Project-based Orientation Course for EE Freshmen: A Motivational Introduction to Engineering

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Abstract - **In 2003 the National Science Foundation funded a preliminary 1-year study to consider the feasibility of a project-oriented Electrical Engineering curriculum in the newly created College of Engineering at the University of North Texas. At the end of this study, a proposal for such a curriculum in a nascent Department of Electrical Engineering was submitted, was funded, and ran for 4 years. The curriculum, strongly influenced by the first cognition and project-oriented course, has been operational and accredited by the Accreditation Board for Engineering and Technology. The course has evolved significantly in bi-annual offerings. This is a brief account of the original course goals and their changing implementation over the years**.

Index Terms – Cognition, Professionalism, Learning to learn

INTRODUCTION

In the new Electrical Engineering curriculum development, several directions were emphasized. The three main goals of the curriculum, also strongly reflected in the introductory freshman course, are as follows:

- Provide, in addition to a solid theoretical foundation in electrical engineering, a motivationally creative and practical laboratory experience that would eventually facilitate the successful transition from high school to college and from college to professional practice [1]. An important part of this effort was to enhance the communication abilities by means of feedback to the student and to gradually develop their decision-making capacity along with their complexity-handling capabilities.
- Provide an introductory business and financial experience through case studies and theory taught by the College of Business.
- Develop cognitive self-awareness capabilities and teamwork practices that would result in improved learning experiences. The course was accordingly titled "Learning to Learn."

These goals appropriately incorporate many of the accreditation requirements of Accreditation Board for Engineering and Technology (ABET), including the central theme of this paper, freshman success. The course evolved in more than 15 offerings through four distinguishable phases: a strong traditional education approach, a stronger cognitive approach, a practical introduction to electrical engineering practice, and finally, a progressively increasing complexity and self-reliance in the design and simulation of circuit applications throughout the course. In a sense, the course became a microcosm of the full curriculum as we explain and relate to its goals.

The course consists of a total of 15 three hour meetings comprising four "mini-projects" with corresponding reports and team presentations of circuit design and simulation by a collaborative team of three students and 11 formal lectures in a blended modality. It consists of three major lecture course sections, starting with learning and communication topics; following with cognitive issues and self-development through critical thinking; and finally, dealing with the engineering profession, social and ethical responsibilities, and social issues and technology. The 11 formal class lessons use instant feedback through the use of clickers, short writing assignments, and multiple-choice questions for each lesson. All written material is graded and feedback is provided. The lesson topics, which constitute the backbone of the course, are the answers to introductory questions such as "how to learn," learning styles, intelligence, personality and cognition, metacognition and planning, self-awareness and critical/analytical thinking, time management, professional organizations and codes of ethics, technology, standards, and social issues and responsibilities.

DELIVERY MEDIA AND USE

The course is delivered in a blended form with a classroom and a light distance education component, accessible via the Internet. For both components, we have been using a commercial product called "Blackboard Vista," [2] which is based on presentations from Microsoft PowerPoint (PPT) graphics and other interactive software. It is also possible to use short video clips and we use a few, originating from You Tube interviews or done ourselves with a simple video cam (to explain the use of the experimental kit that we use.)

In addition to the PPT presentations used in each of the eleven formal 50-minute lecture classes, extended by class discussions and mini-project teamwork in class, supplementary reading homework material from a variety of sources and nature, including some interactive cognitive material is provided. Thus the academic requirements for a three-semester-credit-hour course are well justified.

An important factor that is well-received by the students is who does the work that results in the grade. The work is clearly divided into individual work and teamwork, and there is explicit advice that not doing each as designated could result in disciplinary action. There is also strong advice on asking for help from the instructor, assistants, or other University resources without hesitation, whenever needed. Unfortunately, it is too often not followed or followed too late to be effective.

