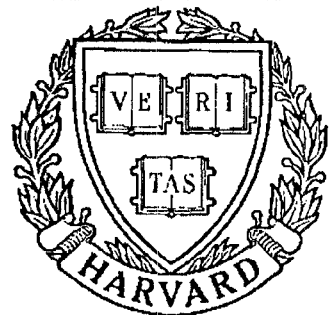


TECHNICAL RESEARCH REPORT



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Teaching Engineering Design to High School Women

by G.M. Zhang and J.W. Dally

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G. M. Zhang and J. W. Dally

College of Engineering
University of Maryland
College Park, MD 20742

Abstract

There has been a pressing need to develop a program to gain an understanding of major engineering principles and an insight into various engineering careers to the students who will soon graduate from high school. This paper presents the experiences of teaching high school women during the 1991 & 1992 Summer Study in Engineering Program. The program, initiated in 1975, is designed to foster the young and intelligent high school women to find out if engineering is the right career for them in this challenging world. Teaching engineering design through a project approach is the primary focus of this program. By actually building the product, the students are exposed to the product development cycle and gain important hands on experience. The participating students are organized into groups to learn the concepts of team work and co-operative learning. They acquire entry level computer skills through the preparation of technical reports and engineering drawings. Our experiences have shown that the women students are motivated and enthusiastic in learning engineering fundamentals and developing their critical thinking skills. They experience college life through participation and gain confidence in making future decisions in their coming years of academic careers.

1. Introduction

The development of technology and increasing competition in the 20th century

challenge our educational system to provide the high school women with superior knowledge, design skills, and realistic industrial experience. It has been a well-known fact that women are still under represented in Science and Engineering. Recognizing the strategic need for encouraging talented women to pursue engineering education in college, the University of Maryland has provided funding for high school women to study engineering in the summer. From 1975, high school women after the completion of their junior year in high school enroll in the College Park campus to participate in the summer program.

From our observation, most of the women students at high school have an aptitude for math and sciences, which are the foundation courses for an engineering career. However, the course structure in high school does not provide a clear picture about engineering in particular. In fact, high school students do not have much opportunities to find out exactly what being an engineer entails. Consequently, most of them have very few ideas what they are interested in. In order to remove these enigmas, the summer program offers two engineering courses at entry level to answer "what is an engineer? what does an engineer do?" for the participating students. The two courses are "Introductory Engineering Science" and "The World of Engineering."

In this paper, we present our experiences in offering the course "Introductory Engineering Science" to high

school women during summers 1991 and 1992. There were twenty one and twenty three women students enrolled during the summer 1991 and 1992 programs, respectively. Unlike the traditional teaching method by lecturing, we developed a new teaching method for high school women. It focused on teaching engineering design through the project development cycle. The participating students were organized into four groups of 5 or 6 students each. Each group designed a playground seesaw (in the summer 1991) or a glider (in the summer 1992) based on the basic engineering concepts learned in the classroom. They used computers to prepare technical documents and engineering drawings. Then, each group manufactured, assembled, and tested the designed product for enrich hands on experiences.

This paper is organized as follows. In section 2, we present briefly the women student's motivations and their expectations by attending the summer study program. In section 3, we describe the basic course structure, and four major activities involved in this program. In section 4, we present the students' outcomes with emphasis on their academic achievement, personal development, and preparation for college education. Section 5 summarizes the results and describes its impact on increasing enrollment of women students to learn science and engineering.

2. Motivations and Expectations

In this section, we briefly describe how the women students are motivated to enroll in the summer study program and what their expectations are.

It seems a common phenomenon that high school students start the decision making process to plan their future career when they enter the senior year. It is not uncommon that they hesitate selecting engineering as their major simply because they know little about what is involved in engineering and what field will fit their future need. The following paragraph is taken from an essay of one of the

participating students participating in the summer 1992 program.

"One of the purposes of high school is to get students acquainted with various subjects so that they will be aware of all the possibilities surrounding them when they choose a career. Unfortunately, many women students, who graduate from high school, know little or nothing about the engineering field. After taking many challenging classes in high school, I am least familiar with the engineering field. My math class is the only class which is closest to the engineering in particular. My parents are both electrical engineers. Many times I tried asking my parents what exactly they do at work. They would go into these long, technical explanations about the designs of their latest projects. I would end up being more confused than ever. I am in this program, so that I can be offered information about engineering simply enough for a high school student to understand."

