

# A HANDS-ON APPROACH TO TEACHING FRESHMEN DESIGN

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2002 North Midwest Section Annual Conference of the  
American Society for Engineering Education  
Technology-Enhanced Learning  
October 10-12, 2002, Madison, Wisconsin

## **Abstract**

The structure of a freshmen engineering design course is presented. The course represents a well-balanced blend of lectures, laboratories, and practical design work, as well as factory tours and field trips and other contacts with practicing engineers. It deals with the fundamental categories of engineering design process, basics of engineering graphics and design, rules and standards of technical communication, CAD-enhanced technical documentation, interdisciplinary design projects and an introduction to solid modeling. The overall objective of the course is to help students understand the peculiarities of the modern design methodologies as well as the importance of concepts such as “on time”, “on budget” and “competitive” product development from ideation to prototype testing and refinement. Various components of the course are discussed. In particular, the hands-on context of the course is emphasized including real life engineering projects.

## **Introduction**

The author taught a freshmen design course entitled *Engineering Graphics and Design* at Indiana Institute of Technology, Fort Wayne, Indiana. In the process, he also further developed some of the categories within the course. This course was intended for all freshmen students planning to pursue an engineering major. It was offered twice a year, and one half of the entering engineering class would take it in the fall and the other in the spring semester. Some of the major characteristics of the course include its emphasis on providing the incoming students with explanations of what engineers do, how engineers communicate among themselves and with other technical and non-technical personnel, as well as introducing them to the specific requirements of team work on real-life engineering projects. It introduced quite a complete view of the various aspects of an engineering career. Modern engineering practices were presented in a systematic way to give the students a fairly clear picture of what to expect upon graduation. As such the course provided invaluable help to all engineering freshmen and in particular to those students who at the time when they entered college were not sure what area of engineering was their top career choice. It also presented the students with adequate engineering challenge at this stage, which for most of them was their first contact with real engineering. Most among the students had very positive feedback on the course in the form of end-of-semester course evaluations and exit interviews.

## **Structure of *Engineering Graphics and Design***

The course consisted the following parts.

- Introduction to Engineering Profession
- Introduction to Engineering Design Process
- Engineering Graphics and Communications
- Use of AutoCAD LT software
- Individual Project
- Interdisciplinary Team Project
- Group Semester Project
- Introduction to Solid Modeling using Pro/ENGINEER CAD software system
- Factory Tours and Field Trips

Brief descriptions of these categories are given next.

Introduction to Engineering Profession. Since the course was intended for all engineering majors, every effort was made in order to discuss topics of interest to various engineering professions rather than some specific ones. At the beginning of each semester several guest speakers were invited to meet with the students and talk to them about their areas of expertise. The engineering department chairs were regularly invited to these sessions. The students appreciated and enjoyed this opportunity to speak with engineers in their areas of interest. The topics of these conversations included the speaker's experience as a practicing engineer, the current situation in the field as well as the anticipated areas holding the most promise for growth.

Introduction to Engineering Design Process. Topics such as traditional, or segmented, design process as opposed to the modern, concurrent design are discussed. The students are prepared to execute a complete design cycle following the concurrent design methodology.

Engineering Graphics and Communications. The following topics are discussed: Sketching, Orthographic Projection, Section views, Dimensioning, Tolerancing, Geometric Dimensioning and Tolerancing (GDT), and Engineering Presentations. Numerous practical examples are presented. The students are required to complete a significant number of assignments in these areas.

Use of AutoCAD LT software. The students are introduced to the basic techniques of generating engineering drawings using the AutoCAD LT software package. Having on mind that all mechanical engineering majors were planned to take a course in computer aided design in their senior year when they would learn the Pro/ENGINEER software the use of AutoCAD Light was deemed adequate at this point. The fundamental techniques of creating and editing multiview drawings are covered. The following topics are covered.

- Setting Up the Drawing Area, including line types and layers, absolute and relative coordinates
- Creating and Editing Drawings at Full Scale, including straight lines, parallel and perpendicular lines, circles, radii, polygons, Trim and Extend techniques.
- Dimensioning Drawings, including Linear, Radial, and Angular dimensions
- Adding Annotation to a Drawing,
- Plotting a Drawing.

The students are also expected to complete on their own several online tutorials. The final drawings from these exercises are collected and graded. Homework assignments related to this portion of the course include drawing favorite objects like, for example, computers, cars, airplanes, backpacks, radios, etc. Multiview drawing with AutoCAD LT of assigned objects are also required. An individual project (see below) is assigned as a means for the final assessment of a student's proficiency in this software.

Figures 1 and 2 show two examples of the use of AutoCAD LT by the students in this course.

Individual Project. Each student is expected to submit a complete engineering drawing of an object of significant complexity in his or her area of engineering. First, the students are required to submit three proposals for their projects. Their suggestions are then reviewed by the instructor who selects one among the suggestions, as is, or with modifications, to assure the uniform level of difficulty of all the projects. The drawing should consist of all the necessary views, including section views, and they need to provide the necessary dimensioning and annotation. As is the case with all the assignments in the course, a firm deadline is given for the completion of the project.

Figures 3 and 4 represent two examples of the individual projects completed by the students in this course.

