INTEGRATION OF PROJECT BASED LEARNING INTO A FRESHMAN ENGINEERING DESIGN COURSE

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Abstract

Engineering Design and Graphics 100 (ED&G 100) is a project-based introduction to engineering design course for all freshman baccalaureate engineering students at the Altoona College of the Pennsylvania State University. In this three credit-hour course, an engineering approach to problem solving is taught with an emphasis on team work, communication (graphical, oral, and written), creativity, ingenuity, and computer-aided design tools. The instructional approach used in this course involves freshman engineering students as active participants in the learning process. Several inter-related but separate mini-projects have been developed in support of the design component of ED&G 100. These mini-projects are designed to introduce students to the basic concepts of electrical and electro-mechanical engineering. In addition to the mini-projects, there are several team presentations, lectures, exercises, and case studies presented throughout the semester.

This paper provides a complete description of the project-based design-driven learning process used in the design component of ED&G 100 course. This paper also describes students' comments regarding the quality of instruction delivered in support of the design component of ED&G 100.

Introduction

Engineering design is defined as the communication of a set of rational decisions obtained with creative problem solving for achieving certain stated objectives within prescribed constraints[1]. The role of design in an engineering curriculum is a key issue to the success of the program and its graduates[2]. A wide variety of pedagogical approaches used to teach engineering design have been reported by Wood et.al.[3]. However, in recent years, the engineering education community has been increasingly interested in project-based learning approach. The use of engineering design projects provides students with a broad context related to the material presented in the classroom lectures[4]. Through project based learning, students are encouraged to assume responsibility for their learning experience and to shift from passive to active learning style. Several studies have been conducted to demonstrate that active learning approach can enhance the cognitive skills of students more readily than traditional lecture-based approaches[5].

Engineering Design and Graphics 100 (ED&G 100) is an introduction to engineering design course for all freshman baccalaureate engineering students at the Altoona College of the

Pennsylvania State University. Upon completion of this three credit-hour course, students should be able to:

- Use computer software packages to assist and document the design procedure
- Communicate effectively through oral and written presentations
- Demonstrate basic lab work skills such as data collection, report writing, and teamwork
- Carry out the design process from problem statement to final design

ED&G 100 consists of three components with each component meeting for a single two-hour period once every week. This gives a total class meeting time of six hours per week for fifteen weeks. The first component of ED&G 100 introduces students to computer application skills using CAD. It also develops student design competencies in the topical area of communication. Topics covered include internet navigation, website design, word processing, MS Power Point presentations, and computer aided design and drafting using AutoCAD.

The second component of the course deals with manual graphic and drafting skills. Students are introduced to the fundamentals of orthographic projection. The topics covered include multi-view projection, dimensioning, lettering, oblique and isometric projection, sectional views, tolerances, scales, and selected topics in descriptive geometry.

The third component of ED&G 100 focuses on team-based engineering design projects. Working together in teams, students work on design projects selected from various disciplines of engineering. This component of the course introduces students to principles of engineering design practice while developing design competencies in problem definition, idea generation, evaluation and decision making, implementation of teamwork, and process improvement.This paper focuses on the engineering design component of ED&G 100.

Pedagogical Framework of ED&G 100

Several mini-projects have been developed to support the objectives of the design component of ED&G 100. These mini-projects have been designed to introduce students to basic concepts of electrical and electro-mechanical engineering. Successful completion of these mini-projects gives students the necessary background to carry out a final design project. In addition to the mini-projects and a final design project, there are several presentations, lectures, group discussions, and case studies presented throughout the semester. During the first week of the semester, a discussion of the undergraduate engineering curriculum of the Pennsylvania State University is conducted. This discussion provides an overview of the various engineering disciplines, typical job assignments for engineers, and salary survey information.

During week 2 of the semester, student design teams are formed and a team-building exercise is performed. This exercise consists of a competition among design teams. The design competition requires teams to build the tallest tower in a limited amount of time using limited quantities of spaghetti and marshmallows. Following this competition, the design teams are asked to reflect on their performance by participating in a classroom discussion. It has been observed by the authors of this paper that, generally, the most successful teams are the ones who first discuss an action plan and then carry it out with effective teamwork. This is the most important point which is

emphasized during the classroom discussion following the above-mentioned team-building exercise. During the second week, students are also provided with a handout titled "How to Write a Technical Document". To develop adequate practice in writing a technical document, students are asked to write a paper on the topic "How to Make a Peanut Butter and Jelly Sandwich". The key objective of this exercise is to allow students effectively develop a technical document. Feedback from this document written by students helps the course instructor develop expectations for the content and the structure of the technical documents that are required for the subsequent mini-projects.

During week 3 of the semester, a lecture on descriptive statistics is presented to the class. The topical coverage of this lecture includes description of mean, standard deviation, linear regression, significant figures, and measurement techniques. Following this lecture, all the teams begin working on a mini-project which allows them to examine resistivity and Ohm's law. The mini-project requires the application of measurement techniques for voltage, current, radius, and length. Specifically, the teams form cylinders of various lengths and radii from Play-Doh to determine the resistivity of the material. Calipers are used to measure the geometric mean radius of the cylinder and multimeters are used to determine the voltage and the current flow in the simple DC circuit built by each team. This mini-project allows students to practice their knowledge regarding measurement techniques and to apply descriptive statistics (mean, standard deviation, and linear regression) to determine the resistivity of Play-Doh. In addition, students are introduced to Ohm's law of DC circuits. The knowledge of Ohm's law is useful for carrying out subsequent mini-projects.