Another important motivation is that the program offers an opportunity to learn to use computers for problem solving in engineering. Also we encourage the participating students to live on campus to experience college life. One student wrote "Applying for this program is going to give me the chance to be on my own and experience college life before I make a decision regarding my career. Going away to college is a really scary thing to do when you are not really sure if this is what you want. I was scared to leave my home to come up here for six weeks, I can't imagine what it will be like when I leave for good".

It is evident that the expectations from the participating students are high. They look forward to a challenging six week program and want to achieve a sense of accomplishment through hard working. As one student stated in one of her reports, "My expectations of this program are great, yet obtainable. I hope to be able to narrow down or even choose the field of engineering I plan to pursue. I hope that this class will be able to challenge me intellectually and stimulate

my interest. I hope to gain more experience and expand my knowledge about computers. I expect to be able to work with various people on different projects, at the same time be able to get a taste of what college life is. Hopefully in the next six weeks I will be able to accomplish all my goals, yet still have a fun time". It is time, as is said, "to swim or to sink". They hope they will be able to "swim" and find some area of engineering that will be suitable to them.

3. Structure of the Engineering Design Course

Our main objective in developing the engineering design course is to create an opportunity for the women students to understand what engineering is about and foster a positive attitude for engineering education in college. In order to effectively achieve this goal, we formulated a new approach in teaching, i.e., the project driven approach.

In this new approach, the focus is letting the participating students work as a team to design, manufacture, and assembly a playground product in the six week period. Meanwhile, we teach them fundamental concepts relevant to the product development cycle. For example, the product selected in the summer 1991 program was a playground seesaw. Although the product is simple, it is sufficiently challenging to motivate the participating students to learn basic engineering concepts. We hope that the students will gain a conceptual understanding of engineering design through the product development cycle, which embodies an active learning process. In the following, we present "teaching engineering design to high school women in the summer 1991" as a showcase study.

3.1 Arrangement of Activities

During the 1991 summer program, the design course, as usual, was taught for six weeks. In each week, the class met three times. Each class period covered two hours and thirty minutes, and was divided into 50 minutes of lecture, 50 minutes of computer

lab, and 25 minutes of group discussion. After class, the students were requested to spend five hours studying individually and/or working with their group members as a team. During the six-week program, each student, on an average, devoted 135 hours to this course. The following list illustrates a general arrangement of the planned activities.

Listening to the lectures:	18 hours	13.3%
Working in the computer lab:	54 hours	40.0%
Studying individually:	27 hours	20.0%
Working on design project as a team:	36 hours	26.7%
Total:	135 hours	100%

3.2 Four Major Activities

The engineering design course for high school women in the summer program consists of four parts. Figure 1 illustrates such a basic structure. Note that an introduction to various disciplines of engineering is provided by the course "The World of Engineering". The following paragraphs give a broad view of all activities of the course.

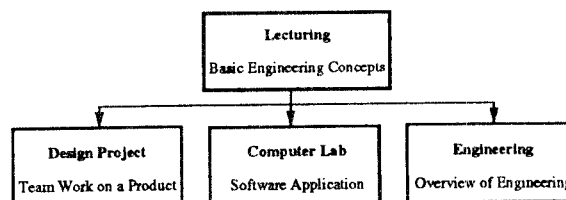


Fig.1 Basic Structure of the Design Course

3.2.1 Lecturing Basic Engineering Concepts

To enable the students to start the design process, the basic engineering concepts involved in the product design should be clearly explained. During the six-week program, we taught these concepts to the students through lectures. Eight basic engineering concepts were selected. They are: Free-Body Diagram; Static Equilibrium; Stress Analysis; Strength of Materials; Safety Factor; Work and Energy; Impact Effect; and Engineering Drawings. These concepts were introduced to them on an as needed basis so that the students were able to perform engineering analysis related to the design of their product. By acquisition of these concepts, the students gained a comprehensive understanding of engineering design and sensed the strong connection between theoretical concepts and engineering applications. As an example of learning the concept of free-body diagram, the students drew the free-body diagram for each of the components of the seesaw product during the design stage. They identified the acting forces and reactions on the component under investigation, and analyzed the conditions for maintaining its static equilibrium to justify their decisions made during the design stage. To aid the learning process, a set of lecture notes was distributed to the students and homework assignments were given to them. These assignments were composed of basic, intermediate, and high levels to ensure that the students from high school were capable of adapting to the college environment. The assignments emphasized creative thinking and trained their problem-solving skills. A mid-term examination and a final examination were conducted to evaluate their progress.

