Session 2793

An Undergraduate Design Experience in a Wireless Computing Projects Course

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Abstract

Traditional lecture courses are heavily focused on learning fundamental, and often relatively theoretical, concepts usually through passive assimilation of information from lectures and texts. In traditional laboratory courses, students learn by completing a carefully prescribed procedure during an experiment. While both these modes of learning continue to play an important role in engineering and computer science education, we have developed a course to provide our students with an undergraduate research experience focused on mobility. In our junior/senior level design course, Mobile Communications Projects, students work in teams under the direct supervision of a faculty member. Students attend a common lecture, in which a variety of topics on wireless communications are covered by participating faculty members; and a lab section, during which the teams of students meet with their assigned faculty member. Additionally, students prepare a final project report and give formal presentations and demonstrations to the entire class. In our framework, students must be proactive. They have an opportunity to set their own goals, and choose their own methods for achieving them. They must integrate what they have learned in more traditional courses with up-to-date information about mobile communications, wireless technology and the relevant application areas of multimedia documents, databases, video, and printing. Sample projects include ePrint, making using of wireless technologies to communicate printer information such as print job completion and maintenance information to a user; Location Management, assisting PDA users to locate the nearest printer, restroom, computer lab, vending machine, etc.; and Multimedia Applications, watermarking for content authentication, video compression and streaming, cryptography, and multimedia security. With our class, students are learning about mobile communications as well as participating in an undergraduate research experience, interacting one-on-one with faculty members, and designing projects that involve teamwork and which address real applications.

I. Introduction

It has been shown that design experiences play a vital role in the curriculum to prepare engineers for the real world[1,2]. In addition to technical skills, these experiences must also address the areas of communication, teamwork, ethics, and the customer[3,4]. Many approaches that address these areas have been developed for capstone design courses[5-7]. The goal of our course is to provide our students with a rewarding design experience in all of these areas that is focused on exploring and developing real-world applications of mobile communications technologies. These technologies are rapidly transforming the way in which we go about our everyday lives. They offer heretofore un-conceived ways to do things differently and more effectively. Because mobile technologies are so tightly coupled to the applications that they enable, and to the end-user who holds the mobile device, development of effective mobile solutions poses unique challenges in terms of preparing students to work in this domain.

Students enrolled in our course learn the fundamentals of mobile communications technology devices that support mobile communications, as well as the essential elements of applications that have the potential to benefit from mobile technologies. Moreover, they learn formal design processes for meeting project goals successfully and on-time. Finally, they understand the importance of working as a team in which each individual provides their own unique part of the total solution. Because mobile technologies have such a broad scope of applicability and are so tightly integrated with the end-user experience, all three of these elements are essential to successful development of solutions.

In traditional lecture courses, including design courses, communication is predominantly unidirectional: from teacher to student, with little discussion. Students can perceive this lack of student-teacher dialogue as faculty indifference[8]. Student interaction with faculty differs considerably in our course. The lab meetings students attend each week are run by the faculty associated with the course, not graduate teaching assistants. This provides them with frequent one-on-one interaction with faculty, something they may have not previously encountered. This interaction can enhance their overall undergraduate educational experience, introduce them to research, and encourage them to on to graduate school[9].

The proposed mechanism for accomplishing this was to organize students in small teams, each working under the supervision of one or two Purdue faculty members. Our new junior/senior design course provides the framework for this effort. Coordination of the course and team activities also makes use of new mobile paradigms. The program involves eight Purdue faculty members in three different departments. The program is modeled after the EPICS (Engineering Projects In Community Service) program at Purdue[5].

II. Course Structure

The new junior/senior level design course *Mobile Communications* Projects is cross listed in three departments (Computer Science, Electrical and Computer Engineering, and Mechanical Engineering) as *CS/ECE/ME 49x* to allow students in each department to earn credit toward their respective majors when they enroll in the course. Students work in teams, of approximately 3-6 each, on projects directed by faculty members who are distributed among the specific focus areas of wireless communications and networking, security, e-services and printer management, and multimedia document repurposing and printing. Two graduate students are employed as teaching assistants for the course. They serve as a technical resource and coordinate the course activities.