The main two interactive Blackboard system facilities for homework that we use are assignments and assessments. The former require short essays and the latter are randomly chosen questions from an extensive database related to the lessons and reading assignments. Since one of the objectives of the course is to enhance written communication skills, which are a very important aspect of the ABET a-k list, we have 11 short essays or topical questions to answer on classroom and reading *assignments* related to course topics. They are reviewed, graded, and provided with some comments on how to improve or correct conceptual explanations. *Assessments* are oriented to sharpen critical reading and thinking [3]. Many of the questions require very careful reading to reach the correct choice. Each item has five questions, and each set has five topics. The database has some 100 questions; a second set may be answered if the student thinks the grade can be improved. The database of submitted answers receives the four presentations and the reports corresponding to short projects (Mini-Projects). This database facilitates the students' private access to the grade e-book.

MINI-PROJECTS

The Mini-Projects constitute the motivational and preferred heart of the course applications. The lectures provide theory of learning, but it is in conducting the design of a simple electronic circuit that the theory of learning is applied. The following points explain why.

<u>New material</u>: The students are faced with a topic, electronics and circuits, about which they have only the background of physics. They must learn "just in time." But in the process, we ask them to think about how they are learning (metacognition).

<u>Teamwork</u>: Quite often, students are faced for the first time with the vagaries of working with two others having different personalities, styles, and knowledge. We ask them to work in alternating roles of leader, reporter, and verifier, showing aspects of administration, documenters, and quality assessment. We ask them also to estimate costs and think of applications for their four projects, which become more sophisticated and open choice as the course progresses. This is their preferred activity in the course.

<u>Oral Presentations and Written Reports</u>: This is possibly the most interactive part of the whole course. Each team makes a presentation and writes a report on each project, and each team member receives the same grade. They learn to depend on each other and at times fill in for each other. They receive input and comments, both critical and encouraging, not only from the grading panel of three but also from their peers, often turning into interesting discussion. The report involves the description of analogies and differences between the experiments using conceptual graphs.

<u>Simulation</u>: After the first project, students are expected to use MultiSim, the National Instruments simulator of semiconductor electronics [4], [5]. One of the advantages is that they can instrument the simulation with multimeters and oscilloscopes. It is probably the hardest part of the course but one that gives tremendous opportunity to compare theoretical behavior with reality and think about the reasons for discrepancies. This has been a recent very successful addition.

<u>"Clickers" or Personal Response Units</u> [6] are used during class as discussion motivators, attention monitors, or just attendance and late arrival indicators. The questions asked are difficult to craft so as to elicit the desired thinking pattern; but when they are well selected, they can produce quite good recognizable learning patterns. Clicker response is credited with a relative larger weight in the final grade also to stress the importance of attendance and punctuality. The grading weight to each of the activities has been adjusted to emphasize attention (no texting) and interaction in class.

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Table I: Estimate of ABET Requirements Coverage

<table>
<tr><th>ABET Criterion 3 Subset of (a)-(k) partially covered by the course</th><th>Estimated percentile of overall requirement covered by lesson</th><td rowspan="9">PART I: LEARNING & COMMUNICATION
1 LEARNING TO LEARN
2 HOW TO LEARN
3 EFFECTIVE COMMUNICATION
4 INTELLIGENCE AND COGNITION
5 PRESENTATION AND REPORT (MINI-PROJECT I)

PART II: COGNITION

6 COGNITION AND KNOWLEDGE REPRESENTATION CONCEPTUALIZATION AND BEING EFFICIENT
7 PROBLEM-SOLVING THINKING; METACOGNITION
8 PRESENTATION AND REPORT (MINI-PROJECT II)
9 CRITICAL AND ANALYTICAL THINKING

PART III: THE ENGINEERING PROFESSION
10 THE ENGINEERING DESIGN PROCESS
11 PRESENTATION AND REPORT (MINI-PROJECT III)
12 PROFESSIOONALISM AND ETHICS/IEEE CODE OF ETHICS
13 CONTEMPORARY ISSUES AND ELECTRICAL ENGINEERING
14 PRESENTATION AND REPORT (FINAL PROJECT)</td></tr>
<tr><td>(b) An ability to design and conduct experiments as well as to analyze and interpret data</td><td>10% Lessons 5,9,10,15</td></tr>
<tr><td>(c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health, and safety, manufacturability, and sustainability</td><td>15% Lessons 8, 10, 11</td></tr>
<tr><td>(d) An ability to function on multi-disciplinary teams</td><td>10% Lessons 5,9,10,15</td></tr>
<tr><td>(f) An understanding of professional and ethical responsibility</td><td>10% Lesson 13</td></tr>
<tr><td>(g) An ability to communicate effectively</td><td>5% Lessons 3,6, 7
10% Lessons 5,9,10,15</td></tr>
<tr><td>(h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context</td><td>10% Lessons 13, 14</td></tr>
<tr><td>(i) A recognition of the need for, and an ability to, engage in life-long learning</td><td>5% Lesson 1
15% Lesson 2
5% Rest</td></tr>
<tr><td>(j) A knowledge of contemporary issues</td><td>10% Lesson 14</td></tr>
</table>

