Using Enrichment Programs to Introduce High School Students to Mechanical Engineering

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Abstract

Most high school students have little idea what practicing engineers do, or of the nature of a university engineering curriculum. Many top students likely choose a non-engineering major simply due to lack of exposure to engineering. While it is not practical to include introductory engineering courses in a typical high school curriculum, shorter-term enrichment programs involving concentrated workshops, can be used to introduce students to the various engineering disciplines. Many high schools have gone to a modified school schedule, which consists of nine week quarters that are followed by a one week break and one week of remediation or enrichment. Enrichment classes are offered over a wide range of subjects of interest to students and can be used for such extracurricular programs.

This paper outlines a first effort at an enrichment program designed to introduce students at Graves County High School in Kentucky to the field of mechanical engineering. It was developed and delivered by mechanical engineering faculty at the University of Kentucky Extended Campus Program in Paducah, KY[1,2], in January 2002. The two-day program involved lectures, short research projects, and laboratory work at the engineering campus. Initial lecture material covered the broad mechanical engineering profession. Additional presentations included gas turbine engines, alternative energy sources (solar and wind), and applications of solid modeling and finite element analysis software. Based on the lecture material, students selected a topic, and used web-based resources to complete a short research paper. One laboratory exercise involved measurement of flow around a golf ball in a wind tunnel, with supervised calculations of the aerodynamic drag coefficient using Microsoft Excel software. Another exercise involved each student creating a solid model of a simple structure using Pro/ENGINEER solid modeling software, and included production of a stereo-lithography (SLA) prototype of their design as a souvenir.

The students were graded on their efforts. Initial assessment of the success of the program was done through surveys of the participating students.

I. Introduction

While engineering is a generally well-known profession among high school students, few actually know what engineers do in the various disciplines. Engineering programs are challenged to somehow provide this information to the high schools to attract incoming students. It is likely that the high dropout rate after the freshman year in most engineering programs can be partially attributed to the students' poor understanding of what an engineer (or at least an engineering student) really does.

While some magnet schools may have a few engineering oriented courses, the vast majority of public high schools do not. Many high schools in Kentucky have initiated what they refer to as a "block schedule", where they have four 9-week sessions followed by a week of break and a week of enrichment programs or remediation. For students with poor grades, the enrichment week is a chance for them to perform makeup work to raise their grade. For other students, the enrichment week can be used to explore activities outside of their regular high school course offerings.

At the invitation of the curriculum counselor at Graves County High School in Mayfield, Kentucky, the faculty at the University of Kentucky extended campus in Paducah developed an enrichment program that was given in early 2002. There were 22 students ranging from sophomores to seniors, with about an equal mix between males and females. The enrichment program in mechanical engineering was combined with a similar effort designed and presented by the chemical engineering faculty. This paper focuses on the portion of the program related to mechanical engineering. Overall, the program was 15-hours, spread over three days. One day involved participation of the mechanical engineering faculty only, one day involved participation of the chemical engineering faculty only, and the third day combined hands-on exercises involving both sets of faculty. The mechanical engineering program outlined in this paper was completed in two days.

The two-day mechanical engineering program involved one day in which the engineering faculty traveled to the high school to present lectures and supervise the students in doing research on the Internet for a short research paper. The second day involved the high school students traveling to the UK engineering facilities for hands-on laboratory work. In the short enrichment program, the overall goal was to provide the students with a better understanding of what mechanical engineering is about. This information would help some of the students who had thought about a career in engineering to make a better educated decision when they get to college, while some who may have never thought about engineering as a career might consider it. In planning such a program, one must keep in mind that mechanical engineering is too broad, and the various areas of emphasis are too deep, to allow for a highly detailed overview. It is only realistic to provide a brief introduction, and one must guard against overwhelming the students with detail. Also, it is important to keep all discussions and project work on a level appropriate for high school students, who have no background in calculus, or university level physics. With sophomores in the class, some of the students had taken very few high school courses in the sciences.

The approach taken was to first make a broad presentation on mechanical engineering, in general. Then, the students were given a more in-depth overview of some specific areas of mechanical engineering through additional lectures. They then got a glimpse of what it is like to be a mechanical engineering student through hands-on laboratory work in a couple of the specific areas covered in the lectures, and through the writing of a short research paper.

The following sections outline the lecture material, the lab work, and the research paper projects.

II. Lectures

A. Careers in Mechanical Engineering

As an introduction to what engineers do, a videotape from ASME was shown that illustrated the broad range of activities in which mechanical engineers are engaged. The tape showed people with all degree levels in various engineering fields, and covered what they often did in a normal workday. Additional information was provided on employment opportunities in the local area, as well as salary expectations.