Each student and faculty member is issued a Pocket PC for the duration of the semester, each equipped with a card for wireless 802.11B access and a 128Mb storage card. All computers and other hardware assigned to students must be returned at the end of the semester. The equipment is used to wirelessly exchange e-mails, schedule meetings, keep track of project tasks, and share project data. They are also be used to investigate mobile computing and networking issues.

All students meet together each week for a common lecture. In addition, each student is assigned to a lab section that meets weekly for 1hr. and 50 min. with their designated faculty member. The laboratory (Figure 1) is well-equipped with servers, PCs, printers and reference material. There is a conference table for team meetings and workstations for each team. Each student is issued a key to the lab for the semester. The lecture topics are listed in Table 1 and cover a wide

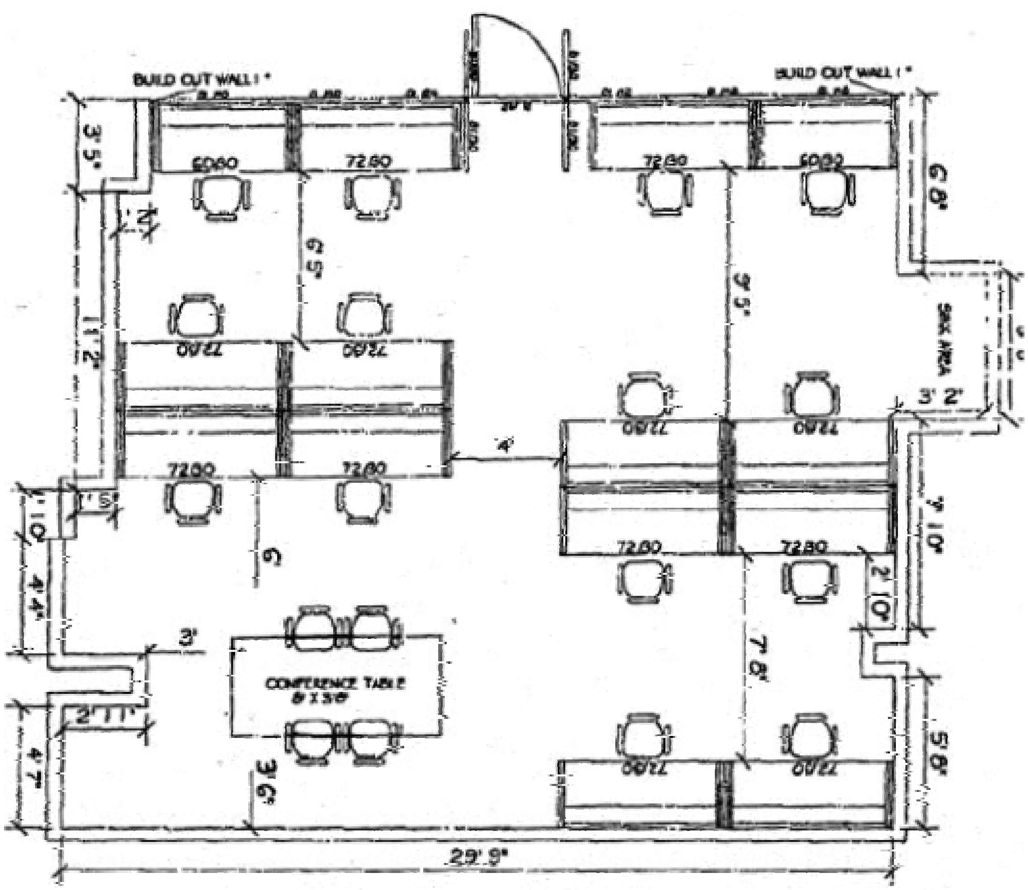

Figure 1: Plans of the course laboratory.