GRADING WEIGHTS

The grade in the course gives priority to the oral presentation and the written report by allocating to those two activities an equal share of 40% of the final grade. Next in importance are the homework activities of Assessments and Assignments given that cover critical thinking and cognitive aspects of assignments. These include the self-analysis of learning styles according to Richard Felder's categorization [7] and the popular Myers-Briggs personality analysis [8]. The results notwithstanding, it seems that the students consider their own character and individual learning abilities at a critical and important point in their personal development and decision-making.

In addition to the grade assignment, up to 5% bonus points are given for optional participation in written discussions on such topics as nuclear energy disasters, ethics, professionalism, and timely social issues related to technology.

ABET AND THIS COURSE

This course has been team-taught by a wide variety of instructors over the last $7^1/_2$ years. During the last 3 years, it has been under the main direction of the author of this paper with the assistance of graduate students. It is the evolved result of some seven contributors whose credit is only identified under the title of some lessons. We gladly cite in particular the influence of Dean Ray Landis whose textbook [9] is cited as a resource for this course and has been influential in the design of the course. For those contributors whose credit is not recognized, we apologize but hope they are glad that their contributions have survived the different offerings.

One strong motivation guiding the evolution of the course has been the ABET guidelines. We recognized seven Course Learning Objectives (CLOs) related to the standard ABET (a)-(k). They are summarized in Table I with reference to the ABET publication on accreditation [10].

THE ELEVEN LECTURES

We provide a brief syllabus of the 11 classroom lectures in three layers:

PART I: LEARNING & COMMUNICATION - The first third of the course lays down the objectives of the course and outlines the different activities and their methods. The emphasis of this introductory layer is on the principles of learning in different domains and the pyramids of Bloom [11] and the styles of Felder [7]. Communication is presented as a basis for learning in the aural as well as the visual domains. There are exercises in determining the most desirable and preferred styles of learning according to Richard Felder. Intelligence in humans and machines is discussed and related to knowledge and understanding. Short- and long-term memory aspects are discussed. The importance of class notes and successive reviews is emphasized. The manner and practice of the first Mini-Project report and presentation with feedback set the pace for the following ones.

1 **LEARNING TO LEARN:** This lesson is the introduction to the different objectives and activities involved in the course; clicker registration and Blackboard access. A baseline questionnaire on the background on the learning objectives is taken to compare with the same at course end.

2 **HOW TO LEARN:** This lesson is oriented to the student attending a university for the first time with an introduction to the differences to be expected, the importance of time management, and the continuous activities in all of Bloom's domains and Landis' survey of important academic skills. Emphasis is put on asking for help as soon as needed and where to find it.

3 **EFFECTIVE COMMUNICATION:** This lesson is about how to interact with an audience and communicate via presentations and reports. A general format is provided for each case, and the usual advice on good presentation practices and standard technical reports are given. Rubrics are explained. Communications as part of learning as an exchange between audience and presenter or reviewer and author are considered.

4 **INTELLIGENCE AND COGNITION:** A brief survey of reasoning in human and machines and on the potential for improving individual reasoning processes is presented. The works of Bloom and Felder and how to apply their results and those of others are central to this lesson. Optionally, the students may take, for additional credit, a Myers-Briggs personality test to encourage self-reflection.

5 **PRESENTATION AND REPORT (MINI-PROJECT I):** A panel of three faculty members and graduate assistants provide constructive feedback on the team's presentation and read and comment on a printout of the report, emphasizing the improvements possible in each. A simple timer circuit with an LED output is easily simulated and used as an example for the presentation and report formats.

