Integrating Research Experience into Entry Level Electrical Engineering Graduate Courses

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Abstract -Supported by Embry-Riddle Aeronautical University (ERAU) Center of Teaching and Learning Excellence (CTLE), we implemented the teaching practice of incorporating research experience in two entry-level graduate courses in the Master of Science in Electrical and Computer Engineering (MSECE) program at ERAU. This practice is accomplished through introducing a small-scale research project in each course, which allows students to experience firsthand engineering research activities. Through the project experience, students are well prepared for the upcoming graduate research project (GRP) or thesis towards the end of their master's program of study. It is found that students are better motivated and prepared for research activities through the project experience they received via our teaching practice.

Keywords: Electrical engineering education, graduate engineering education, research experience, active learning

INTRODUCTION AND MOTIVATION

For engineering graduate students, it is highly beneficial to introduce research activities as early as possible in their graduate program of study. Students develop domain expertise, gain an understanding and appreciation of the research process and its practice, and acquire team, communication, problem solving, and higher-level thinking skills. Students with this experience are better equipped to make informed judgments about technical matters and to communicate and work in teams to solve complex problems [Bernat, 1].

Aside from the thrill of generating new knowledge, working on a research problem provides many other valuable opportunities including [Kuther, 2]:

- Working one-on-one and develop a mentoring relationship with a faculty member.
- Exposure to methodological techniques that will help them complete their theses or GRP.
- Get writing and public speaking practice by submitting papers to professional conferences or journals.

Moreover, motivated students can pick up projects and contribute to further faculty research programs as well.

For ERAU's MSECE program, a graduate research project (GRP) or a thesis is required towards the end of the two-year program. However, we believe that it is essential to expose students to research activities earlier in their study. After all, for many students, research experience is the primary reason to pursue a graduate degree in the first place. Most graduate students exhibit a strong desire in participating in research activities once they start to take graduate courses.

Another important motivation for this teaching practice has to do with the content of many graduate level engineering courses. Often, students are exposed to in-depth theoretical knowledge in these courses, but lack the motivation to devote sufficient effort to these materials, because it is difficult for them to see the relevance of the

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theory (such as linear algebra, probability theory, and random processes) to real world engineering problems. We believe the most effective way to address this problem is to incorporate research activities in these courses. It has been our experience that students always exhibit keen interest whenever applications of theory to practical engineering systems are mentioned in class.

RELATIONSHIP TO THE SCHOLARSHIP OF TEACHING AND LEARNING

There have been many studies reported in the literature about integrating research experience into college classrooms [3-5]. In [Jenkins, 3], after examining various research evidences from various countries, it is argued that "All higher education institutions and all degree programs should educate all students to understand how knowledge is constructed through research and to understand the research process", and "All higher education institutions should support (and require) all academic staff to be scholars/aware of current research developments in their discipline and in the teaching of their discipline". In [Beane, 4], many types of methods and examples of integrating research into classrooms are mentioned, such as posing a hypothesis, writing a proposal, background research, data analysis and modeling, and making research presentations. [Nyhus, 5] describes an effort to enhance integration of research and education through an interdisciplinary undergraduate research symposium.

It is our belief that the most important benefit of integrating research experience in engineering courses is student engagement achieved through active learning. Various rigorous studies have shown that active learning techniques (such as introducing student activity into the traditional lecture, collaborative/cooperative learning, and problem-based learning) enhance academic achievement, student attitudes, and student retention [Prince, 6]. One of the problems with the current understanding on active learning is that, many active learning proponents do not consider engaging out-of-class activities as part of the active learning tradition [Drake, 7]. However, challenging out-of-class assignments clearly requires student engagement in higher order thinking activities, thus providing the same benefits of in-class activities. The teaching practice presented in this paper promotes such kind of out-of-class activities.

RELEVANT COURSES AND EXPECTED OUTCOMES

The new teaching practice was implemented in EE 515: Random Signals, and EE 510: Linear Systems. The two courses were developed and have been taught in each Fall semester. The courses are core courses offered at the beginning of the MSECE program (for both Electrical Engineering and Computer Engineering tracks), and they are theoretic in nature. By providing the opportunity to participate in small-scale research projects, students are expected to not only have enhanced motivation in learning course materials, but also develop understanding of the knowledge discovery and engineering research process. In addition, the writing of research project reports provides students with extremely valuable training experience in technical writing and presentation skills.

IMPLEMENTATION

In this project, research experience is introduced through in-class presentation of research topics by the instructors, followed by a small-scale project assignment. The project report was counted as an extra credit assignment.

For EE 510, the project topic is the Recursive Least Square (RLS) algorithm. When analyzing linear systems, sometimes the measurements under investigation do not exactly fit the theoretical system dynamics due to noise. RLS is one of the classic adaptive filter algorithms. It is used to identify a linear noisy system, where the weights of the estimated system are nearly identical with the real one. RLS is the basis of commonly used estimation technique, Kalman filtering, which is used extensively in engineering applications, such as satellite tracking and industrial process control.