Table 1: Course syllabus and semester milestones. Homework assignments are based on the weekly lecture topic.

Lecture	Lecture Topic	Milestones
1	Organizational Meeting	Introduction to course, form teams, visit lab.
2	The Design Process	DURING LAB: Begin discussion of team organization, individual, and team goals
3	Programming for Mobile Communications I	TEAM: Complete responsibilities form
4	Programming for Mobile Communications II	TEAM: Written proposal due at time of lab. Set up team website. INDIVIDUAL: Deadline for having a design notebook.
5	Wireless Systems I	INDIVIDUAL: Review of design notebooks.
6	Printing in a Wireless World	
7	Wireless Systems II	
8	Physical Layer Communications I	INDIVIDUAL: Self assessment and peer evaluation.
9	Physical Layer Communications II	TEAM: Progress report.
10	Midterm Project Reviews	INDIVIDUAL: Review of design notebooks. Midterm presentation.
11	Multimedia Applications for Wireless	
12	Cellular Technology	
13	Multimedia Security for Wireless	
14	Global Positioning System	INDIVIDUAL: Review of senior design outcome matrix.
15	Final Project Presentations	TEAM: End-of-semester report due. End-of-semester presentation. INDIVIDUAL: Self assessment and peer evaluation. Review of design notebook.

range of wireless topics. These include programming environments used in the course, the design process, wireless systems, physical layer communications, multimedia applications, security, printing, cellular technology, and the global positioning system. Homework assignments are based on the weekly lecture topic beginning with introductory programming assignments to familiarize the students with the software environment. Programming for Pocket PCs is required for most of the projects and for some of the homework. According to the needs of the projects, students are expected to have good programming skills in one of the following languages: C/C++, Basic, and Java. The Microsoft Visual Basic and Embedded Visual C++ development environments are used as well.

Also listed in Table 1 are the course Milestones. During the first few weeks of the course, students form teams and organize their team structure. They are able to pick the project they are most interested in working and select a team leader. As students progress on their projects, all work is recorded in design notebooks, which are graded throughout the semester. Design notebook are used to document their work and as a reference for future students who work on the project.

In Week 4, teams submit a project proposal in which they spec out their projects. During the middle of the semester, each team writes a progress report and gives a midterm presentation. At the end of each semester, the students prepare a final project report and give formal presentations and demonstrations.

Team reports and all presentation materials, including streaming video are posted on the teams' websites which are maintained by a webmaster from each team. Provided for the students on the course website are guidelines for keeping a design notebook, maintaining the team webpage, the project proposal, presentations, reports, and equipment. Links to helpful resources related to mobile communications are also provided.

In the middle and at the end of the semester, students complete a self-assessment of their progress in four areas: technical, communication, teamwork and leadership, and any other areas of significant accomplishment. Occurring at the middle and end of the semesters as well, students evaluate their team members with a peer evaluation form. Here, students rate their peer in the following categories:

- Contribution to teamwork
    - Design
    - Implementation
    - Documentation
    - Integration
    - Testing/Debugging
- Takes responsibility and shows initiative towards team goals
- Completes the given tasks promptly
- I would like to work with this individual in the future
- Any comments

Semester grades are determined by the breakdown shown in Table 2. Sixty percent is based on the student's individual performance (attendance, homework, their design notebook, and weekly progress reports, etc.) and forty percent is based on the team's performance (progress reports, presentations, team website, and deliverables).

Table 2: The two components in grading are the individual score (60% of the grade) and the team score (40% of the grade).