B. Alternative Energy Sources (Solar and Wind)

Energy is an important part of mechanical engineering, but many areas of energy studies lack the “sex appeal” needed to keep the attention of high school students. For this reason, the topic of alternative energy sources was chosen to introduce them to this area. Solar photovoltaic energy conversion systems were covered for various applications, such as remote locations, specialty low power and residential systems, and large-scale grid power generation. Wind energy was also covered, starting with the basics of the windmill and generator systems. Various applications were also addressed, and included important design considerations, such as noise, peak power limitations, wind availability, and economic considerations. After the energy presentation, a short quiz was given to determine their retention and understanding of the material.

C. Gas Turbine Engines

Gas turbine engines are interesting devices. The design and operation of these machines involve all the topics that are covered in the undergraduate mechanical engineering curriculum. Additionally, high school students are familiar with gas turbine engines due to their use in jet powered commercial and military aircraft. This familiarity was used as a basis for a discussion of applications where gas turbine engines are used, e.g. helicopters, ship propulsion, and electric power generation. Furthermore, in the area of aircraft propulsion, the differences between turbojets, turbofans, and turboprops were discussed along with the advantages of each machine for certain applications.

Following the presentation of the applications of gas turbine engines, the individual components of the engine and the thermodynamic cycle of the mechanism were discussed.

D. Applications of Solid Modeling and Finite Element Analysis Software

With the wide use of home personal computers today, many high school students are experienced computer users. Therefore, one engineering tool that high school students can readily relate to is solid modeling software, such as Pro/ENGINEER. Students don't need any significant mathematical training to grasp the basic concepts of solid modeling. Also, everyone can understand the importance of being able to predict whether any given part, as designed, is likely to break in service. So, a brief introduction to static stress analysis using finite element software is an appropriate topic for high school students. In this lecture, students were given an introduction to the overall design process. A simple example involving modeling of a basic hook was used as an illustration of using solid modeling combined with finite element analysis to predict the adequacy of a design for some expected loading. Two Microsoft Powerpoint slides related to the hook example are shown in Figure 1. This simple example was followed by an example where stresses were calculated through finite element analysis of a much more complex system, a centrifugal compressor blade. The students were also given an overview of rapid prototyping using SLA.

III. Projects

This part of the enrichment program involved hands-on projects for the students. The 22 students were divided into groups of 11 and rotated between the mechanical engineering and the chemical engineering projects. For the ME portion, initially, half the students in the ME area went into the lab to perform the wind tunnel experiment. The other half

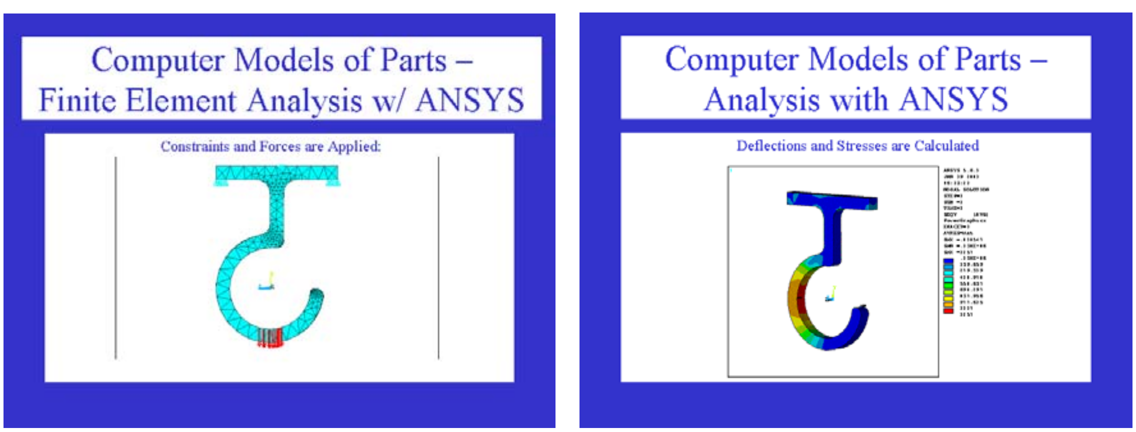

Figure 1: Powerpoint slides from the lecture on solid modeling and finite element analysis of a hook. The model, with constraints and loads applied, is shown at left. The calculated stresses are shown in the color contour plot at right.

went into the computer lab to learn how to use a computer spreadsheet to compute and graph the results of their wind tunnel measurements, and then to do a hands-on solid modeling project using Pro/ENGINEER. Then, the students rotated, so that all students completed all of the hands-on activities. The total time involved in the ME hands-on activities was approximately 4 hours.

