A Case Study of a College-Wide First Year Undergraduate Engineering Course

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Abstract—**A discipline-specific first year introductory course has been the norm in engineering education. Most of these courses are often theme-based and use engineering design as a device to emphasize the relationship between the various components of a field like Electrical and Computer Engineering. Online learning has also been incorporated in such common courses to enhance student experiences. As an alternative to a first year discipline-specific engineering course, there have been recent efforts to develop common first year engineering courses that target all engineering disciplines. One rationale for such a common courses has been an early instillation of common engineering education elements like ethical and social dimension of engineering design. A problem-based curriculum is often used in such first year introductory engineering courses to also ensure that students find relevance in the Physics and Math course being taken in the first two years of engineering. Students are also challenged to work on a design project in a multi-disciplinary team. A college wide engineering course allows students to learn about various engineering disciplines and wisely choose an engineering discipline.**

In this paper, we introduce the "Introduction to Engineering" freshman course offered to all students enrolled in the College of Engineering. The course consists of lectures, labs, recitation sessions, and a competition. Students are introduced to the major responsibilities of engineers, presentation skills, documentation, teamwork, problem solving, design process, ethics, and the basic concepts in each of the six engineering disciplines offered in the College. We evaluate the course outcomes by collecting and analyzing the student's feedback over 2 years. The results are very encouraging and reflect a positive learning experience. We share some of the challenging multidisciplinary project ideas offered to the students. We also discuss the topics covered in the course and the relationship of each topic to the ABET criteria.

Keywords- First Year Undergraduate Course; Engineering Design; Labs; Competition; ABET.

I. INTRODUCTION

A program-specific first year introductory course has been the norm in engineering education [1]. A classical example of this approach is a two course sequence that was offered to mechanical engineering students to design a Rube Goldberg machine [2]. Similar to this course, program-specific courses are often theme-based and use engineering design as a device to emphasize the relationship between the various components of a field like electrical and computer engineering [3]. Student experiences in such courses have also been enhanced using online-learning [4].

While first year discipline specific courses have been common in engineering education, there have been attempts to develop a common first year engineering course that targets all engineering programs as an alternative. One rationale for such a common course has been an early instillation of common engineering education elements including ethical and social dimension of engineering design [5].

A first year common engineering course often employs a problem-based curriculum to ensure that students find relevance in the Physics and Math courses being taken in the first two years of engineering [6]. For example, Ahlgren [7] describe a course that taught various engineering disciplines to freshmen. The course includes a common design project whereby students were asked to develop a fully mobile autonomous mobile robot. One key component of this course was mentorship of the team. Similarly, Troy el al. [8] describe a one hour course for all nine computing and engineering majors that exposes students to engineering principles through an open-ended design experience. In this course, students were required to build an HO-scale train model. Merrill et al. [9] describe a similar common two course sequence that asks freshmen students to design and build a toy roller-coaster.

One key challenge in designing a first year problem-based course is that students in the first year of engineering have little design experience. Consequently, reverse engineering has been proposed as one mechanism to address the lack of experience issue in these courses [10]. Ethnographic methods have also been used to study how students participate in such first year introductory courses [11]. A low-cost wireless platform to allow students from electrical, computer and mechanical engineering to develop their own design problems and solutions has also been explored in [12]. The impact of various alternative pedagogical devices such as analysis-driven textbook design projects, dissection projects and projects involving actual clients on the development of design process in such courses has been reported in [13]. An interdisciplinary form of such a design course that goes beyond engineering disciplines and involving first year engineering and second year graphic design students has also been successfully piloted in [14]. Finally, such common courses have been used to address gender disparity in new engineering disciplines with Mechatronics as an example [15].

What has emerged from these experiences with a first year common engineering course is the concept of a "cornerstone" engineering design course that is offered in the first year of engineering and emphasizes multidisciplinary teaming, engineering problem solving, project management, documentation, data collection and analysis, use of appropriate computer tools, communication and technical presentations [16]. In addition, these cornerstone courses also include a specific hands-on engineering component [17].

This paper presents a case study of a common first year undergraduate engineering course developed at the American University of Sharjah (AUS). AUS currently has six ABET-accredited undergraduate engineering programs. The "Introduction to Engineering and Computing" course, referred to as NGN110, was developed to explicitly satisfy ABET's (a-k) criteria [18] for engineering programs.

The rest of the paper is organized as follows. A detailed description of the course is presented next. This is followed by a description of how ABET criteria were used to design the course. This is followed by an evaluation of the course for three consecutive semesters. The paper ends with a conclusion.

