AC 2008-635: A CASE STUDY: A NEW COURSE ON ENGINEERING PROJECT AND MANAGEMENT FOR FIRST-YEAR GRADUATE STUDENTS IN ELECTRICAL AND COMPUTER ENGINEERING

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A Case Study: A New Course on Engineering Project and Management for First-Year Graduate Students in Electrical and Computer Engineering

Abstract

The electrical and computer engineering (ECE) department at the University offers a graduate curriculum that is designed to help students develop skills for system integration and acquire effective business and technology practices, as well as, fundamental knowledge in the ECE field. As part of the curriculum, a new course on engineering project and management has been recently introduced to first-year graduate students. This new course guides students through a complete design cycle from inception to completion with a pre-defined project of a complex system. This paper focuses on the experience and lessons learned from offering the Capstone-like, project-based design course to first-year ECE graduate students. It reports details of the course and pedagogical approaches to achieving the course objectives. Evaluation results are also presented on course outcomes and learning experience of students.

Introduction

In recent years, the trend in engineering education and its approaches has evolved towards incorporating hands-on projects into engineering courses and also part of an engineering curriculum. Such educational approaches in higher-educational institutions are often referred to as the project-based learning. In ABET-accredited undergraduate programs, the so-called Capstone project or senior design project is offered for this purpose typically over two semesters and considered a mandatory course for students to fulfill the requirements for the program. Within an engineering course, various activities relevant to a small engineering design are often incorporated at different levels. The intent of the project-based learning is to prepare and produce engineering students with skills and knowledge necessary for fast-paced, high-tech engineering industry.

In graduate programs, class projects are also commonly assigned as part of the key components for the course in addition to traditional techniques of enforcing student's learning such as homework, quizzes, and exams. However, complexity of such projects is often based on the assumption that students have reasonable technical and non-technical skills from their undergraduate education such that the application of appropriate new knowledge from the graduate course is the main focus in order to successfully carry out the project. For first-year graduate students with an engineering degree from an ABET-accredited higher educational institution, this would not be an issue although student's competency may slightly vary. In most engineering graduate schools, however, there is a large population of international students. This situation is particularly true in our Electrical and Computer engineering (ECE) with a recent large influx of international students from Asia. We learned from the recent experience in educating them that their undergraduate curriculum reflected on their transcripts is not much different from that of an ABET-accredited institution. But the reality is that the actual content appears to be somewhat different and that the majority of the international graduate students are theory-oriented but lack understanding of the system-level approach to their studies, which is normally gained through the project-based learning.

In an effort to meet the educational needs for the emerging workforce of U.S. industry, our ECE department offers a graduate curriculum that is designed to help students systematically develop system integration skills and acquire effective business and technology practices. As part of the curriculum and to address the issues mentioned above, a new one-semester course on engineering project and management has been recently introduced for first-year graduate students. This new course guides students through a complete design cycle from inception to completion with a pre-defined project of a complex system. For the required complexity for the course, a wireless cellular communication system, in particular, the third generation (3G) Wideband Code-Division Multiple-Access (CDMA) system [1], is considered for the design exercise and project management. In this course, based on the technical standards available from the standardization organization, students are required to produce design requirements and specifications as well as other documents such as functional decomposition, project management plan, and test plan. Actual design and verification are conducted in a team environment using modern software and hardware tools. Ethics and legal issues are also discussed as part of the course. In the subsequent sections, details of the course are provided, as well as, evaluation of course outcomes and students' learning experience in this course.

Course Objectives and Topics

In our ECE graduate curriculum, the *Engineering Project and Management* is a core course intended for the first-year graduate students. This course focuses on the skills required to manage the development of effective system architectures from concept through engineering design and production. The course objectives are i) to understand ethics and the common development process of engineering systems; ii) to develop design-for-testing concepts; iii) to develop skills for management of engineering design projects; and iv) to develop skills for effective technical writing and oral presentation. Towards achieving these objectives, the course topics include 1) project overview and proposals; 2) engineering design processes; 3) requirement specifications; 4) project management, system integration, and team work; 5) functional decomposition; 6) system modeling and toolsets; 7) software/hardware simulation and control; 8) testing and system integration; 9) oral presentation; and 10) technical writing.

