Teaching Freshman Engineering Design at a Two-Year College

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Abstract

This paper presents preliminary conclusions about teaching engineering design to freshman engineering and technology students at a two-year college. Many educators realize the need for freshman students to learn some basic skills in order to succeed later in various engineering and technology disciplines. These skills include computer applications software, oral and written communications, technical report writing, and data analysis. A number of institutions are also teaching the fundamentals of engineering design to freshmen. By working in teams to design practical products, students not only immediately apply the basic skills that they have just learned, but also are involved in the activities of the engineering design process, technical drawing and computer-aided design, team work, report writing, and presentation. This also allows students to become involved in engineering content at an early stage and helps them develop interests in engineering and technology disciplines. Therefore, they will have a better chance to successfully complete their programs. This paper also discusses some other related issues such as curriculum development, course content, teaching strategies, and appropriate means of assessment.

1. Introduction

A design project is usually a capstone course in traditional engineering education. To complete a design project, students are assumed to have completed all required courses and have mastered a comprehensive knowledge in discipline so that they can apply what they have learned to the design project. A new approach is to teach fundamentals of engineering design (FED) to freshman students. The first objective of this approach is to allow students to learn the engineering subject matter right from the beginning [5]. When students spend several semesters in non-major courses without encountering engineering subjects, they may lose interest in engineering. Engaging them in engineering and technology courses at an early stage may keep their interest and improve the retention rate. The second objective is to provide an opportunity for students to work in teams and solve practical problems as professional engineers do. By designing a product, the students learn about the engineering design process, write and present technical reports, and use relevant software packages.

In summer 1998, New Jersey Institute of Technology (NJIT) held workshops for regional community colleges and pre-engineering programs. Partially funded by the Gateway Engineering Education Coalition grant from the National Science Foundation (NSF), these workshops presented several FED modules developed by NJIT and invited other colleges to re-develop the FED modules. At the workshop, I presented a plan to pilot FED at Essex County College (ECC) [6]. After piloting FED at ECC in the fall 1998 semester, I presented some preliminary results at a conference held at NJIT in January 1999 [7]. This paper presents some preliminary results from the pilot in the fall 1998 and spring 1999 semesters at ECC.

2. What Is Covered in FED?

Some schools have taught FED to freshmen as an integrated package. For example, NJIT offers *FED 101 Fundamentals of Engineering Design I* [4], which includes engineering graphics, computer-aided design (CAD), and a design project. Students must also take *HSS 101 English Composition: Writing, Speaking, Thinking* [4] concurrently. The semester contact hours are six and three respectively.

To teach engineering design to a true freshman who has never taken any college courses and to expect a design project, including a formal report and CAD graphics, presents a lot of challenges. There are many topics to cover in FED. What should be covered in FED for freshman students? For a freshman who lacks the necessary preparation, a comprehensive engineering design project is unrealistic. Instead, freshman design projects should set reasonable goals, such as:

a. Understanding the engineering design process

b. Working in teams to design a simple product

c. Using some software packages to carry out the design:

Word processor:	Prepare the proposal and report
Spreadsheet:	Perform simple data analysis
CAD:	Illustrate the design

d. Browsing the web and using the library to check references

e. Oral and written presentations

3. Description of *ENR 100*

I piloted freshman engineering design projects in *ENR 100 Introduction to Engineering, Technologies and Science* [1]. *ENR 100* is currently a three-credit course recommended for engineering and technology students in all majors. It requires *ENG 096/97 English Foundations I/II* and *MTH 092/093 Elementary Algebra* [1], the highest level of remedial courses, as co-requisites. At ECC, many students are placed into one or more remedial courses in their first

year. By merely reviewing subjects which they may already have learned in high school, and without taking any courses in their chosen engineering and technology majors, some of them may lose enthusiasm as college freshmen. *ENR 100* is a bridge course that allows freshmen to learn some engineering and technology topics to help maintain their enthusiasm in their respective majors. It was designed to introduce students to various engineering and technology fields and help them become more familiar with their chosen majors. It also teaches them some fundamental and necessary skills in oral and written communication, word processing, spreadsheets, and mathematical analysis.

