Project Based Learning in Wireless Communications Utilizing Deployed Wireless Networks

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Abstract—Project-Based Learning (PBL) can significantly motivate students to learn engineering concepts. This paper reports on the experience at Princess Sumaya University for Technology of utilizing PBL to enhance the teaching of wireless communication course. In the project, students are asked to collect real world measurements of cellular towers signal power. The data is then plotted versus distance for different environments. Students are asked to share their measurements and compare them to expected theoretically predicted values using known path loss models. This paper describes the project and the feedback collected from students.

Keywords—Project Based Learning; Path Loss; Radio Strength Signal Indicator (RSSI)

I. INTRODUCTION

In recent years, accreditation institutions around the world have been seeking a change in the way engineering students are being taught. After studies were conducted with recent graduates at the university level, research indicated that graduates were not well-prepared for their entry into a real-world, industrial environment. Without proper skills in working in teams, applying concepts learned in the classroom, or engaging in real-world projects, students were ill-prepared for their post-graduate experience.

Research indicates that the traditional “chalk and talk” method of education has not given engineers the skills they need for post-graduate success [1]. According to research conducted by Mills and Treagust [1], engineering students are graduating with a good fundamental knowledge of engineering and science concepts, but they don’t know how to apply this information to the real world environment. This poses problems for future engineers being unprepared for their careers upon graduation. The traditional “chalk and talk” method of education has not given students the proper skills desired for future engineers such as working in teams, applying concepts learned in the classroom, or engaging in real-world projects [2].

According to the American Society for Engineering Education (ASEE) [3], there is a distinct need for engineering education to change to meet new industry challenges and national needs in the field. “Today, engineering colleges must not only provide their graduates with intellectual development and superb technical capabilities, but following industry's lead, those colleges must educate their students to work as part of teams, communicate well, and understand the economic, social, environmental and international context of their professional activities. These changes are vital to the nation's industrial strength and to the ability of engineers to serve as technology and policy decision makers.”

Furthermore, accreditation organizations such as ABET (The Accreditation Board of Engineering and Technology) and curricula design associations, such as IEEE/Association for Computing Machinery (ACM) and Computer Curricula 2001 have implemented objectives that should be added into the engineering curricula to better prepare engineers for their futures [4].

The Accreditation Board of Engineering and Technology (ABET), establishes criteria for universities to maximize learning among students and to better prepare them for their future careers. The ABET criteria changes yearly to keep engineering programs competitive with the changing industrial environment. ABET's criteria for accrediting engineering programs for 2014-2015 requires that engineering courses be designed to meet a vast array of desired outcomes [2]. Criteria 3 Student Outcomes, were designed as a guide for the skills educators should design into the curricula to ensure that students achieve specific skills in their engineering coursework by the time of graduation. ABET's Engineering Accreditation objectives states that engineering courses should encourage students to apply their technical knowledge (of mathematics, science, and engineering) and be proficient at identifying, formulating, and solving engineering problems. Students should be able to design a system, component, or process to meet desired outcomes, (taking into account economics, environment, health and safety standards, etc.)
conduct experiments, and be able to analyze and understand data. Students should also be able to utilize modern engineering tools (such as MATLAB) that are needed for engineering practice.

ABET has recently adapted some “softer skills” into its criteria including the students ability to communicate effectively, work in a team-based environment, act in a professional and ethical manner, and possess the desire to be a life-longer learner. Unfortunately there had been a disparity between these educational standards and those actually achieved by recent graduates.

Given the objectives of the ABET criteria for university graduates and the needs for today’s engineers; the traditional “lecture-based” method of teaching engineering is simply not sufficient. A more hands-on approach known as Project-Based Learning (PBL), has been introduced into engineering courses (in various disciplines) around the world. By definition, ‘Project-based learning begins with an assignment to carry out one or more tasks that lead to the production of a final product—a design, a model, a device or a computer simulation. The culmination of the project is normally a written and/or oral report summarizing the procedure used to produce the product and presenting the outcome [5].’

By offering a hand-on, applied approach to learning, PSUT hoped that students would have a learning experience that would better-prepare them for future field work in their respected fields of engineering.

II. LITERATURE REVIEW

The application of hands-on learning techniques such as problem-based learning or project-based learning (PBL) in engineering are becoming more prevalent than in the past. Since its introduction, project based learning has shown to greatly impact students knowledge of core concepts taught in the classes, especially when it complements the lectures.

In literature, Shankar and Einstein [6], introduced PBL to a wireless communications course in the junior year of an undergraduate degree. Since most courses introduce PBL prior to graduation (i.e. in the senior year or in graduate courses), this class tailored the coursework to combine both lecture and PBL. This was accomplished through a series of projects throughout the semester that covered a wide range of topics discussed within the course (including fading, path loss, and cell coverage). Upon course closure, the PBL method was evaluated by the professor through a survey. The survey indicated that the combined use of lectures, mini projects, and targeted homework problems were helpful to students in learning the new course content. It was especially helpful to students because an appropriate course book was not readily available for this particular wireless communications class.