II. Course Description

The "Introduction to Engineering & Computing" (NGN110) course is a 2-credit hour freshman course required for all students enrolled in the College of Engineering at AUS. The College of Engineering at AUS currently consists of six departments: Civil Engineering, Chemical Engineering, Computer Engineering, Computer Science, Electrical Engineering, and Mechanical Engineering. The class size for NGN110 is typically 400 and 300 students in the Fall and Spring term, respectively. The goal of the course is to help students:

- Develop an understanding of the major responsibilities of engineers and computer scientists.
- Learn the different ways engineers and computer scientists work and communicate with those in other professions
- Build a basic background in engineering problem solving, information gathering and time management
- Develop knowledge of the ethical responsibility of engineers and computer scientists in their profession.
- Foster an appreciation for the roles of engineers and computer scientists in modern society.
- Develop some background in computer science and the five engineering majors in the College of Engineering at AUS.
- Understand some basic concepts of laboratory experimentation, data interpretation, and laboratory report writing.

During the NGN110 course, students are expected to engage in the following activities: 1) attend common and recitation lectures, 2) attend various engineering laboratories and 3) work on a common engineering design project. Each of these components is described next.

A. *Common and Recitation Lectures*

Students enrolled in NGN 110 typically attend two lectures per week for a total of 15 weeks a semester. There is one 75-minutes common lecture and a 75-minutes recitation lecture each week. The common lecture is given in a main auditorium and is attended by all students. Eight out of the fourteen common lectures cover general engineering topics, including Team Work, Engineering Design, Problem Solving, Documentation, Oral Communication, Ethics, and Sketching. The remaining six common lectures cover the six Engineering programs being taught at AUS. The goal of the latter lectures is to provide the students with an idea of which engineering majors exist in the College of Engineering and to help them select a major that they like.

In addition, and in an attempt to allow for better faculty/student interaction, the students are split into smaller groups for recitation lectures. The recitation lecture is given in smaller classrooms with a maximum capacity of 35 students each. Each recitation instructor meets with the students every other week. The first recitation introduces the students to basic concepts in using spreadsheets for engineering calculations and reporting (MS Excel). During this recitation the students are asked to calculate statistical parameters including an average, median, mode, maximum and minimum. Students are also instructed to plot and find the slope and the regression parameter of a straight line. They are also stepped through the process of using the spread sheet application to calculate a function for several values of the independent variable.

The second recitation provides several examples of the ten steps involved in an engineering design process. These steps include: identification of the need, problem definition, literature search, indentifying the constraints in a process, enumerating the criteria for judging different designs, designing alternative options, analysis, making a decision, developing a list of the specification for the most efficient design, and communicating the result of these design steps to an audience [19, 20]. Each step in the engineering process is discussed in details and its importance is illustrated using everyday examples. Practical details are provided for each step. For example, when discussing the literature search step, the instructor introduces a variety of information sources available including, the library, the internet, professional societies, vendor catalogues, governmental documents, and individual experts etc.

In the third recitation, students acquire a hands-on experience with project management software (MS Project). They are instructed on how to produce a GANTT chart for a simple project. The program is then used to illustrate how the total duration of a project and the total costs are calculated using MS Project. As with the spreadsheet recitation discussed earlier, the project management recitation is conducted in a computer laboratory.

The fourth recitation outlines the problem solving process in the context of engineering design. The instructor starts by discussing the different types of problems which include research, social, knowledge, resource, and design problems [19, 20]. Students are subsequently introduced to the art and science aspects of problem solving. The instructor then asks students to form groups and discuss the solution of two simple engineering problems. For example, one problem may deal with concepts of statics and dynamics, while another with simple circuit design.

The fifth recitation discusses different ethical situations typically faced by a practicing engineer. Students share their opinion on typical ethical dilemmas they might encounter in their professional life. The cases discussed include, environmental awareness, copyright issues, professional integrity and seminar etiquette.

In the final recitation session, students present their design project findings (see description below) in front of their instructor and colleagues. Typically each group (4-5 students) is given ten minutes for a presentation and five minutes for questions. Each student is expected to present for approximately two minutes and is required to abide by the presentation guidelines introduced in previous lectures including the size of font, the number of slides, the number of lines per slide, maintaining eye contact, tone of voice, etc.

B. Laboratory Experiments

In addition to the common lectures and recitation sessions, students are required to conduct six laboratory experiments; one in each engineering program being taught at AUS. These laboratories are of paramount importance since students gain a practical experience in the different engineering disciplines, which in turn may help them decide on their prospective majors. For example, the Chemical Engineering laboratory introduces students to water treatment processes and how is it achieved using distillation columns, and heat exchangers. Table I shows the various laboratory experiments for each engineering program.