PART II: COGNITION: While there were basic cognitive concepts covered in the previous basic layer, we now look at finer points of representations, conceptual relations, metacognition, and critical analysis that facilitate thinking.

6 **COGNITION & KNOWLEDGE REPRESENTATION:** We emphasize the difference between knowledge and understanding and the need for the former to precede the latter. We show an example of the potential to facilitate thinking when an appropriate representation is used and the unavoidable requirement to use symbols to communicate. We also show them how they can be helped at the University.

7 **CONCEPTUALIZATION AND BEING EFFICIENT:** The use of concept maps [12] is encouraged in showing classes of objects but available software has even more powerful options. Also, we emphasize the concept of sequence of actions and optimization of the time to do all activities. Video clips are shown. The rule of 60 is discussed.

8 **PROBLEM-SOLVING THINKING: METACOGNITION -** This important lesson explains the concept of metacognition as the cycle of activity-(self-observation)-feedback and change and uses an example from [9]; there is emphasis on creativity and Edison's work and advice.

9 **PRESENTATION AND REPORT (MINI-PROJECT II):** The specification only requires certain components to be used and has more degrees of freedom in the circuit and its application.

10 **CRITICAL AND ANALYTICAL THINKING:** The critical thinking process is specified; some puzzles illustrate the issue of critical and analytical reasoning. Complexity, worst case design and tolerances, the work of "The Critical Thinking Community," and examples are presented.

PART III: THE ENGINEERINGPROFESSION: This segment of the course is strongly oriented to the issues of design in engineering, ethics, and professional engineering.

11 **THE ENGINEERING DESIGN PROCESS:** We consider the engineering design process and point out an interesting analogy with the cognitive pyramid of Bloom [11] with a strong emphasis on testing and verification of the design.

12 **PRESENTATION AND REPORT (MINI-PROJECT III):** The specifications for this project were given well in advance and there are warnings on deciding ahead if new components are needed. Very general but demanding requirements.

13 **PROFESSIONALISM AND ETHICS/IEEE CODE OF ETHICS:** This lesson covers the requirements to become a professional engineer and a number of case studies [13] to study and give an opinion. The IEEE Code of Ethics [14] is studied, and an invitation to participate from the IEEE Student Branch is presented by its officers.

14 **CONTEMPORARY ISSUES AND ELECTRICAL ENGINEERING**: This is a broad ranging lecture with consideration of technology as a social factor [13] in communications, climate [15], navigation, globalization [16], nuclear power disasters, the question of international commerce and competition [17], and in general what electrical engineers can do to help humanity.

15 **PRESENTATION AND REPORT (FINAL PROJECT):** This project is totally up to the

students to select. The presentation and report are due on the same day. It tests their planning ability and swiftness in teamwork. A party follows.

THE FOUR MINI-PROJECTS

We utilize a simple electronic kit manufactured by Radio Shack with associated manuals [18] as an instrument to apply our learning practices and as a motivational device to provide hands-on teamwork, presentations and reports. Each Mini-Project involves increasingly open design and complexity of circuits and integrated circuits. With each one, there is a demonstration of the built circuit, its simulation [4], [5], a presentation, and a report associated with the project. Therefore, there are also good opportunities for self-reflection on personal interaction, learning styles and consideration of the continuation of the personally motivated learning imperatives in all of Bloom's domains [11] for an ethically responsible, socially active professional. While the specifications of the projects change each semester, the short-term projects start with a simple flasher, follow with an analog circuit integrating the concept of input-processing-output, change to a simple more complex but introductory digital circuit and finally an entirely open limited-scope project totally chosen by the team. Prizes are usually awarded to recognize the outstanding presentations.