3.2.2 Project Driven Approach

We believe that students at the high school level have intuitive ideas, at least, about engineering design; especially with products like seesaw and glider, that are familiar to them. In fact, the familiarity allow them to define the product specifications and constraints with ease. In

this paper we took the development of a seesaw as an example to explain how students were motivated in a project driven approach.

Common sense dictates that the design process involves creative thinking, application of modern technology and economic considerations. They initiated their own designs by first imitating, then modifying the existing seesaws, and finally arrived at their own designs. A good engineering design not only ensures outstanding performance of the designed product, but also offers ease in manufacturing piece parts and facilitates the assembly operation. To follow this philosophy, we taught them that the engineering design of a product is a three-stage process, i.e. design, manufacturing, and assembly. We emphasized the importance of integrating the manufacturing and assembling stages because a design experience would not be completed without building the product and testing it to ascertain that it met the design specifications. Without going through the manufacturing stage of the piece parts and the assembly stage of its final product, the designer would not be able to justify his or her work.

During the teaching process, we expected that the students would ask us "How does one design, manufacture, and assembly a seesaw product?" To effectively stimulate the students, we worked out a set of clear and detailed guidelines for the design, manufacturing, and assembly stages through group discussions. Figure 2 provides a list of the major tasks identified in the three stages. For example, to answer the question "How does one start the project of designing a seesaw?" We responded by asking the students to discuss what you could do and let the students to work out a list of the tasks to follow. As a result, the students, working as a team, visited public playgrounds where seesaws were located to determine how different seesaws worked and what were their primary components. Table 1 presents the specifications of the seesaw design formulated by one group. It is evident that the completion of the first three

Table 1 Design Specifications of the Seesaw

Users	For use by individuals of both sexes age 3 to 10 with a weight limit not to exceed 300 lbs.
Social Aspects	Capable of entertaining social groups of up to four children
Space	Intended to be used by family units on their own property.
Assurance	Guaranteed to be safe, durable, easy to maintain, with good spare part availability, and low replacement cost.
Product Life	The anticipated life of the product is 10 years.
Assembly	Rudimentary assembly by the consumer.
Total Cost	The total cost not to exceed \$125.00

tasks listed in Figure 2 enabled the students to initiate their design.

Figure 3 shows a typical general assembly drawings of a seesaw design prepared by one design group. When the women students completed the product design, they took the responsibility for manufacturing and assembling the seesaw components. First, they went to local stores to purchase the raw materials needed. When they were at the stores, they realized some of their component designs were unrealistic. For example, the dimensions of woods available at the store did not fit their needs. Before starting the component manufacturing, they had to modify their component designs to meet material availability and costs. During component manufacturing, the students had to learn skills associated with conventional hand tools such as saws, hammers, and drills. The

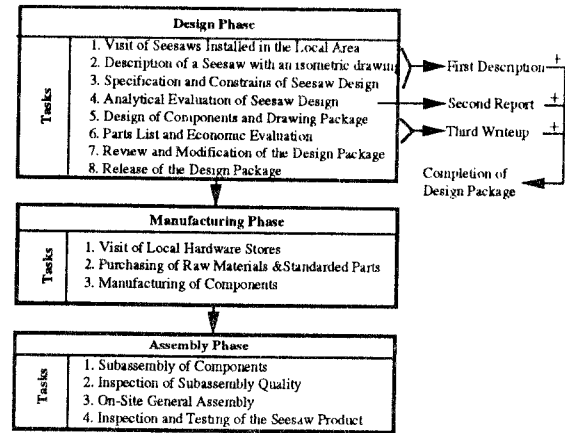


Fig. 2 Major Tasks Involved in the Design, Manufacturing, and Assembly Stages

students were eager to learn these practical skills even though some of them had previously never hammered a nail. Figure 4 shows the workspace where the women students were busy manufacturing components. During the assembly and testing stage the students learned more work-related design experience such as the concept of tolerance and the importance of process planning. The students learned that the dimension of a hole should be larger than the diameter of a shaft which rotates inside the hole. When assembling the handle bars shown in Fig. 3, the students learned that the shoulders on the vertical bars should be made before the horizontal handles were attached to them. When the whole seesaw product was assembled, they sensed the importance of making a prototype during the product development cycle. The prototype suggested the changes necessary in the product design (in the next stage to follow). One student said "It's amazing that you can learn so much from the design of an object as simple as a seesaw."