Pedagogy

For learning effectiveness and to achieve the course objectives, course instructions were based on textbook [2], supplementary materials and handouts, assignments, lectures, in-class discussions, group work, laboratory work, use of library and Internet resources, and instructor's feedback. The entire class was divided into small teams of 3 or 4 students each and two teams were paired as a group for the reasons further detailed below. With two class sections of the course due to large enrollment, there were 4 groups in one section, i.e., 27 students, and 6 groups in the other section, i.e., 36 students. The topics covered in this course were organized in a manner such that either as an individual or group as necessary, students could submit written reports as milestones along the way. There were seven Written Reports on 1) System Overview, 2) Requirement Specifications, 3) Functional Decomposition, 4) Project Management, 5) Ethics, 6) Subsystem

Design and Simulation, and 7) Project Documentation, respectively. Students were instructed to produce a complete but succinct report without committing plagiarism. For clear instructions in submitting a report and to enforce students learning in being able to follow instructions given, each report assignment came with explicit instructions on a specific report format including font size and page limitation, along with a submission deadline that has a specific time of the due date. The submission by the deadline was managed on line as on-line submissions were naturally time-stamped and was effective in delivering a clear message to students that adhering to the instructions and hitting the deadline is important and is enforced in this course. Since this approach was not meant just to be strict on students, if anyone had reasonable excuses, late submissions were accepted without penalty although such flexibility was not formally announced to students.

System Overview:
Along with a few lectures to briefly go through vocabulary and signal processing techniques in the necessary specifications documents such as 3GPP TS 25.101[3], 25.211 [4], 25.212 [5], 25.213 [6], and 25.214 [7], the first written report on System Overview as an individual assignment was requested for students to get further familiarized with the documents. Due to different background of students, a generous approach was taken such that students could focus on noting on where to look within the standards for further details when necessary, rather than mastering the system specifications. To facilitate the completion of this assignment, class time was spent as necessary to answer any questions students had.

Requirement Specifications:
On Requirement Specifications, lectures were given on user/marketing requirements and engineering requirements using the course textbook. Then, given the 3GPP specifications as the fundamental constraints to be incorporated into the project, each group of two teams was asked to come up with a product and its user and engineering requirements along with justifications. In each group, one team was asked to function as marketing department and the other as engineering department for the project. Once marketing and engineering departments finished discussing about the product and came up with the requirements, which was submitted as the first part of Written Reports entitled Initial Discussion of Requirement Specifications, the requirements from each group was handed over to the next group in a round-robin fashion which would serve as the manufacturer (or designer) of the product. In this fashion, each group was designated as a buyer (of the product for which they composed user and engineering requirement) and also a manufacturer (of the product from another group). The manufacturer in turn analyzed the buyer's requirements for the feasibility of successfully finishing the product design and delivering the product, and produced the second part of the Written Report entitled Analysis of Requirements Specifications. In practical situations, there would be more dialogues and negotiations between the buyer and manufacturer, but due to time constraints, the Analysis of Requirements Specifications was considered final for the manufacturer to design the product. The group serving as the manufacturer was given the freedom to revise the Initial Discussion of the Requirements Specifications in any way appropriate to reflect the group's design capability so the group feels comfortable to design the product as specified for the rest of the semester for the course.

Functional Decomposition:

Lectures on Functional Decomposition followed to guide each group to specify design components from the requirements in a top down approach, as opposed to a bottom-up approach. One thing the instructor noted from this exercise was that students had difficulty to come up with design modules that would satisfy the requirements once put together for the product – which is a clear indication of the lack of system-based approach to engineering design. In other words, students had a tendency to design a small module as a product or project without being concerned about a much more complex product. When a complexity is increased as intended in the course to enable the learning of a system-based approach, it wasn't an easy task for them. Once all design modules were identified and specified with a limitation of up to 3 layers of subsystems, the manufacturer was instructed to select a few modules that could be designed within the time frame of the remaining semester; the designs of the remaining modules were to be replaced with appropriate technical documentation for completeness of the product design.