Individual Score (60%)	Team Score (40%)
Attendance (10%) Homework (10%) Design notebook (15%) Weekly progress report (15%) Senior design outcome matrix, Peer evaluation, Self-assessment (5%) Participation (5%)	Progress reports Presentations Website Deliverables

III. Projects

We envision a campus in which printers that students may use are no longer confined to laboratories, but rather can be found everywhere, and can be accessed wirelessly from anywhere. As they walk to class, students will access notes for the class from the web on their PDA in a PDA-viewable form, and then print those notes in a different format on a printer near the classroom. After class, they will print the homework assignment that was just announced, on their way to the student lounge, again from the web, using their PDA. They may snap a photo outdoors for a class project, and then print it at photo-quality in a nearby building. Simple location information from the PDA will identify the nearest printer with the desired resources; and the printer will notify the student via their PDA, when their print-out is ready. In order to make this vision a reality, a number of significant problems in wireless communication and networking, security, e-services and printer management, and multimedia document repurposing and printing must be resolved. These issues will be tackled by teams of highly motivated students eager to explore this new wireless world.

During the first lecture of the semester, students are presented with project overviews from the faculty members involved with the course. These projects range from e-services for printing to networking to multimedia to assistive technologies and students select their project from this list. Many of these projects are on the leading edge of wireless communications and provide open-ended design problems for the students. The nature of these projects and the one-on-one interaction with faculty members during lab, much like a graduate research group, exposes the students to research and all of the possibilities that come with it. The remainder of this section provides an overview of course projects.

E-Services for Printer Management (ePrint): The project will develop Java based tools that utilize the ChaiVM in the networked HP printer to form a distributed printer-based printing resource identification and customization environment for mobile and networked devices. The first semester of this project included the development of a ChaiService to acquire real-time printer status information.

Global Positioning System – Device for the Visually Impaired: The goal of this project is to design and develop a portable GPS device that aids members of the Purdue campus who are visually impaired to navigate around campus. The device will have three primary functions: 1. A *where-am-I?* button to give the user's current position on campus, 2. A mode to provide audio directions to the user for a desired destination, and 3. A schedule mode to tell the user his/her next class and its location on campus. A GPS receiver will be used to gather position information of the user. Input will be from a custom HCI overlay on the touch screen and synthesized speech via an earphone will be the output.

A Mobile Communications Solution for Assertive Community Treatment Teams: Assertive Community treatment is a new model in which a group of 10 care providers, typically consisting of one psychiatrist, two RNs, one employment specialist, a substance abuse specialist, an office manager/statistician, three case managers, and a team leader care for approximately 100 mentally ill clients. Assertive community treatment is an evidenced-based practice that has been shown to yield much better outcomes than traditional treatment models. As the 10 members of the treatment team work throughout each day with their 100 clients, they must be in constant communication with each other, be able to access information about the client's treatment history, and be able to add new information to the database from which the team works. The team does not work in a single location, as is the case with traditional medical care. Instead the team is dispersed in the community working directly with their clients, helping them in a variety of ways throughout the day.

The goal of this project is to develop a mobile communications solution that will effectively enable team members to stay in touch with each other, and access client data. This solution will likely be based on a combination of cell phone and PDA technologies, with a remote server for the database. Although assertive community treatment teams elsewhere are starting to use PDA technology, to our knowledge no one is using wireless technologies to integrate data recording and access, with communications, in a mobile environment.

Multimedia Applications: Imaging, Video, and Security: Projects include JPEG2000, watermarking for content authentication, video compression and streaming, cryptography, and multimedia security. Implementation of the JPEG image compression standard and image watermarking for security.

RFID Tag Equipment Identification System: This project involves the use of RFID equipment to implement applications that intend to better the campus life for students at Purdue University. Examples of applications are locating books in the library using RFID, and Indoor Navigating/Locating classrooms.

Security. Low cost encryption schemes, suitable for use by mobile devices are generally not robust. However, we believe that it will be possible to exploit the special nature of printer-bound data to achieve robust compression even with such schemes. An example would be encryption of the data after compression, rather than as plain text, which is known to greatly increase robustness of even simple encryption methods. We will also examine watermarking schemes to control the right to print on a given printer, the right to copy printer output, and to authenticate who did the printing, and on which printer. These are all especially important issues in an environment where printers are widely dispersed in very public areas, and where the user will generally not be present when the print job is completed.