Hands-on simple laboratories are a major part of the course, taking up one-half to two-thirds of total class time. These labs span the available majors at ECC: for example, a CAD design lab and a robot programming lab for mechanical, manufacturing, and CAD majors; a surveying lab for civil/construction and surveying majors; and a circuits lab (to be developed) for electronics majors. Field trips are also arranged. Through these hands-on labs and field trips, students can develop more interests on engineering and technology careers.

An introductory textbook on engineering [3] is supplemented by lecture notes and lab manuals developed by ECC faculty. Some of the topics covered in this course include:

Engineering disciplines
Report writing and presentation
Resume writing and job interview
Engineering ethics
Computer programming lab (QBASIC)
Word processing lab (Microsoft Word)
Spreadsheet lab (Microsoft Excel)
Math analysis lab (MathCAD)
CAD lab (AutoCAD)
CAM lab (MasterCAM)
Robotics lab (Eshed robot)
Surveying lab

Through *ENR 100*, students are given the opportunity to develop interests in engineering technologies and become better prepared to take their subject courses. Since *ENR 100* already has many components of engineering design, such as the design process and CAD, it provides a natural vehicle to pilot freshman engineering design.

4. Piloting FED in *ENR 100*

ENR 100 provides necessary skills for freshman students to complete their FED project. These skills include steps in the engineering design process, word processing, report writing, and CAD. The only new component is the FED project. The design project can serve as a comprehensive assessment for the introductory course. Students apply the knowledge and skills they have learned in the course to complete the design project.

4.1. How Do We Teach FED in *ENR 100*?

At ECC, engineering and technology students first take *ENR 103 Engineering Graphics*, then take *ENR 105 Applied CAD*. The conventional CAD lab in *ENR 100* is an orthographic drawing with step-by-step instructions. The biggest challenge for teaching FED in *ENR 100* is that since this is their first engineering course, the students have not learned the fundamentals of engineering and technical graphics. Therefore, most of them do not have the concept of orthographic projections, isometric drawing, dimensioning, and scaling. The problem is that there is no time to teach them graphics in *ENR 100*.

For non-engineering or non-technology major students, pictorial views are much more recognizable than orthographic views. This is because we see 3D objects in our daily lives. I decided to teach students 3D solid modeling as a CAD tool for their FED projects. Once students grasp the concept of size and location measurement, they can create simple solids, such as rectangular blocks, cylinders, and spheres; then manipulate these simple solids to construct more complex solid models by union, subtraction, and interference. After the 3D solid model has been created, it can be easily viewed as pictorial and orthographic views.

4.2. Individual Proposal

In my class, I describe the design project requirements to the students at the first class meeting. This way, they can begin to think about a product to design and relate course content to their designs from the beginning. There are usually many questions about the design project. Students wonder about their ability to design a product, the kind of product to design, the complexity of the product, and the way they will make the product. I make it clear to the students that it is not the complexity of the product, but rather the design process, that they should focus on. After they complete their program, they can design more complex products. At this stage, they are only asked to create a 3D solid model using a CAD software package. Since the freshman students have not taken major courses and come from various engineering disciplines, it makes sense to allow them to design simple products that can be applicable to their daily lives.

I first ask students to write individual proposals. I show them some design examples to give some ideas and encourage them to come up with their own original ideas. I allow students a couple of weeks to turn in their proposals so that they have enough time to think about their designs and to prepare their proposals using a word processor that they have just learned in the course. A three-page format is required for the proposal [2]. The first is a cover page that includes the title of the proposal, the student's name, course code and title, department, institution, and date. The second page is a description of the proposed product. Students are encouraged to describe their products using as much detail as possible. The third page is an illustration graph of the product. Since the students have not learned CAD yet, they are allowed to sketch the graph for now. However, the graph in their final report will be a CAD drawing. The guidelines and requirements for the proposal are handed out to the students.