Project Management:
All subsystem modules for a product were to be completed within the available time frame by a means of actual design in software and verification or technical documentation as determined in the previous step of functional decomposition. For project management, a Gantt chart was used. Each group was asked to come up with a Gantt chart for every group member's distinct but balanced contribution to the product. This exercise was split into two phases; first for the group's product and second for individual member's tasks. In the end of this exercise, each and every member of the group had to know what he/she needed to do for the product (and to pass the course). This two-phased exercise seemed very effective in having everyone in a group get involved in the exercise; otherwise, there would have been some members of a group as passive participants in such team-based work.

Ethics:
While subsystem design is on going over a period of time in and outside of the classroom, lectures on ethics were given, including actual cases in committing plagiarism and its consequences, as well as, case studies for students to produce a Written Report on ethics. The IEEE Codes of Conducts were also discussed. The timing of addressing the issues on ethics could have been earlier in the semester, but it was decided to get the design work on track first as the time to complete a product in one semester was challenging. Also, those lectures on ethics played an important role to have students stay in classroom for the coursework, as well as, providing a moment to enjoy a light topic in a relaxed environment when design work could be considered hard and stressful.

Subsystem Design and Simulation:
A Written Report on Subsystem Design and Simulation was collected from each student about 2 weeks before the semester ended. Each student was asked to report in this Written Report his/her own design work for assigned implementation-based modules, as well as, documentation-based modules, as per his/her project management schedule specified in the Gantt chart. As part of the exercise to create a succinct document and also to reduce the possibility of committing plagiarism, the format of the Written Report was divided into two parts, the main body and appendixes. The main body of the report was to include approaches and technical descriptions directly related to the design and also present key results from simulation/verification. The number of pages for the main body was limited to a small number, e.g., 5 pages including the

cover page and references. All codes for software implementation were part of the mandatory items for submission and students were instructed to put them in Appendixes. To promote as much implementation as possible in software, as opposed to the page limitation for the main body, no page limit was set for Appendixes. Additional simulation results were allowed in Appendixes as well, to accommodate students who went ahead with more work and wanted to demonstrate it.

Project Documentation:
A Final Project Report was mandated from each group, integrating all group members' work and contributions into one document for the final project documentation. For this purpose, one or two editors were elected from each group and responsible for production of a succinct final report. There was no page limit to provide flexibility in producing a final report with all contributions taken into account. All members of each group were reminded that they must respond to the editor's request for any matter related to the final documentation.

Oral Presentations:
While work on subsystems and simulation was on going, oral presentation from each student was carried out on the work he/she was involved in. Although the goal of this exercise was for students to practice to make a good oral presentation, the definition of good presentation could vary, depending on situation and the characteristics of the audience. The learning focus in this course was on the ability to quickly adapt to the situation and the characteristics of the audience, and ultimately attracting the interest of the audience and making a presentation that the audience would applaud and appreciate. In short, an audience-centered presentation was emphasized. Common techniques were introduced based on the instructor's experience and observations of other presentations as well as discussing the topics in the textbook. As students were eager to know how he or she did, the instructor provided feedback to each and every student right after his/her presentation in a manner that the entire class could benefit from it. In addition, each presentation was peer-evaluated based on ten criteria such as clarity of speaker's speech, the ability to make difficult ideas or concepts clear, poise and classroom mannerisms, and the ability to pace presentation for people emphasis, to list a few. Peer-evaluation itself was considered a good tool to encourage students for a better presentation and class participation.