TABLE I. TOPICS COVERED IN EACH LABORATORY

Discipline	Laboratory Experiment
Chemical Engineering	Water Treatment
Computer Science	Creating Platform Games
Computer Engineering	Autonomous Mobile Robot System; FPGA Based Electric Train Collision Control System; Remote Monitoring and Control of Home Appliances
Civil Engineering	Compressive Stress of Hardened Concrete
Electrical Engineering	Patient monitoring system through internet; Automatic Assembly and Sorting in Factory Production Line
Mechanical Engineering	CNC Milling Machine

Several aspects of these laboratory experiments are worth mentioning in this context. First, the students are given the opportunity to function in multi-disciplinary teams. Each group typically includes students from 3-4 different engineering programs to simulate a real engineering experience. Note that the majority of freshman students are initially admitted to their intended majors; however, a small number of students are admitted as undeclared majors. Second, the laboratory reports ensure that students are exposed to the proper documentation of engineering projects. Finally, as with all laboratory experiments, students get a chance to formulate and solve engineering problems in a controlled setting.

C. Common Design Project

All students are assigned the same design problem as a course project. Students are expected to work on the team project for at least 8 weeks. Table II shows the projects that were assigned for three consecutive semesters starting in Spring 2008. Students are required to submit a progress report, final report, and present their findings in a 15-minute group presentation on their design project. A design competition is organized at the end of the semester to motivate student performance. Participation in this design competition is mandatory. The winners of the contest receive cash prizes and certificates. The competition is conducted in a public university space and the university community at large is invited to attend the competition.

The following factors are typically considered when selecting a project idea for each semester.

Project material: The materials required for the projects must be readily available and cheap. As shown in Table II, the materials used in each projects include paper, Q-tips, glue, etc are readily available.

Project construction: The project should not require any specialized tools, instruments, or lab space. It is logistically difficult to assign projects that require special tools for design and assembly because of the large number of students enrolled in the course. Therefore, as Table II shows, none of the projects require any specialized tools.

Science and math background: A successful execution of the project should not require a background in math and physics beyond a high school education. Again, this is evident in the choice of projects as depicted in Table II.

Students are expected to follow the 10-steps design process to execute their common design projects as outlined earlier. The first step in the design process is to conduct a literature review to understand the basic principles involved in the assigned project. For example, for the paper and Q-tips project, students reviewed the basic principles of bridge design and construction. The key engineering insight for the bridge design was the need to use a “truss” composed of triangles.

TABLE II: DETAILS OF THE PROJECTS ASSIGNED TO NGN110 STUDENTS

Term	Project title	Project criteria	Project constraints
Spring 2009	Paper bridge	Carried load/bridge weight is as high as possible	- Material: papers, tape and staples - The carried load must be at least 6” above the bottom of the bridge. - The bridge can’t be taped or attached to the ground.
Fall 2009	Q-tips bridge	Carried load/bridge weight is as high as possible	- Material: Q-tips and glue. - Q-tips cannot be bundled together. - The maximum bridge weight should not exceed 120 grams. - The carried load must be at least 10” above the bottom of the bridge.
Spring 2010	Paper airplane	The airplane fly time is as long as possible	- Material: papers and glue - The airplane weight should be at least 15 g. - The airplane should fly at least 6 seconds.

Figures 1 and 2 show some examples of the paper and Q-tips bridges constructed by the students. Similarly, during the literature review process for the paper airplane project, students learned about basics of aerodynamics. One novel airplane design incorporating these principles is shown in Figure 3.

Finally, as per the design process, the students were also required to develop design criteria and compare at least three different designs alternatives based on these criteria and then select the best design. A sample of the criteria developed by students to compare the various design alternatives in the Q-tips bridge project is shown in Figure 4. The students then score each design alternative against the various design criteria like appearance, reliability etc. Finally, at the end of course, the students are required to submit a technical report and deliver a technical presentation summarizing their main findings.

Figure 1. Samples of the paper bridge project.

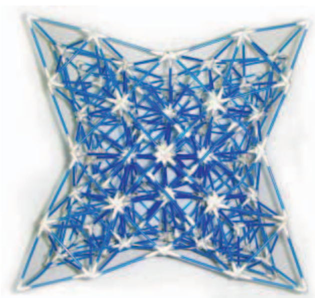

Figure 2. Samples of the Q-tips bridge project.

Figure 3. Samples of the paper plane project.