After learning about least square algorithms, students are asked to develop the RLS technique in theory through derivation, and then simulate the RLS method in MATLAB to confirm the validity of the theoretical formulation.

For EE 515, the research topic is signal separation techniques based on the Central Limit Theorem (CLT). According to CLT, the sum of independent source signals is always closer to Gaussian distribution than any individual source signal. Therefore, the deviation from Gaussian distribution, i.e., non-Gaussianity, can be used as a measure of the degree of mixture of independent signals. The maximization of non-Gaussianity is an effective and efficient guiding principle to extract source signals from their linear combinations. These techniques are commonly referred to as Blind Source Separation (BSS), or Independent Component Analysis (ICA). The methods are applicable in a variety of scientific and engineering applications, such as financial data analysis, biomedical signal processing, and wireless communication systems, etc.

The coverage of CLT occurred approximately in the middle of the semester. After the theorem was explained in class, the instructor made a presentation on the basic principle of signal separation, and a simple algorithm to perform signal separation from the sources' linear combinations. Then, students were assigned the project to study the effect of block size and thermal noise on the performance (such as signal-to-interference ratio and convergence speed) of such algorithm through computer simulations.

At the end of the semester, inspired by their project experiences in EE 515 and EE 510, several students asked for an additional research project to explore on their own. At their request, we assigned them a project on Singular Value Decomposition (SVD) for data compression. First, we introduced to them the realization of a straight-forward compression and decompression scheme. This is to show the basic idea of reducing memory storage requirement with SVD. Second, students were tasked to test various processing block sizes on a given image to study the effect of block size on the quality of compression. Also, students studied an adaptive rank selection scheme and examine the effect of image complexity on the algorithm's rank selection. Finally, students discussed possible enhancements and drawbacks of SVD-based image compression scheme at the end of the project report.

ASSESSMENT

Direct assessment data were collected through project reports, including project summary, MATLAB program code, performance figure generated by computer simulations, and discussions of project results. The benefits of such direct assessment is, student learning outcomes, research potentials, technical writing skills, team working skills, programming skills, and the ability of apply math and science knowledge are all measured. Moreover, since students from both electrical and computer engineering tracks were taking these two graduate courses, they also experience collaboration with students from different backgrounds.

Between the two courses, a total of 12 students completed the projects. The course grade achieved by these students averaged 92 out of 100, while the average grade for the remaining students was 83. This demonstrates the impact of completing the project assignment on student learning and motivation.

From the student work, it is clearly seen that, while personal characteristics such as learning curve of individuals and capability to work under time pressure are influential to the project-based learning [Hsu, 8], most students demonstrated their ability of applying math and science knowledge to engineering problem solving. This is illustrated by theoretical derivations. Also, students practiced the use of MATLAB software to perform computer simulations, and learned to summarize the findings of simulation results and confirm the validity of theoretical formulations. Through the performance of both analytical work and verification via computer simulations, the project cultivated students' ability to use the knowledge of math and science in engineering research effort.

In addition, students had the opportunity to improve their writing skills significantly, especially in terms of technical report writing. We paid special attention in guiding them through the process of project report writing. Many of their initial draft of project reports only contained computer simulation results, and the information provided in the report was incomplete, confusing, and in the wrong order. As a result, we decided to instruct them concerning the appropriate format of technical project reports, and students were able to produce reports with much improved quality to facilitate the evaluation of their research results. They learned to follow the well-accepted format of technical report, including abstract, introduction, theoretical derivation, computer simulation results, conclusions, and appendix sections.

At the end of the semester, we conducted a five-question survey to solicit students' subjective opinions on the project assignment. The survey results showed that all students who completed the assignment very appreciative of the experience, not only because the experience helped them draw connections between theory and engineering practice [Nelson, 9], but also they gained confidence for conducting research for GRP or thesis, which occurs at the end of their graduate program of study.

CONCLUSION

This paper describes our recent effort in incorporating research experiences in the introductory graduate courses in electrical and computer engineering, namely, "Random Signals" and "Linear Systems". Through initial experimentation and assessment of the teaching practice, it is concluded that many benefits were achieved, including:

enhanced motivation in learning advanced engineering knowledge; firsthand experience in research activities; cultivation of critical thinking and problem solving skills; ability to apply math, science, and engineering knowledge on engineering problem solving; ability of using popular software programs for engineering analysis; ability to interpret data obtained from computer simulations; ability to communicate effectively, especially technical writing skills. It is particularly noteworthy that, several students even asked for an additional research project to explore on their own at the end of the semester, which indicated the success of our teaching practice in inspiring students' enthusiasm in engineering research.

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