Some students are very excited about brand new designs and inventions. This should be encouraged. However, it should be pointed out that modifications to an existing product which make it simpler or more convenient to use are often more practical.

4.3. Team Proposal

An important requirement of the design project is teamwork. This gives students a chance to practice their communication skills. It also simulates the environment of the real engineering design process. From the presentations of individual proposals, some products may appear to be similar. Those students with similar products are naturally grouped into two or three-person teams. From now on, they will work as team members, exchanging ideas and modifying the products to come up with a team proposal. As a team, they may share duties. For example, one student will check the references, while another will survey the market for existing products. In groups formed by students with different products, students may come up with a new product or work out a compromise.

4.4. Market Survey and References

In order to make improvements on a product, one must first become familiar with existing products. Students are required to conduct a survey to find similar products that are available on the market. Through the market survey, students also obtain more information about the product such as dimensions, parts, and functionality. Students are also required to do research in the library and on the World-Wide-Web to look for related product information. After collecting a variety of product information, students are encouraged to make any improvement on the existing product, no matter how small the improvement is.

4.5. Engineering Design Process

After students have learned the fundamentals of engineering design from the introductory course, they can immediately apply the design process to their design project. A generic design process usually consists of five steps [3]: developing functional specifications, making the concept or reverse engineering design, generating design alternatives, selecting and modeling the best alternative, and testing and verifying the design. In making modifications and finalizing the design, team members become involved in serious discussions about technical specifications. Each person tries to convince the other members of the team to accept his/her design ideas. To succeed, they must learn how to work as a team, convey their ideas to others in the group, and accommodate the ideas of other team members.

4.6. CAD Drawings

The curricula at ECC for most engineering technology programs require students to take *ENR 103 Engineering Graphics* in the first semester and *ENR 105 Applied CAD* in the second semester. A student first has to learn the fundamentals of engineering graphics and instrument-assisted hand drawing, then learn a CAD package to create CAD drawings. In both hand and CAD drawings, students begin with orthographic projections. They then move to isometric and

oblique drawings as well as auxiliary views. Finally, they learn how to use CAD to create 3D drawings.

However, entering freshman students have neither learned engineering graphics nor acquired enough CAD skills to create a meaningful drawing. There is insufficient time to teach them the necessary graphics and CAD using the traditional steps. My solution is to directly teach them 3D solid modeling using CAD. As a matter of fact, we see 3D objects all the time in our daily lives, but few entering freshman students have ever read multi-view drawings. Therefore, most students feel more comfortable learning how to use CAD to create 3D objects than to learn the new concepts of orthographic projections. In addition, CAD software provides basic 3D solid objects such as the box, sphere, cone, and cylinder. Students can directly use these primary 3D objects, with 3D solid modeling techniques of union, subtraction, and intersection, to create their own designed 3D objects. The process is relatively simple and similar to using building blocks to construct objects. It eliminates the need for the students to learn many drawing commands or to accumulate CAD experience. Figures 1 and 2 show examples of the students' designs. Some students in my *ENR 100* class take *ENR 103* concurrently and are amazed by how easy it is to obtain orthographic views from a 3D solid model. Indeed, I think that it will help students to understand orthographic projections by showing 3D solid models and their orthographic views using a CAD package.

4.7. Presentations

The presentation of a completed design project consists of two parts: written and oral. It is required that the written report follow the format of a technical report and be prepared using a word processor. The final report must be an expansion of the proposal. Guidelines are given to students, listing the components of the final report:

Cover (Title, names, course, institution, date)
Table of contents
List of figures (CAD drawings)
Introduction (Market survey and reference data)
Description of the product (How does it work? What improvements have been made?)
Conclusion (Successes, lessons learned, future improvements)
References
Appendices

The written report can be done as a group. However, group members must share responsibilities. For example, one may perform the word processing, another may prepare the CAD drawings, and the third coordinates actions as the group leader.

The oral presentation is an important part of the design project. Students must have both written and oral communication skills to convey their design ideas. They must be able to present their work in a conference setting, manage time, and deliver key points.