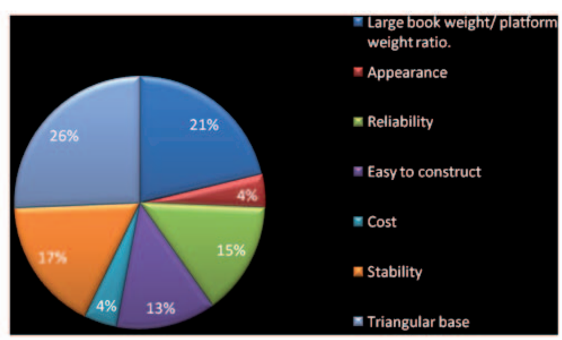

Figure 4: Sample of the student developed criteria for the Q-tip bridge.

III. Relationship to ABET Criteria

One key consideration in the design of the NGN110 course was the extent to which the course addressed the program outcome criteria outlined by ABET. ABET is an engineering accreditation commission that accredits engineering programs in the United States and abroad. Criteria 3 of the ABET accreditation process deals with program outcomes [18]. Each program seeking accreditation is assessed against criteria known as ABET's (a-k) criteria.

Table III shows the (a-k) ABET criteria for a program and how each criterion can potentially be satisfied by each element of the course developed at AUS. For example, Table III shows that working on the design project should contribute to ABET criteria (a), (c), (d), (f), (g), (i) and (k). The shape of circles in Table III shows the strength of relationship between the ABET criteria and the degree to which it is addressed by a course element. Filled circles, half circles, and blank circles represent strong, medium, and weak relationships, respectively. For example, as Table III shows, the recitation on Engineering Ethics is only expected to contribute towards a student's understanding of ethical issues in engineering (partially covering ABET criterion (f)). The absence of a circle indicates that no obvious contribution is expected.

IV. Evaluation

In order to evaluate if the course met its objectives, a student survey was designed and deployed over 3 semesters. The students were asked 10 questions related to how much they learned from the NGN110 course. Each question corresponded to one of the considered ABET criterions: (a) and (c-k). As shown in Table III, ABET criterion (b) was not considered since freshman students don't typically have the adequate background to engage in designing experiments.

The survey results over the 3 semesters were similar and indicated that the students agree that the 10 ABET criterions are met in this course. Specifically, the design project allowed the students to utilize their knowledge in mathematics, science, and engineering to solve engineering problems. It also helped them work in multidisciplinary teams and communicate effectively. The departmental laboratories allowed the students to solve engineering problems and to learn tools across different engineering disciplines. The departmental lectures introduced the students to contemporary issues in each Engineering program and made the students realize the need to engage in life-long learning to learn about programs other than theirs. The students also got an idea of the various Engineering majors at AUS and that helped them select a major that they like. The main lectures and recitations helped the students learn how to design a system, component, or process to meet desired needs. It also helped them understand the professional and ethical responsibilities of engineers. Overall, the results were very encouraging and reflected a positive learning experience.

V. Conclusion

This paper presented the design, implementation and evaluation of a common first year engineering course that uses everyday materials as the basis of a design project where the students are forced to follow a strict engineering design methodology. The course has been designed to explicitly address the various ABET program criteria. An evaluation of the course over three semesters suggests that first year students are able to negotiate the design process and problems quite successful and in addition their perception of which elements of the course contribute most to each ABET element is generally in agreement with the course design.

The experience we gained from running this course for three semesters suggests that with appropriately chosen design problems and a combination of program-specific laboratories and lectures combined with common lectures on topics of engineering design can begin to introduce engineering students to all the major elements of ABET criteria from the first year.

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TABLE III. MAPPING ABET CRITERIA TO VARIOUS COMPONENTS OF THE COURSE

	Course Elements / ABET criteria	(a) an ability to apply knowledge of mathematics, science, and engineering	(b) an ability to design and conduct experiments, as well as to analyze and interpret data	(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	(d) an ability to function on multidisciplinary teams	(e) an ability to identify, formulate, and solve engineering problems	(f) an understanding of professional and ethical responsibility	(g) an ability to communicate effectively	(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	(i) a recognition of the need for, and an ability to engage in life-long learning	(j) a knowledge of contemporary issues	(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
	Departmental Lectures								○	○	○	
	Departmental Labs				●	○		◑				◑
	Design Project	◑		●	●	●	○	●		◑		◑
Main Lecture Topics	What is Engineering?									○	○	
	Team Concepts				◑							
	Design Process			◑								
	Documentation						○	◑				
	Oral Presentations						○	◑				
	Engineering Ethics						◑					
	Sketching							◑				○
Recitation Topics	MS Excel							○				◑
	MS Project			○				○				◑
	Problem Solving					○						
	Design Process			◑								
	Engineering Ethics						◑					

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