Teaching Engineering Design to First Year Engineering Students:
A Case Study

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Introduction

Engineering design is the communication of a set of rational decisions obtained with
creative problem solving for achieving certain stated objectives within prescribed
constraints. Engineering design is a systematic and cognitive process. The methods
faculty choose to teach engineering design relate to the skills and competencies they want
their students to develop. Design competencies help one define educational outcomes,
develop plans for achieving integrated design experience, and document educational
program success. Categories of design competencies include: information gathering,
problem definition, idea generation, evaluation and decision making, implementation,
communication, teamwork, and process improvement.

Engineering faculty tend to use at least one of four approaches to teach engineering
design: lecture, faculty as guide or coach, case study, and industry involvement. The
faculty at the Altoona College of the Pennsylvania State University (Penn State Altoona)
uses lecture method as the primary vehicle to teach engineering design process to the
engineering freshmen.

Engineering Design and Graphics (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. In this three credit-hour course, engineering design and
principles are taught through team-oriented design projects supported by communication
skills: graphical and written. The course has three components with fifteen double
periods (two hours each) for each segment of the course. The first component of the
course introduces students to computer application skills including CAD. The second
component deals with manual graphic and drafting skills. The third component focuses
on team-based engineering design projects. Working together in teams, students work on
design projects selected from various disciplines of engineering. This paper provides a
description of the topics covered in each of the three components of this course. The
instructional approaches used to teach this course are described and the engineering
design projects conducted by the students are outlined.

Students normally take the course in their first or second semester. The class meets for
three double periods per week for a total of 6 hours. The class is divided up into three
groups during the first meeting. For example a student may attend computer skills on
Monday, graphical skills on Wednesday and Design laboratory on Friday. Three faculty
members teach the three components during the same time frame with students attending
each component of the course once a week. Each component of the course is weighted equally in the final grade calculation.

It is also the intent of this course to increase the student interest in the field of engineering with hope of reducing the transfer rate of students who leave the engineering major. Moreover, this course is one of only three engineering courses that students take during their first two years at Penn State. The majority of the course load for students during the first two years of any engineering program consists of math, physics, chemistry, English, arts, social sciences, and humanities. This situation does not give students much of a chance to experience what engineering is really all about before they have to make a decision about what specific engineering major they wish to pursue.

Computer Skills Component of ED&G 100

The computer skills portion of the course introduces students to personal computers and their usage. It also develops the students design competencies in the communication area. The lecture method most closely describes the teaching technique employed for this area of the course. No formal textbook is required for this portion of the course. The instructor provides students copies of his own prepared class notes. The class is taught in a multimedia classroom with 24 IBM personal computers networked together to a campus server. The monitors are 19” high-resolution monitors. The first topic covered is email. The students are each given an email account in web mail and are shown how to send and retrieve email massages. This skill will be vital to their success at the university as many faculty use email extensively to communicate to their students. Students are sometimes also expected to hand in homework via email. Students are shown how to navigate the Internet and how to find information on the Internet with the use of a search engine. This activity also develops the student’s design competencies in information gathering. Website design is also covered using Front Page 2000. Students are expected to put their completed WebPages on the Internet. Word processing using MS Word is explained to the students with homework including a brief paper being written in MS Word. Students also use this communication skill in writing proposals and business letters for the engineering design portion of the course. Databases are taught using MS Excel software. Students are expected to be able to manipulate and graph data at the completion of this topic and are asked to make simple histograms as part of an assignment for the engineering design portion of the course. MS PowerPoint presentations are also covered with students creating a short PowerPoint presentation. PowerPoint presentations are also sometimes required in the engineering design portion of the course. Lastly, computer aided design and drafting is introduced for six double periods of instruction using the CAD software package AutoCAD. Students are expected to complete in-class CAD quizzes and are able to make simple multi-view projection drawings with dimensions. Students are sometimes expected to make simple CAD drawings of their design projects for the design portion of the course. In future offering of the course the coverage of solid modeling using a package such as Pro-Engineering is being considered.
Graphical Skills Component of ED&G 100

The graphical skill portion of the course introduces students to the fundamentals of orthographic projection. The lecture method is used for this area of the course and students develop design competencies in communication. The topics covered include: multi-view projection, dimensioning, lettering, oblique, isometrics, sectional views, tolerances, scales, and selected topics in descriptive geometry. Students are expected to make drawings using drafting instruments and velum paper. Drafting boards are provided in the classroom. Sketching skills are emphasized throughout the course. Homework on each topic is collected along with in-class quizzes. Manual instrument drawings of design projects are sometimes required for the design portion of the course. A graphics textbook and drafting instrument kit are required for the course. We realize that many schools do not teach manual drafting skills. However it is our opinion that the fundamentals of orthographic projection can be best taught using manual techniques. The skill of manual sketching cannot be underestimated. Many of our campus industrial advisory board members still feel a strong need for engineering graduates to be able to make quick hand sketches of machine parts while on the plant floor without the aide of a CAD machine.

Engineering Design Laboratory Component of ED&G 100

The engineering design portion 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 teamwork and process improvement. The teaching techniques employed in this portion of the course are the lecture method and the faculty as a guide or coach method. No formal textbook is required for this portion of the course although several articles related to engineering design and manufacturing are handed out in class. The articles give students information regarding all the steps involved in the design process and the factors that must be considered when designing a product. Students are also given instruction in measurement techniques using micrometers, vernier calipers, dial calipers, thread gauges, feeler gauges, analog and digital multimeters.