During week 4, the course focuses on the art of making technical oral presentations. A lecture focusing on effective oral presentation techniques is presented and a model oral presentation is made to the ED&G 100 students to demonstrate the effectiveness of the techniques discussed in the class. Items emphasized in the discussion include:

- the use of an "attention-getting" introduction (an example of a poor introduction is compared with an exciting attention-getting introduction
- the reasons why should the audience be interested in the oral presentation
- mapping the presentation, that is, informing the audience where the presentation is going
- making smooth transitions between major points
- conclusion
- visual aids
- delivery of the presentation

It should be noted that prior to the discussion of technical oral presentations, students have already been introduced to the use of Powerpoint in the computer application skills component of ED&G 100. To apply the oral presentation skills discussed in class and the use of Powerpoint, all the student teams are asked to prepare a 20-minute oral presentation on "How Things Work". Students are informed that the team presentations are to be made during week 6 of the semester and that the teams may choose something of interest to them to be presented to the class.

During week 5 of the semester, engineering design and optimization techniques are discussed. Several case studies are presented to emphasize the trade-offs that engineers inevitably

encounter. Since the ED&G 100 students have already learned the use of Excel in the computer skills component of ED&G 100, they are asked to use Excel to design a resistor of fixed value minimizing the cost function.

During the 7th week, discussion in the class focuses on power and energy in electrical systems. This class discussion makes use of a AAA battery specification sheet to help demonstrate these concepts. This information sets the stage for an associated lab activity which allows students measure the parameters of a battery (internal voltage and internal resistance) to model the operation of a battery. A flashlight bulb is given to every team so that the team members may characterize the voltage versus current characteristics of the bulb. Using the bulb characteristics, students can determine the power needed by the bulb at various voltage levels and the total energy dissipated by the bulb over time.

Based on the data obtained during the week 7 lab activity, the ED&G 100 student teams are assigned another mini-project during week 8 of the semester. This mini-project involves designing a flashlight. Each team has to decide if two batteries should be connected together or used separately in order to produce ample light for and adequate amount of time to allow the team members safely exit a cave. Teams make use of the battery specifications, bulb data, and battery model to justify their design proposals. All the teams are required to build the flashlights to see how well their performance predictions compare with the measured data.

During week 9, the concepts of mechanical torque and power in rotating systems are presented to the students. This presentation covers dc motor and its electrical model. It is emphasized during the presentation that the application of Ohm's law to the dc motor model allows the prediction of performance parameters such as speed and torque. In addition, the concept of mechanical advantage is discussed with a focus on gear and pulley systems for rotating machines.

The final design project for ED&G 100 course is presented to the class during week 10 of the semester. The design challenge for each team is to design a soda can lifter using dc motors, a gear box, and two AAA batteries. The key objective of this design project is to design and build a device which is capable of lifting as many soda cans as possible to a height of 1 meter within a given time constraint. Bonus points are awarded to the teams who can automate the loading and unloading of cans from the lift. This design project allows students to apply many of the previously learned concepts in an interesting and competitive forum because a design competition is held during the last week of this course. The design project pulls together many previously discussed concepts. These concepts include:

- Ohm's law
- power and energy capacity of batteries to calculate available energy for the system
- dc motors and gear boxes
- trade-offs and optimization

During the final five weeks (week 11-15), ED&G 100 class meeting generally consists of a 45-minute discussion followed by one hour of open lab time for students to work on the final design project. The class discussions during the final five weeks provide an adequate coverage of topics such as ethics in engineering, ergonomics, and intellectual property.

Students' Comments

During Spring 2003 semester, a questionnaire was administered to ED&G 100 students at the Altoona College of Penn State University. The objective of the questionnaire was to obtain students' comments regarding the quality of instruction delivered by the course instructor in support of the design component of ED&G 100. The questionnaire consisted of three subjective items:

1. What did you like best about the course?
2. What did you like least about the course?
3. What suggestions do you have for improving the course?

Summarizing students' comments regarding the instructional approach used to teach ED&G 100 course during Spring 2003, it appears that they liked the hands-on mini-projects conducted by them. Students also liked conducting the final design project. Most of the students indicated that there was nothing that they did not like about the course. Most of the suggestions for the improvement of ED&G 100 were related to the technical specifications for the final design project. Another important suggestion was to provide students with a more rugged gearbox for implementing the final design project.

Conclusion

Engineering Design and Graphics 100 (ED&G 100) is a project-based introduction to engineering design course for all freshman baccalaureate engineering students at the Altoona College of the Pennsylvania State University. Several mini-projects have been developed to teach the design component of this course. The mini-projects have been designed to introduce students to the basic concepts of electrical and electro-mechanical engineering. Completion of a team-based design project is an essential requirement. The paper presented a detailed description of the design component of ED&G 100 course. The paper also provided a description of students' comments regarding the quality of instruction delivered in support of the design component of ED&G 100.

During Spring 2004, the project-based instructional approach will continue. However, the focus of most of the mini-projects will be digital electronics. Topical areas to be taught in digital electronics include combinational logic circuits, minimization of logic functions, and digital system design.

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Biography

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Sohail Anwar holds a Ph.D. degree in Industrial and Vocational Education from the Pennsylvania State University and a M.S. degree in Electrical Engineering from the University of Texas at Arlington. He completed additional graduate coursework in control theory and applied mathematical sciences at the University of Texas at Arlington. He is currently serving as an associate professor of Engineering and the program coordinator of Electrical Engineering Technology at The Pennsylvania State University, Altoona College. Since 1996, he has also served as an invited professor of Electrical Engineering at IUT Bethune, France.