In [7], two different US-based universities collaborate to create an innovative project-based learning experience that encourages students to work together in teams to build wireless sensors that relays data over a radio-frequency link. The course was designed to offer weekly seminars (from either university), using interactive Internet conferencing. Course lectures included telecommunication topics such as signal processing, microwave systems, etc. One of the most innovative aspects of the research was the long-distance team collaboration between students from different universities. Evaluations from students indicated that they valued the course collaboration and the application of research projects built into the course.

In research conducted by Fefai and Fagan [8], a wireless communications course benefited from PBL through the application of commercially purchased software. This course integrated the CelPlan software to expose students to one type of software that is used in the industrial environment for research and development purposes. The aim was to improve the students’ overall knowledge of wireless concepts that are used in real-world industries. This research is considered a work in progress and has not yet been evaluated for its effectiveness.

Research conducted by Padgett, Black, and Ferguson [9] at the Rose-Hulman Institute of Technology, features an innovative hands-on, project-based learning element, through the addition of a laboratory component that utilizes an infrared (IR) communication system. Students at the Institute participate in a multi-week laboratory project that drew off their course content to construct, troubleshoot, and integrate subsystems into a communication system. Student feedback indicated that the laboratories helped to reinforce concepts learned in class, motivate the students, and enhance their problem-solving skills. All of these of which are vital skills in the real-world setting.

Research conducted by Sarkar and Craig [10] was designed to attract students to a wireless networking course that was hands-on, interesting and that would bring excitement to topics that are typically considered “dry and boring.” The team of researchers developed low-cost projects used throughout the semester using Wi-Fi Modules and PC cards found in electronics stores. The aim of the research was to provide a hands-on learning experience to students in an introductory level course in wireless networking and communications. The 3 different projects focused on topics such as a programmable interface controller (PIC) Sounds Generator project, the IR signs produced by TV remote controls, and setting up a wireless link between 2 different computers. Both student and faculty feedback indicated that the projects were useful and valuable to students.

Frolick and Fortney [11] enhance a first-year basic engineering design course from a seminar-only course to one that utilizes PBL. The course projects focus on the utilization
of a low-cost wireless circuit, the CricketSat, to perform a multitude of projects related to wireless sensor networks and actuator projects. The course encourages students to work in partnership to develop problem statements and projects. This brought what the authors have termed a “working reality” to the course, which has shown to give second year students more confidence in building, testing, and analyzing circuits.

In [12], Cassara, developed one of the first instructional wireless information network laboratories to better prepare students for the post graduate careers in wireless. One hour of weekly lecture is followed up with a 4-hour experiment lab to reinforce lecture concepts. The laboratory is divided into stations that include a “spectrum analyzer, digital storage oscilloscope, RF signal generator, noise generator, true root mean square (rms) voltmeter, dc power supplies, function generators, printers, desktop computer, frequency/event counters, double balanced mixers, and power splitters.” Following each lab experiment, students are required to write both a laboratory reports and present an oral presentation. Utilized by more than 800 students to date, this laboratory has provided students with a hands-on laboratory experience that augments their theoretical wireless knowledge.

Research by Chenard, Zilic, and Prokic [13] discusses the teaching methodology and laboratory used in a course on wireless embedded systems. The course drew off of students’ previous knowledge of digital systems, wireless networking, and computer architecture, to create a semester-length project in the area of systems engineering. The course used a flexible hardware platform to complement the teaching of the course.

Research conducted by Wang and Jiang [14], aimed to simplify the teaching of wireless local area network (WLAN) through simulation. Viewed as a “complex” topic, the authors suggest applying NS-3, open source software, to better enhance the teaching of the course. NS-3 is a network simulator that is often used in research and educational settings. This simulator improved the teaching quality and stimulated student interest in the course.

In [15], Linn introduces a low-cost wireless laboratory that assists professors in the classroom by providing visual real-time demonstrations in wireless communication systems. It is also powerful enough to conduct research in the wireless communications. Despite its low cost, the lab is quite comprehensive including complete transmission, channel emulation, reception (coherent and noncoherent), and probing capabilities. Student surveys indicated the effectiveness of the lab in the course.

Utilizing live cellular network to augment the teaching of wireless communications was proposed in [16]. Alqudah proposed utilizing operational WiMAX or GSM networks to collect field measurements of Radio Strength Signal Indicator (RSSI), by recording distance from serving tower and RSSI, students are able to generate graphs of measured path loss for different environments. Students can then compare field measurements with theoretically predicted path loss. This paper build upon this idea and reports on actual implementation of this project at PSUT. Below we describe the course coverage, methods and show sample results, and we share students’ feedback.