A. Flow around a Golf Ball

A major application area for mechanical engineers is fluid mechanics. An application of fluid mechanics that the high school students have practical experience with is aerodynamic drag. The students understand that cars, boats, and airplanes are designed with streamlined shapes to reduce drag. This concept can be illustrated for the interesting question of "why do golf balls have dimples?" The students know that the dimples are used to increase the flight distance of the golf ball, but not necessarily the reasons why.

An experiment was set up in a wind tunnel used for classroom instruction on the University of Kentucky, Paducah campus. A photograph of the wind tunnel is presented in Figure 2. The wind tunnel consists of a contracting inlet with flow straightening honeycomb followed by a plexiglas test section. Downstream of the test section is a slowly diverging diffuser and a fan that draws the flow through the tunnel. Directly upstream of the fan is a screen to protect the fan blades from any solid objects that travel downstream during tunnel operation. The maximum tunnel velocity is 26 m/s. This velocity is not large enough to cover the entire Reynolds number range desired, but is large enough to illustrate the drop in the drag coefficient of the golf ball once the Reynolds number gets large enough that the flow becomes turbulent.

To illustrate this concept a smooth wooden ball of similar size to the golf ball was used to simulate the golf ball without dimples. Both balls were mounted on a threaded rod. The rod with the smooth ball or the golf ball was mounted in a two-component force balance. A photograph of the golf ball and the threaded rod is presented in Figure 3.

This was a hands-on team experiment that had some "wow" factor, but also covered a topic that they could grasp. A discussion of wind tunnels and how they operate was presented to the students followed by a discussion of how to safely operate the wind tunnel. Each student selected one of the following tasks: 1) adjust fan speed, 2) measure tunnel velocity, 3) measure drag force using the force balance, and 4) record the data. Due to the number of students involved, one set of students conducted the experiment for the smooth ball and the second set of students conducted the experiment for the golf ball. Idle students were also used to record data for redundancy. Since the students did the actual experiment there was some variability in the results, depending on how carefully the students conducted the individual measurements.

Preceding the actual experiment a discussion concerning the drag on the sphere and why the drag changed with the dimpled golf ball was presented to the students. This concept was reiterated during the experiment where the students could see the difference in drag between the smooth sphere and the golf ball. Following the experiment, the students reduced the data using a spreadsheet in the computer laboratory.

Figure 2: University of Kentucky, Paducah model wind tunnel used for classroom instruction.

Figure 3: Golf ball mounted for insertion in two component force balance.

B. Solid Modeling with Pro/ENGINEER

In the hands-on project using Pro/ENGINEER, a very simple structure was modeled – a toy building block. Each student worked through the development of the model individually in the undergraduate computer lab at the University of Kentucky facility in Paducah. They were provided step-by-step instructions. The point of the project was not to teach the students how to use the software, but rather to give them a basic feel for how it works, and the power of the tool. Upon completion of the models, each student's part file was used to create an SLA prototype in the Rapid Prototyping Lab at the

University of Kentucky Center for Robotics and Manufacturing Systems (CRMS) in Lexington 250 miles away. The students inscribed their initials on each part within their Pro/ENGINEER models so that it was possible to determine which prototype belonged to which student. The prototypes were subsequently sent to Graves County High School as souvenirs for the students. As expected, some students ran into some difficulties, as is usually the case when one uses software with which they are unfamiliar. However, everyone was able to complete at least a portion of their model, and an SLA part was created based on their Pro/ENGINEER file, whether it was a complete model, or not. So, the project was successful in giving the students a basic feel for how a powerful design tool could be used in an actual design setting.

Figure 4 shows a representative Pro/ENGINEER model of the toy block. This particular model shows the student's initials, PJS, inscribed on the side. In Figure 5, a student's prototype is shown (left) beside an actual toy block. The initials, CJ, are visible on the prototype.

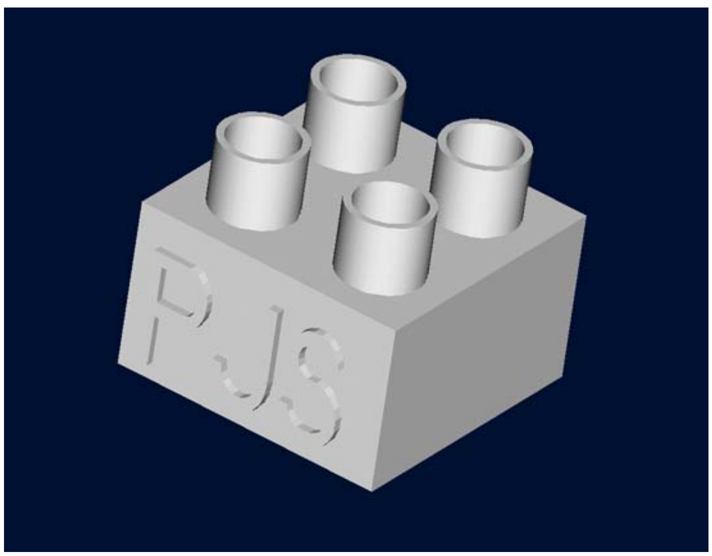

Figure 4: A student's Pro/ENGINEER model of a toy building block.

