threaded discussions list; how much time was spent helping students who had serious homework problems; and how much time was spent learning new software. We are interested also in how they perceive their role as student mentor—in other words, do they feel like a teacher, a fellow student, or both?

In scaling up the program, we expect the student mentor role to become increasingly important. This semester they demonstrated a capacity to facilitate more than we had expected of them, such as resolving many of the technical problems students were having——leaving more time for instructors to focus on course content and design.

Overall Evaluation: The *Introduction to Electrical Engineering* course this spring has resulted in more questions than answers. For example, as the program expands in geographic distance, how will we motivate and interact with teachers to generate similar enthusiasm to that which we experienced in this group of local teachers, who we were able to work with face-to-face? Familiarizing the high school teachers with using the Internet and the software environments that are crucial elements of the delivery of EAP courses was a problem this semester (interestingly, this was not so much a problem with their students, which we attribute to the students' interaction with the peer-mentors). What kind of training they require and how we will deliver it are questions that, to date, remain unresolved. We also want to look at what kind of development staff is needed to expand and sustain the program, which is a critical issue for any distance education initiative.

CONCLUSIONS

The Early Admissions Program and this pilot course, *Introduction to Electrical Engineering*, has become a learning environment for teachers and students alike. Working with our counterparts involved in SMET education in the public schools, and the mutual understanding of the constraints and expectations of both institutions that grew out of this working relationship is an important first step toward developing more seamless curriculums in the SMET disciplines [16]. We expect that the enormous amount of work required to develop and deliver this course will pay dividends in the solid foundation that it has provided for new courses we are in the process of negotiating for the program. Certainly, the delivery techniques and pedagogy that emerged as part of developing this course will inform not only EAP courses, but also more traditional, on-campus courses——particularly as electronically delivered courses are becoming more commonplace in academia.

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