THE PRESENT AND THE FUTURE

The evolution and continuous improvements implemented have resulted in a high degree of acceptability for a freshman course from the author's personal experience. The use of conceptual maps, National Instrument's simulator, and the emphasis on communications and teamwork seem to have been well accepted. The assessment at five levels of learning from None to Very Much for each of the seven Course Learning Objectives (CLOs) in the last two offerings show significant improvements, as shown in Tables II and III and Figure 1. Each student evaluates each CLO at one of five levels. The rows add up to the number of students.
These results are summarized in Figure 1 for comparison

Table II: Assessment of Qualitative Degrees of Achievement for CLOs for the Fall-2011 EENG1910 Learning to Learn – Project I Course Using the Student Survey Data

CLO	Achievement Level → 1	2	3	4	5	LOW 1-2	MEDIUM	HIGH 4-5	Overall Degree
1	1	2	3	10	9	3(12%)	3(12%)	19(76%)	H
2	0	2	2	11	10	2(8%)	2(8%)	21(84%)	H
3	0	2	3	8	12	2(8 %)	3 (12%)	[illegible]	H
4	1	3	4	4	13	4(16%)	4(16%)	[illegible]	M/H
5	1	4	7	7	6	5(20%)	7(28%)	13(52%)	M
6	1	3	12	4	5	4(16%)	12(48%)	9(36%)	M/H
7	0	4	9	12	0	4(16%)	9(36%)	12(48%)	M/H
Sum per level	4	20	40	66	45				

An informal anonymous senior year survey, serving as a horizontal evaluation, taken this year with eleven students who had taken the freshman course (transfer students are exempted) produced proportionate results within 10% of those in Table III and a number of positive unsolicited comments.

Table III: Assessment of Qualitative Degrees of Achievement for CLOs for the Spring-2011 EENG1910 Learning to Learn – Project I Course Using the Student Survey Data

CLO	Achievement Level → 1	2	3	4	5	LOW 1-2	MEDIUM	HIGH 4-5	Overall Degree
1	0	0	4	14	6	0(0%)	4(20%)	20(80%)	H
2	0	0	9	11	10	0(0%)	9(38%)	15(62%)	H
3	0	1	2	14	13	2(8.5%)	2 (8.5%)	20(83%)	H
4	0	0	6	12	6	1(4%)	5(21%)	18(75%)	H
5	0	0	6	14	4	5(21%)	6(25%)	13(54%)	M
6	0	0	7	12	5	3(12.5%)	6(25%)	15(62.5%)	M/H
7	0	1	4	13	6	4(16.5%)	3(12.5%)	17(71%)	M/H
Sum per level	0	2	41	94	55				

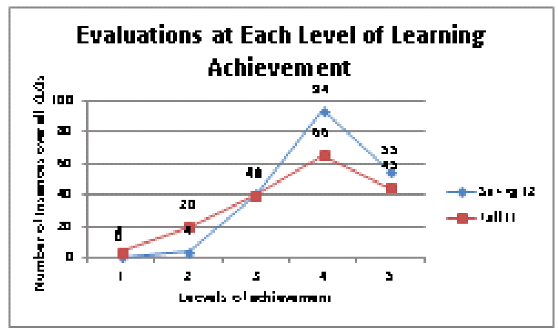

Figure 1. Sum of all the instances of each level of achievement for all CLOs for Fall 2011 and Spring 2012

There is noticeable improvement at the high levels of learning performance. The course will be transferred from Blackboard Vista to Blackboard Learn, which according to the software provider offers better functionality. This will be an opportunity to review the whole course. At the same time, we are considering using this blended approach in a distance education setup, provided that adequate networking facilities exist for team interaction and collaboration, involving software that facilitates distant work and information exchange. The presentations would be held over the Internet and with a webcam. While we have significant concerns using this modality, there is no question that it seems the wave of the future in education. It would require the purchase of the Radio Shack kit (~$45), the MultiSim National Instruments student version diskette (~$20,) and a webcam (~$20), not far from the cost of a hard-cover text. We plan on the first pilot for Spring 2013.

FINAL WORDS

Considerable time and effort have been dedicated to a cognitive-based ABET-oriented course that is at the same time highly motivational at the freshman level via project transition and help throughout the student's time in higher education. In particular, the project orientation is a strong motivational factor that encourages collaboration and self-confidence in learning new material as the joint responsibility of teacher and students as collaborators in a team.

General, University-wide evaluations conducted at the end of each semester rate this course at average or above average levels relative to all other courses but not below average, and more favorably yet when compared with most other STEM freshman level courses. Recent comments generally indicate a labor intensive but rewarding experience.

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