3.2.3 Learning Computer Skills

As indicated in Fig. 2, at the end of each stage, we asked the students to summarize what they had accomplished. We requested that they prepare technical documents and engineering drawings using computers. Three computer application programs were selected and taught through practice and self-instruction with on-site assistance. They were 1) WordPerfect (word processing software); 2) Lotus 1-2-3 (spreadsheet software); and 3) AutoSketch (computer-aided design software).

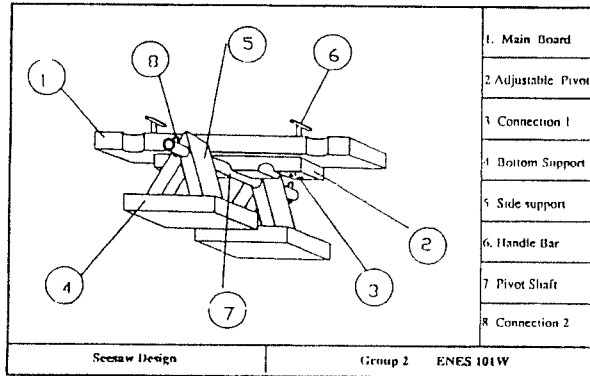


Fig. 3 General Assembly Drawing of a Seesaw Product

To our surprise, the students learned the computer skills with great enthusiasms. They spent hours by hours working in the computer lab to practice their skills in using computers. Their accomplishment was far beyond what we expected. By examining the quality of the assembly drawing shown in Figure 3, its accuracy with respect to the component arrangement and its appropriateness in selecting the projection angle indicate that the women students have a good understanding of preparing engineering drawings.

4. Outcomes of Women Students

Our experience with the 1991 summer program has been extremely favorable. We taught the high school women engineering design through a project driven approach. While they were learning basic engineering concepts and computer skills, they applied these concepts into the design project. The dynamic learning environment enforced them to actively interact among themselves as well as with the instructor. We summarize three major outcomes of the participating women as follows.

4.1 Academic Achievements

First they gained new knowledge in science and engineering. The general response from them was that the knowledge they gained is helping them tremendously in mathematics and physics in their senior year at high school. More important is that they



Fig. 4 Women Students Working on the Shop Floor

have raised their academic standards. They liberate themselves from doing homework to seeking a better and deeper understanding of the concepts in mathematics, physics, and other subjects. The computer skills they learned during the summer program will prove helpful in the future. In fact, most of them have used these skills in preparing letters, essays, English papers, term papers, reports, and science fairs during their senior year.

4.2 Personal Development

The project-driven approach created a working environment to stimulate the students to a more advanced stage of cognitive development. On one side, the design experience met their developmental need for personal autonomy. They learned the skills to allocate time, money, and available resources. On the other side, peer-centered learning through team work offered them diverse experimental backgrounds and perspectives. When they related a design effort with a team effort, they brought different interests and views and began to work together. During the group decision making process, the important skills of patience and compromise had to be developed. They understood the social and technological systems, and strengthened their personal qualities that foster discipline, self-confidence, and the ability to work with others. At the end of the summer program, the students learned that "It would be impossible to satisfactorily complete the project without team work". One student remarked that, "We gained knowledge from each other as well as made friends".

4.3 Preparation for College Education

The satisfaction of their academic achievements and personal development has encouraged the participating women to pursue college education after the graduation from high school. They felt more prepared for college because they knew what to expect from college courses and what it would be like to manage their time for studying. One student remarked that, "The knowledge I gained over last summer proved to be useful in my senior

year. Over the summer I learned how to analyze material. The course I took taught me how to think. Many times high school material does not require one to think. I feel more prepared for college now that I have experienced it at the University of Maryland. The summer program was set up and run very effectively. Although many times I became frustrated with the work, I think that it was good for me because it gave me a true taste of the school work at a college level. I enjoyed the course because it was difficult, and because I was challenged by it". We also received very positive responses from the students' parents. Since the 1991 summer program, we have received letters and phone calls to inquire about information related to the engineering programs available at the University of Maryland and other universities. Quite a few parents came and visited us. To our surprise, 75% of the participating students have indicated that they would major in engineering. Two students indicated that they would major in biology and chemistry.

5. Conclusions

In the summer study in engineering program, we introduce engineering science to high school women. Using a project driven approach, we teach them engineering design through the product development cycle, i.e., actually making a prototype of a real product. In the program, the participating students learn engineering fundamentals and computer skills, develop their critical thinking skills, and gain an educational experience that is relevant to their future need. The program provides them with a great opportunity to understand what is engineering is about, and motivates them to foster a positive attitude towards engineering.

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