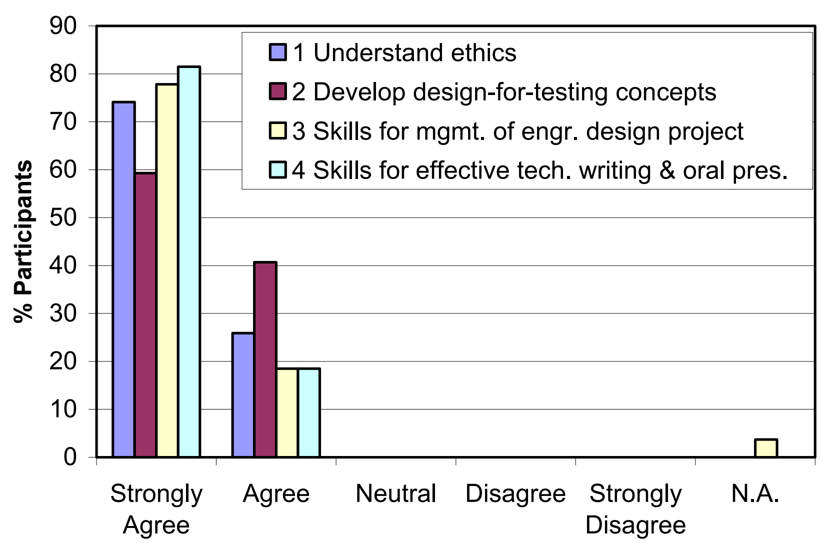

Figure 1: Evaluation on achieving course objectives

Student Evaluation Results of Course Outcomes

In the end of the semester, student evaluation was performed on line as part of the regular course evaluation required by the

University. Based on the data from all 27 students participated in the evaluation, Figure 1 shows students responses to achieving the four course objectives shown in different color codes for the bar. More than 70% of the students strongly agree that the course provided them with an opportunity to understand ethics and acquired skills to manage engineering design project. More than 80% students strongly agreed that this course was successful in developing effective technical writing and oral presentation skills. For all objectives, no one disagrees that this course didn't achieve the course objectives. This response translates into an average score of 4.7 out of 5 when a score is assigned in a descending order from Strongly Agree (5) to Strongly Disagree (1).

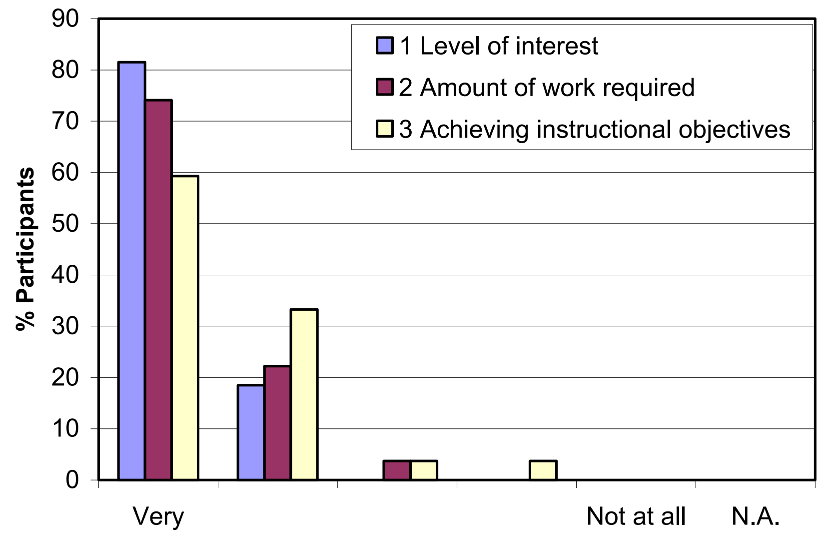

Figure 2: Students perception of the course

Figure 2 shows the students responses to the following questions: 1) How would you rate your level of interest in this course? 2) Whether the amount of work required in this course was heavier compared to other courses, and 3) How effective has this course been in achieving its instructional objectives and/or student learning outcomes? The level of student's interest in this course was very high as evident from more than 80% in favor while the amount of course work was seen heavier. These results show an interesting aspect that they had to work more but maintained high interest in the course. The average score of the overall items was 4.7 out of 5.