Wireless Networking and Applications: Projects include wireless networking, network applications, web-service, etc. in the context of building a "cool campus" environment. Two projects include the Wireless Application Development Team and the Computer Science International Design Competition (CSIDC) Team.

IV. Course Assessment

The course was first officially offered during the Fall 2002 semester. Six teams comprising a total of 27 students were enrolled in the class. (During the Spring 2002 semester a total of 43 students were registered for mobility as a project course.) Table 3 summarizes the responses from the end of the semester survey. Students rated the impact the mobility course had in 13 areas such as their technical skills, their communication skills, their resourcefulness, and their interest in undergraduate research projects.

Table 3: A summary of end of the semester student survey results in response to, "Evaluate the impact that the mobility course has had for you on each of the following: Please select one choice. (A=excellent, B=good/above average, C=average, D=marginal/below average, F=poor)".

	A (4)	B (3)	C (2)	D (1)	F (0)	Average	StdDev
Your technical skills	2	15	4	1	0	2.82	0.61
Your understanding of the design process	5	12	5	0	0	3.00	0.65
Your communication skills	5	13	3	1	0	3.00	0.72
Your ability to work on a team	10	10	1	1	0	3.32	0.76
Your leadership skills	6	12	4	0	0	3.09	0.65
Your resourcefulness	8	12	2	0	0	3.27	0.61
Your organizational skills	8	11	2	1	0	3.18	0.77
Your ability to acquire new knowledge	12	7	2	1	0	3.36	0.84
Your programming skills	7	8	5	1	1	2.86	1.05
Your understanding of wireless protocols	2	13	4	2	0	2.71	0.73
Your knowledge of wireless applications	4	12	5	0	0	2.95	0.62
Your interest in undergraduate research projects	10	7	5	0	0	3.23	0.79
Your interaction with faculty	5	15	1	0	0	3.19	0.48

The areas on which the mobility class had the greatest positive impact were student's ability to acquire new knowledge (key for any researcher), ability to work on a team (an important factor when finished with school), resourcefulness (a valuable attribute for any engineer), interest in research projects (a goal of the course). These were followed closely by the student's interaction with faculty and organizational skills.

Responses to the open-ended question, "what factors influenced your decision to take the mobility course?", highlight the students' interests in cutting-edge wireless technology and research. Some example responses include:

- "interest in wireless communications"
- "This course deals with cutting edge technology and the topics treated here are interesting"
- "The possibility to help create something new"
- "get intro into R&D, interest in mobility-type applications"
- "wanted to work on a research team developing new technology"

Additional feedback from students noted the high-level and breadth of wireless topics presented in lecture. This is expected due to the diverse backgrounds (despite the prerequisites) of students who enroll in the course. This is being addressed by providing more structure to the lecture series in the course. Additionally, some of the professors involved in the course give supplementary lectures during lab.

Students are evaluated on their understanding of wireless technologies throughout the semester in homework assignments, reports, and presentations, all of which are factored into their grade as shown in Table 2. To date, students have been found to have a solid command of these technologies directly relating to their project. We expect the work from some of the teams to lead to technical papers and possibly even patents.

V. Summary

Perhaps the most significant finding has been the almost unbelievable level of interest and support from both students and faculty members in this project. Even without widely advertising the project to the student body, news about it has spread by word of mouth among them; and we have had numerous inquiries. They are also eager for an undergraduate research experience. They really enjoy the opportunity to interact one-on-one with faculty members, and to get to know them better. Finally, they are seeking opportunities to participate in design projects that involve teamwork and which address real applications. In short, students think that mobility is cool; and the opportunity to learn about it in the context of a design experience that involves teamwork is especially attractive.

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