Interdisciplinary Team Project. The main idea of this exercise is to expose freshmen engineering students to a real-world-like engineering environment and provide them with an opportunity to apply the methodologies of modern design process. In particular, the concurrent engineering approach is stressed and applied. The objective of the project is for the students to learn working in a design team environment within which they design, build, test, and refine the product satisfying the budget constraints of the project. Working in interdisciplinary teams the students are expected to develop a product that meets a given set of performance requirements. At its various stages the project must meet several firm deadlines and remain within a predetermined budget. In addition to delivering a working prototype the teams are required to also generate a complete set of the necessary technical documentation. The student design teams are composed of three to four students pursuing various majors and are determined by the instructor and the goal is to have students majoring in different areas of engineering sit together and work effectively as a team. Important engineering concepts, which help tie

together theoretical and practical components of the engineering design process, are introduced and applied.

The projects included the following products, one per semester.

- A transportation vehicle capable of transporting a person over a given range and using a given energy supply
- A battery powered hovercraft capable of carrying a specified payload over a distance
- A mousetrap spring powered vehicle capable of transporting a specified load.

A copy of the complete project proposal for building a hovercraft is given in Appendix I.

As indicated in the project proposal, a competition between all the teams is held at the end of the semester and the grades are partially based on the teams' placements in the competition. Many other elements of the design affect the teams' grades: the quality of engineering documentation (produced using AutoCAD), uniqueness of design, as well as meeting all the deadlines throughout the process. Also, a peer evaluation is conducted and a person's grade is significantly affected by the responses by his or her teammates.

An example of a mousetrap spring powered car design is shown in Figure 5. Figure 6 is a picture of another mousetrap car. Figures 7 and 8 show two design teams with their final designs on the day of the competition in the personal transportation vehicle category.

Group Semester Project. This is a "paper project." The students work in teams on problems involving conceptual and to some extent detailed design of a product. They are required to evaluate various design alternatives while clearly identifying the 'pros' and 'cons' of each alternative. Once they agree on the alternative of their choice, they develop a set of technical documentation. A written report describing the design activities is prepared and submitted. Also a technical presentation on the project is given to the class. Peer evaluations are conducted and the responses summarized and taken into account when assigning individual grades. This project too has a very specific timetable attached to it. As an illustration the specific project guidelines are given in Appendix II

The design topics included systems of considerable complexity. Appendix III lists the topics selected from Reference 1, which were used in the spring semester 2000.

In an attempt to further emphasize the hands-on character of the course sometimes a topic for the group semester project, which deals with a current need at the school, is chosen. The proposal for a net raising mechanism described in Appendix IV represents such an example. This particular problem statement was formulated in collaboration with the athletic department.

Introduction to Solid Modeling using Pro/ENGINEER CAD software system. Since Pro/ENGINEER represents a very complex software system for computer aided design

only bare fundamentals can be included in this course. Nevertheless, this introduction serves a twofold purpose: To make the students aware of the existence of this category of CAD – the so-called ‘high-end CAD’ – as opposed to the low-end software, and to get them excited about what is coming in their education. (The author also teaches high-end CAD software suites.) The software used for this purpose is Pro/ENGINEER, a high-end computer aided design package by Parametric Technology Corporation. It is a parametric, feature-based, solid modeling system. In roughly three hours some among the basic features of solid modeling are introduced to the students. These features include: Protrusions, Cuts, and Holes.

Factory Tours and Field Trips. One to two tours of industrial companies in the area are organized. The examples of the companies visited include Navistar, Zolner Pistons, Dana Corporation, and a local foundry. Also, two times the annual Design and Manufacturing Show and Exposition in Chicago was selected. The benefits to the students of attending such events are manifold. They get a chance to meet practicing engineers in various areas of engineering. They learn about the production programs of the companies. It is believed that, for a freshmen-engineering student taking his or her first course in design, it is rather helpful to meet people whose profession is design.

### **Discussion**

The current ABET requirements for accreditation of engineering programs stress the need for a wide representation of design disciplines throughout the curricula. Having a course in engineering design at the freshmen level in which the students can learn about various aspects of engineering and then engage in real life engineering exercises is definitely very helpful. It helps the students to, first, decide whether engineering is what really interests them, and then, if so, what kind of engineering is closest to their talents and interests. Finally, it exposes the students to situations, which parallel real-life engineering work. The modern day design-engineering environment consists of several components. These components involve the concurrent engineering methodology, multidisciplinary teams, use of powerful software for computer aided engineering, and strict requirements to deliver a product on time and within the budget, in addition to having to function and compete in a global market. The sooner an engineering student encounters all or some of these elements the better he or she will be prepared for the modern workforce. Combining these exposures with a series of topics covering the fundamentals of engineering graphics and communication is believed to be the right approach.

### **Conclusions**

A hands-on approach to teaching freshmen engineering design has been presented. The course described here represents a successful blend of various practical activities in which the students engage and a series of lectures on the fundamental topics in engineering graphics and design. The emphasis of the course is on practical design in

a teamwork environment following the modern concurrent design methodology. Several design exercises are presented. The concepts such as “on time”, “on budget” and “competitive” design are stressed throughout the course. It is believed that the course context and the teaching method have proven to be optimal for students entering the field of engineering. In one semester a solid understanding of some of the most important concepts in the engineering design process is developed. The course represents an important building block for a successful engineering career.

### **References**

1) Bertoline, G.R., et al., Technical Graphics Communications, 2<sup>nd</sup> Ed., McGraw-Hill, 1997, pp. 921-926