In understanding what instruction methods would be most effective, Figure 3 shows the primary elements of course instruction. For each of the items listed, students were asked to indicate its effectiveness in enabling them to learn and achieve the course objectives. Among 10

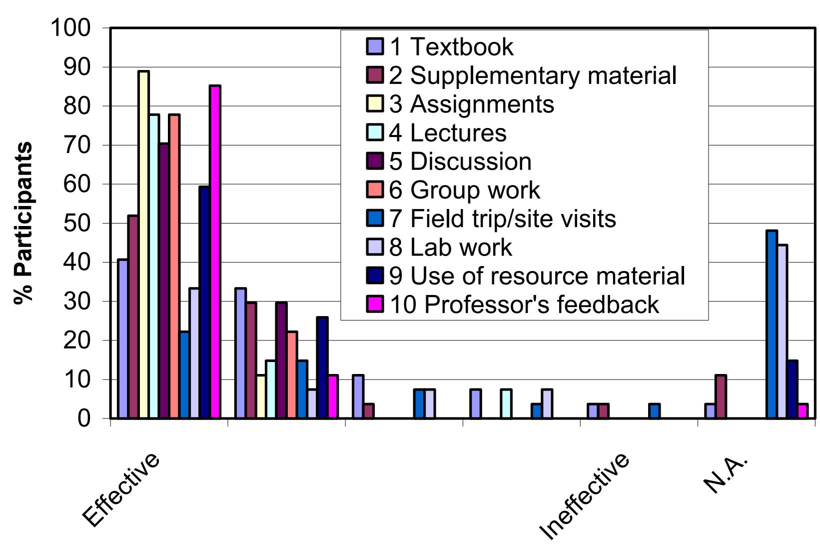

Figure 3: Evaluation on instructional elements

elements listed, 5 elements are favorable to more than 70% of the students. They are 3) assignments, 4) lectures, 5) discussion, 6) group work, and 10) professor's feedback. While it would be generally true that depending on the course, different elements may have more impact on students learning than others, in this course, students activities on their own such as completing assignments, discussion and group work are important and effective elements for the effectiveness of learning. Moreover, the instructor's close interaction with students and providing timely feedback on student activities play an important role. Both the 88.9% for assignment and 85.2% for professor's feedback translate into an average score of 4.9 out of 5, which is a fairly high score considering the number of students, 27, who participated in the evaluation. Although not shown here, the assessment of student academic performance was perceived very fair with an average score of 4.8 out of 5 over all six elements adopted in this course.

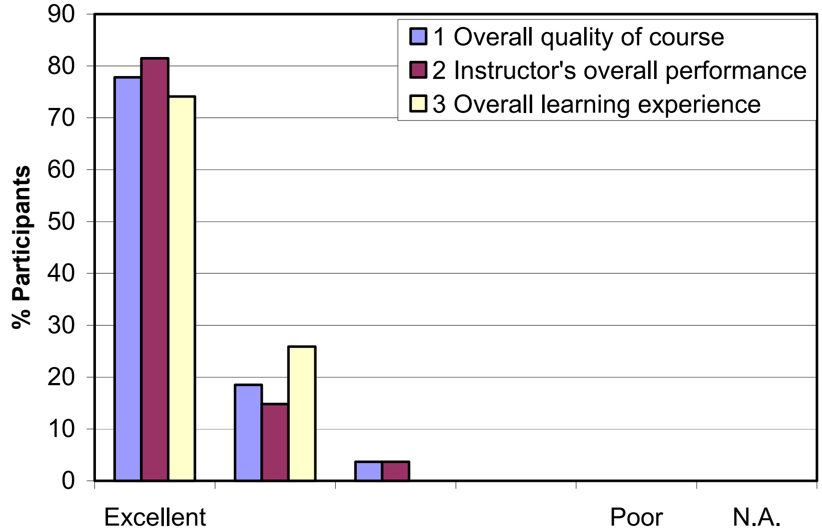

Figure 4: Overall evaluation

Overall, the student responses to this course were very positive when the overall course quality, instructor's performance, and students learning experience were collectively considered, as shown in Figure 4. With the instructor's performance being most satisfactory, the average score over all three elements was 4.8 out of 5.