III. COURSE DESCRIPTION AND OBJECTIVES

The Cellular Communication Course is a 3 credit, senior-level course, given in the 5th year of the undergraduate degree in Electrical Engineering. The degree is obtained after completing 163 credit hours. The course covers fundamental topics in wireless communications including:

- Cellular system design concepts and fundamentals, frequency reuse, channel assignment, handoff strategies, system capacity, trunking, grade of service
- Mobile radio wave propagation: large scale path loss and propagation mechanisms and model.
- Small-scale fading and multipath, Rayleigh and Ricean Distributions.
- Modulation techniques for mobile radio.
- Multiple Access Techniques for wireless communications.
- Wireless systems and standards

The outcomes of the Cellular Communications Course are:

- Understanding the cellular and frequency reuse concept.
- Understanding of wireless propagation of Electromagnetic wave (reflection, diffraction, and scattering) and associated losses.
- Understanding and application of turning theory and application of Erlang B, and Erlang C formulas.
- Basic Design and Planning of a wireless cellular system.
- Understanding some of the contemporary issues in the cellular communications engineering profession.
- Applying analog and digital communications principles to cellular and wireless communications

The outcomes of the course are tailored to enable equipped graduates who are able to join the telecommunications industry.

IV. METHODS

PSUT’s Electrical Engineering Program aspires to prepare students for industrial entrance by giving them opportunities
to apply the engineering concepts they learn in the classroom to a real-world application. Since many of PSUT professors have worked in the industrial setting, they understand the need for skilled and well-prepared engineers.

The Cellular Communications course at PSUT was designed to balance the teaching of engineering theories and concepts with the need to apply this information to a related project. In this project students are assigned to collect performance metrics of live cellular networks. At the beginning of the semester, the project was introduced to the students along with the objectives, methods, and tools. Students are asked to utilize their mobile handset to collect Radio Signal Strength Indicator (RSSI) in any geographical location they choose. Along with RSSI, the student should register the approximate distance from the cellular tower.

In order to study the effect of the terrain and operating frequency, students submit their readings to a shared folder created on the cloud (Dropbox®). Students are allowed to collect the data set any time during the semester after the project is assigned. After completing the data collection, students are asked to plot the measured RSSI vs. distance to calculate path loss and compare their readings to others. A typical graph looks similar to Figure below. Students are also expected to compare the accuracy of different models covered in the class in predicting path loss. Students submit a report at the end of the semester that includes their collected data and other students’ data. Students are expected to explain the results they obtained based on environment terrain, foliage, etc. Students are also required to present their work to the class during the last week of the semester.

When asked about the relevance of the project in reinforcing engineering concepts that were learned in classroom, nearly all students strongly agreed with this premise and found the project “useful.” Everyone agreed that having the project deal with a practical real-life problem made the course and the project more interesting. Students also felt that the project enhanced their understanding of cellular communication, propagation models, and network coverage. All students agreed that the effort and time spent on the project was worth the outcome.

When asked for suggestions to improve the overall project experience, the number one suggestion from students was to have more time allocated to complete the project. Some students also mentioned needing more guidance on how to write the research paper. When asked what they liked best about the project, the students mentioned the benefit of working in a team-environment and having practical experience that allowed them to better understand the theories that were covered in the class lectures. A few students mentioned that having more suggestions for where to locate a better location to optimize signal strength would be valuable in completing the project in a timelier manner.

| Table I: Student Response to the Cellular Survey Project-Based Learning Initiative |
|---------------------------------|------------------|------------------|------------------|------------------|------------------|
| Overall the project was useful | Strongly disagree | Somewhat disagree | Neither Agree nor disagree | Somewhat Agree | Strongly Agree |
| The project helped to reinforce/learn concepts taught in the classroom | 0 | 0 | 4% | 39% | 57% |
| Dealing with a real-life problem made the project more interesting | 0 | 0 | 15% | 46% | 39% |
| Project raised my interest in cellular networks | 0 | 0 | 0 | 36% | 64% |
| Project reinforced my understanding of propagation models | 0 | 0 | 19% | 54% | 27% |
| Project reinforced my understanding of cellular networks | 4% | 0 | 4% | 58% | 34% |
| Project reinforced my understanding of network coverage | 0 | 0 | 20% | 20% | 60% |
| The effort/time spent on the project was worth the outcomes | 0 | 0 | 8% | 40% | 52% |

V. STUDENT EVALUATION

![Fig. 1. Predicted and measured path loss using Radio Strength Signal Indicator (RSSI)](image-url)
VI. CONCLUSION

This paper reports on the experience at PSUT of utilizing project-based learning to enhance the teaching of a senior-level wireless communication course. Students are asked to use their mobile phone to collect field measurements of signal strength and generate path loss graphs of their measurements and those of and other students. The results are compared to predicated values using known path loss models.

Adding a practical project to the class added excitement and motivation. Students’ feedback has been very positive as demonstrated by a formal survey and informal discussions.

REFERENCES