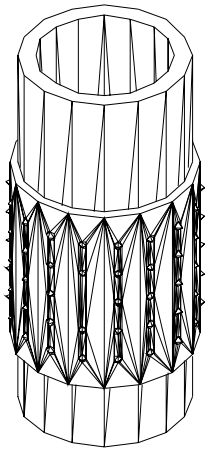

Figure 1. Cup (Designed by Dayne McIndoe and Michael McWilliams)

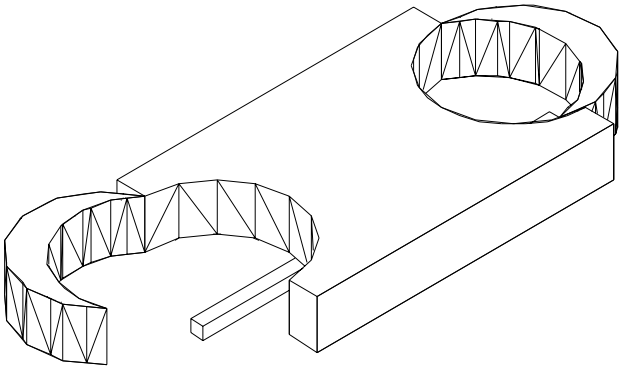

Figure 2. Cup Holder (Designed by Rene Morales and Duane Roopchand)

4.8. Grading

The concept and procedures of engineering design are tested together with other topics taught in the introductory course. Since students learn engineering design through a project, the assessment is based on the project they completed. The design project is graded based on the complete portfolio including the individual and team proposals, the written report, and the oral presentation. Whenever teamwork is involved, the teamwork is graded first, and then adjustments are made for individual contributions. Grading of individual work is important since it engages every student in teamwork.

5. Results

When asked about their design projects, all of the students replied that they enjoyed the experience. The following are selected excerpts from the students' answers.

> "The term project has helped me to learn how the design process works in the real world."
>
> "I learned how to create a 3D solid."
>
> "I've learned a lot about the importance of time management and planning."
>
> "I learned the steps used to design a product and how to work with AutoCAD."
>
> "I accomplished many things while doing the term project. For the first time I was able to put my ideas on paper. I was able to use AutoCAD … and the project enabled me to understand the process of designing a new [product]."
>
> "By doing my term project in engineering design, I have become more familiar with AutoCAD and the engineering design process."
>
> "We have designed something that I think could and will be of great use in the business world today."
>
> "I'm glad I had the opportunity to learn AutoCAD for the first time. It's a great experience."
>
> "The most important aspect of our term project was my ability to think of an invention and actually design it."
>
> "I think it was a good idea to think of projects that could be used in everyday life."
>
> "By doing the term project, I realized that my imagination is more active than I thought."

6. Conclusions

Preliminary conclusions about teaching engineering design in a freshman introductory course are as follows.

a. When asked their options about the FED project, all of the students answered positively. They enjoyed the experience of working as a team to design their own products, and are glad that they learned something new from the project.

b. Teaching engineering design in a freshman introductory course has several advantages. Through the design project, students immediately apply the design process and software skills that they have learned from the introductory course. Furthermore, students become involved in projects early and their interests in engineering and technology fields are stimulated.

c. The difficulty is that freshmen usually lack the necessary training in graphics and CAD. Time is also limited for a design project. Therefore, the design products should be simple. They should focus on design concepts rather than details. Visually friendly 3D solid modeling was used to create the CAD drawings.

d. The written proposal and report, as well as the oral presentation, are important parts of the design project. The report should follow the format of a technical report and be created in a word processor. The proposal should begin as early as possible. It is preferable to collect a preliminary proposal in two weeks after the beginning of a semester so that there is enough time to make any necessary modifications and to complete the project.

e. If a stereolithography apparatus (SLA) is available, it can be used to make a quick production of prototypes from 3D solid models of CAD drawings. An SLA machine creates a prototype by constructing layers of plastic resin. With SLA, other concepts can be included in the design project such as inspection and quality control.

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