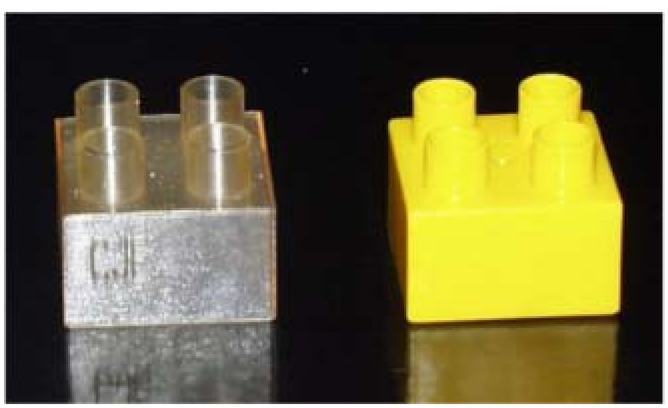

Figure 5**:** A student's toy block SLA prototype (left), and an actual toy building block.

C. Research Papers

Immediately after the lecture on the alternative energy sources, the students were given an assignment to go to their computer lab and conduct searches on the Internet to support a two-page report on either solar energy or wind energy. Inevitably, some students chose to play video games while in the computer room, but all were responsible for turning in their paper the next day. As might be expected, the quality of the papers ranged from quite thorough to somewhat poor and illustrated varying degrees of references from the web.

IV. Assessment of Student Performance

The students' work was graded on a five-point scale. Work on the various projects was averaged. Each student's score on the five-point scale was added to his/her grade in another class. Therefore, each student, depending on performance, had the opportunity to improve his/her grade by half a letter grade in a high school course by participating in the program. The average grade was three points out of the five points possible.

V. Student Survey Results

Eleven of the students who completed the program returned surveys. The results are summarized below. The surveys covered both the mechanical and chemical engineering components of the overall program.

All eleven respondents indicated that they intend to attend college. Six indicated that before taking the program, they were interested in engineering as a major, while five said they were not. Two said they were more likely to consider it after taking the program, three were less likely, and six reported no change in the likelihood that they will major in engineering. Nine of the eleven either agreed or strongly agreed that the program increased their knowledge of what engineers do, and the other two responded that they "somewhat agree" that their knowledge of what engineers do was increased.

One question asked which parts of the program (including the chemical engineering portions) were most interesting, and they were allowed to circle as many as they wished. From the mechanical engineering portions, six selected the solid modeling portion, two selected the introduction to mechanical engineering, two selected the gas turbine engine portion, and two selected the alternative energy sources portion. They were also asked what parts they found least interesting. Three selected solid modeling, two selected the introduction to mechanical engineering, four selected the gas turbine engine portion, and one selected the alternative energy sources portion. Due to an accidental omission in the surveys, the wind tunnel experiment did not appear as a choice on the questions about which parts were found to be most and least interesting.

Eight of the eleven respondents also commented that they would like to see more hands-on activities, apparently in place of the lecture portions.

VI. Summary and Conclusions

This paper overviews an enrichment program designed to provide high school students with an introduction to the field of mechanical engineering. The approach taken was to give them an overall view of the field through an initial lecture, then focus on some specific areas with lectures and hands-on projects. An attempt was made to select topics that students could relate to with no background in calculus or university-level physics. The primary topics covered were: (1) Alternative Energy Sources (Solar and Wind); (2) Gas Turbine Engines; and (3) Applications of Solid Modeling and Finite Element Analysis Software.

Success of the program in achieving its goals was assessed through graded student work and follow-up surveys. The initial feeling is that the program was basically successful, because on the surveys, all eleven students indicated that they agreed, at least to some extent, that the program increased their knowledge of what engineers do. However, only half the students returned surveys, and the numbers involved may not be considered to be statistically significant. Actually, perhaps the best indicator of program success will be whether any of the students involved will choose mechanical engineering as a college major. This information is not yet available, as the majority of the students who participated were sophomores and juniors, and have not yet graduated from high school.

VII. Acknowledgement

The authors would like to thank Mr. R.J. Robinson and his staff at the University of Kentucky Center for Robotics and Manufacturing Systems Rapid Prototyping Lab for creating the SLA prototypes of the toy building blocks.

VIII. References

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