Survey Results on Student Background

International students, particularly those from India, in our graduate program are largely divided into two groups; those in the first group took undergraduate courses in the

Table 1: Student Background - General

Section A: General		
Major in undergraduate education	1. Electronics & Communications	66.7%
	2. Electrical & Electronics	26.7%
	3. Other (please specify):	6.7%
Have you had any industrial experience in an ECE field after completing your undergraduate education?	No	90.0%
	Yes	10.0%
Have you had other graduate education in ECE before coming to the University?	No	83.3%
	Yes	16.7%
Gender	Male	83.3%
	Female	16.7%

areas of what is referred to as *electronics and communication engineering* and the second group in the areas of what is referred to as *electrical and electronics engineering*. Generally speaking, those in *electronics and communications* have coursework similar to a typical ECE curriculum in the U.S.A, covering courses in the areas of, for instance, electronics, electric circuits, communications, control, and semiconductors. Those in electrical and electronics, however, tend to have coursework more specifically focused on the areas of electric power which is a subset of the specialty areas within the typical electrical engineering curriculum in the nation. Those in the *electronics and communication engineering* typically take a two-semester project course which may be similar to our Capstone or senior design project. But such a course doesn't seem to be offered to those in *electrical and electronics*, although it may be dependent on particular institutions. To understand students'

Table 2: Student Background - Academic

Section B: Academic background 1: Disagree 2: Somewhat agree 3: Agree		
Have you ever completed a project in a course?	No	30.0%
	Yes	66.7%
	No Resp.	3.3%
Have you ever written a project proposal in a course?	No	50.0%
	Yes	50.0%
You already knew what engineering design process is.	1	23.3%
	2	60.0%
	3	13.3%
	No Resp.	3.3%
Have you ever been involved in an entire engineering design cycle, from project inception to completion?	No	53.3%
	Yes	43.3%
	No Resp.	3.3%
Have you ever written a requirement specifications document?	No	83.3%
	Yes	16.7%
You already knew what requirement specifications are?	1	46.7%
	2	43.3%
	3	10.0%
Have you ever been involved in project management in a course project or on your job?	No	76.7%
	Yes	20.0%
	No Resp.	3.3%
Have you ever used the Gantt chart for project management?	No	90.0%
	Yes	10.0%
Have you ever defined project deliverables and milestones?	No	76.7%
	Yes	23.3%
You work well in a team environment	1	10.0%
	2	16.7%
	3	73.3%
You are good in designing individual modules that will be integrated into a complete system.	1	0.0%
	2	53.3%
	3	46.7%
Have you ever been involved in simulation of a component and/or entire system using a software tool?	No	13.3%
	Yes	86.7%
Have you ever been involved in laboratory testing for a course project and/or commercial product?	No	36.7%
	Yes	63.3%
Have you given more than one presentation for a course project or commercial product?	No	23.3%
	Yes	76.7%
Were you aware of key factors to make an effective and well-received presentation?	No	33.3%
	Yes	66.7%
Have you ever published in a conference and/or in a public domain?	No	83.3%
	Yes	16.7%

background better, a survey was conducted during the course, and its results are illustrated in Tables 1 and 2. Valid responses were obtained from 30 students from two sections of the course.

Table 1 shows general information about the students in this course. As shown, the majority students have their undergraduate background in *electronics and communications* but still one third of the class came with the *electrical and electronics* background. Table 2 shows more detailed skill and/or experience pertinent to engineering project and management. The 66.7% of the students who responded with a yes coincides with the percent of the students with academic background in *electronics and communications* in Table 1. But the percent of the students who responded with a yes declined for more detailed aspects of engineering project and management, such as involvement in an entire engineering design cycle (43%), requirement specifications (16.7%), project management (20.0%), experience with the Gantt chart (10.0%), and having defined project deliverables and milestones (23.3%).

Concluding Remarks

We have presented a case study with the offering of a new course on *engineering project and management* to first-year graduate students, and assessed its effect and student learning experience. We have shown that it may be necessary to continue to offer such a course and properly guide students through a complete design cycle from inception to completion. With the lack of previous experience in carrying out a Capstone or senior design project in their undergraduate curriculum, first-year graduate students in ECE, particularly from foreign countries, will greatly benefit from an introductory course on *engineering project and management.*

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