The first task given to ED&G 100 students is to develop a new product or material or improve an existing product. Examples are given in class of past patented ideas and how some companies have increased their markets simply by just making variations of their existing product line. The students are asked to present their ideas in the form of a proposal using MS Word. The proposal is graded for market feasibility and grammar. Once approved by the faculty, the students are required to perform an Internet search for a company that may be interested in their product idea and write a formal business letter introducing their idea to that company. It is the intent of the letter to receive feedback on their design idea from a company representative such as an engineer. Approximately twenty percent of the students receive correspondence from industry. Several students have even received personal letters from a product development engineers outlining their thoughts on the students’ design ideas. You can see the student’s excitement when they share their letter from industry with the rest of their classmates. We feel this may
motivate some students to remain in the engineering major. It is also hoped that this activity is a way to use industry involvement as a teaching technique for engineering design.

In keeping with the design and manufacturing theme, ED&G 100 students are also exposed to the business side of engineering through a lecture given by Asst. Prof. Thomas Boyle of Business Administration on the topic of company start ups and the principles of entrepreneurship. The Penn State Altoona campus has an entrepreneurship minor for engineering students.

Fundamentals of statistics are also covered with students generating a simulated manufacturing sample by measuring the resistance of groups of resistors, the diameters of groups of bullets or air gun BBs. The mean, mode, median, root mean square, and standard deviation of the sample are calculated. A histogram graph is made using MS Excel. The histogram shows the students the variations that occur in the manufacturing environment. The fundamentals of statistical quality control are also explained to the students with X bar and R range charts being made for the statistical sample.

Another activity designed to show students how products are made and demonstrate the principles of reverse engineering is called Dismantle and Discovery. In this activity the students are required to disassemble everyday items to their most basic parts using simple hand tools. The items used for this activity have included two stroke chain saw engines, four stroke lawn mower engines, electric drills, VCR’s, record players, personal CD players, toasters, toys of all types, electric motors, telephones, keyboards, stereos, speakers, radios, etc. After disassembling the items, the students are required to explain the operation to the rest of their classmates. The students have received this activity with great enthusiasm. It is hoped that this activity will give engineering students more hands-on activities while developing their practical skills with hands tools and an appreciation of assembly techniques used in industry.

Another group activity that the students enjoy, and it helps develop their spatial skills is Spaghetti and Gumdrop Tower construction. In this activity the students are required to work together in groups of three and construct a space structure tower using spaghetti and gumdrops. The minimum height of the tower must be five feet high and be completed in fifty minutes. This task requires the students to come up with a structural design that is sound, as most towers will begin to collapse near the bottom of the structure when the three-foot height is reached. Student design competency in teamwork and implementation is stressed in this activity.

The capstone group design projects require groups of students to work together in teams of three or four to complete the required design project. These projects have included the construction of a raft that floats a minimum payload of two hundred pounds and being constructed using 1” by 2” boards, plastic two liter beverage bottles, duct tape, and rope. The students have used a handsaw and electric drill to build the raft. The design criterion given was to build the smallest raft, using the least number of bottles. The students were given an explanation of the principle of buoyancy. The rafts were raced in the campus
swimming pool on the last day of classes by the student teams. Each member of the team was required to paddle a leg of the race in the swimming pool. The students were also required to wear street clothes during the race. The race was televised on the local television station. A side note was that approximately 50% of the rafts did not float or were unstable and flipped over during the race. The activity was very well received by ED&G 100 students. This activity stressed design competency in problem definition, idea generation, implementation and teamwork.

A second group design project was to construct a model rocket that would carry the heaviest payload to the greatest possible evaluation. The rockets used were solid propellant model rockets available in most hobby shops. The students were given literature on the principles of rocket propulsion and equations that predict rocket trajectory. All rockets given to the students were identical in shape and motor size. The students had to devise a method to carry a payload of steel shot. The center of gravity of the rocket when loaded had to be considered along with payload weight. The activity was well received and most rockets were successful in leaving the launch pad and achieving some height. Another variation of this group activity was to design a model rocket car that was required to complete a thirty-five yard race across a campus tennis court. The same dry propellant rocket engine was employed for propulsion. The car could take any shape provided it would fit inside a one by two foot rectangle. This activity was well received by the students. However, the success rate of cars completing the course of thirty-five yards was very low. This activity helped increase design skills in problem definition, idea generation, implementation and teamwork.

A third group design project that was successful was to develop the necessary circuitry to control a mock industrial manufacturing conveyer system. In this exercise the students were given instruction in digital logic gate theory and operation. They were asked to create a truth table for the process and develop the switching equation from the truth table. They were then required to simplify the switching equation using the Karnaugh Map Method. Lastly they were asked to make logic and IC CHIP diagrams. Using appropriate hardware the student groups built and tested their IC CHIP diagrams. The students also completed a report summarizing their results. This activity made use of several design competencies including problem definition, idea generation, evaluation and decision-making, communication and teamwork.

A fourth group design activity that was very well received was the construction of a full size pumpkin launcher. This activity gave student groups the design freedom to use any launch method they could build for a minimal cost. This allowed for great variation in design with some launchers using leaf springs from automobiles and being quite large. Other designs used coil springs, weights and were compact. Some designs were much more successful than other with the winner throwing a pumpkin over one hundred feet. This activity employed many design skills such as problem definition, idea generation, evaluation and decision-making, and teamwork.

All design projects required students to summarize their design in a short report that included a CAD drawing in a MS Word document.
Conclusion

This paper describes an introductory engineering design course (ED&G 100) taken by all the engineering freshmen at the Altoona College of the Pennsylvania State University. There are three components of this three credit-hour course: computer skills, graphical skills, and team-based engineering design projects. The paper provides a complete description of the topics covered in each of the three components of ED&G 100 course. The engineering design projects conducted by students are also outlined. The faculty at the Altoona College primarily uses lecture method to teach this engineering design course. However, the future offerings of this course will increasingly make use of case studies and industry involvement to complement the lecture approach.

Bibliography


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