The Use of Solid Modeling in Mechanical Engineering Outreach Programs for High School Students

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Abstract

In an effort to attract talented high school student to careers in engineering, the Mechanical Engineering Department at Milwaukee School of Engineering (MSOE) participates in a number of engineering outreach programs. Great successes in these programs have resulted from the use of solid modeling techniques and software to motivate engineering concepts and allow the students to participate in hands-on engineering activities. The outreach programs that now integrate solid modeling technology range from an introductory one-hour experience to a long-term ongoing effort. The four programs specifically addressed in this paper include: 1) a one-hour solid modeling exercise, sponsored by the Society of Women Engineers to attract young women to engineering careers; 2) a half-day session, in which both part and assembly modeling exercises are used to give high school students an exposure to Mechanical Engineering; 3) a week-long effort, in which solid modeling is integrated with rapid prototyping technology and other engineering instruction to provide a comprehensive design/build/test experience; and 4) an ongoing relationship with a Milwaukee area private high school, which integrates solid modeling and rapid prototyping technology to produce physical prototypes of student-designed parts. Both the goals of the individual programs and the specific solid modeling exercises designed to achieve the goals are presented in this paper. Conclusions based on student and instructor feedback over the two years of program implementation are offered.

I Introduction

The Mechanical Engineering Department at Milwaukee School of Engineering (MSOE) participates in a number of high-school outreach efforts to attract talented students to the engineering profession. The purpose of these programs is both to expose students to an overview of mechanical engineering as a career, and to showcase the strengths and capabilities of MSOE. These types of programs have existed in various forms for decades; they traditionally followed a typical classroom model, where a combination of lecture and laboratory demonstration was used to highlight engineering topics.

During the 1998-1999 academic year, an effort was undertaken to re-engineer the mechanical engineering outreach offerings. Review of background literature indicated that the most successful outreach programs were those that integrated the exposure to engineering topics with hands-on activities[1-7]. This fact, coupled with the development of a new solid modeling laboratory, led to the redesign of the outreach offerings. The new format for the outreach programs was to center the activities around mechanical design and solid modeling exercises; in their new format, these programs range from a one-hour solid modeling activity, where a mechanical component is modeled and rendered using *SolidWorks®* solid modeling software, to a full design/build/test experience, where participants design and construct scale-model racers using solid modeling and rapid prototyping technologies.

The remainder of this paper is devoted to detailed descriptions of the activities designed for the various outreach programs offered. Section II will detail a one-hour solid modeling exercise, used as part of a Society of Women Engineers program devoted to attracting talented young women to careers in engineering. Section III will detail a half-day program in both part and assembly modeling, used as part of a week-long program designed to expose participants to the various engineering disciplines. Section IV will describe a week-long design/build/test experience involving both solid modeling and rapid prototyping technology, used to expose participants in-depth to the mechanical engineering profession. Section V will describe an ongoing outreach effort, in which MSOE provides solid modeling and rapid prototyping support to Milwaukee area high schools. In Section VI, conclusions and recommendations based on the two-year implementation of solid modeling-based outreach efforts will be offered.

II A Short One-Hour Outreach Program

For the past several springs, the Society of Women Engineers (SWE) at MSOE has hosted a day-long program for high school students interested in engineering careers. The young women who attend have the opportunity to speak to women faculty members, learn about engineering in general, and participate in several one-hour sessions arranged by different engineering departments. The Mechanical Engineering Department's sessions consisted of having the students model a flying disk, such as the one shown in Figure 1.

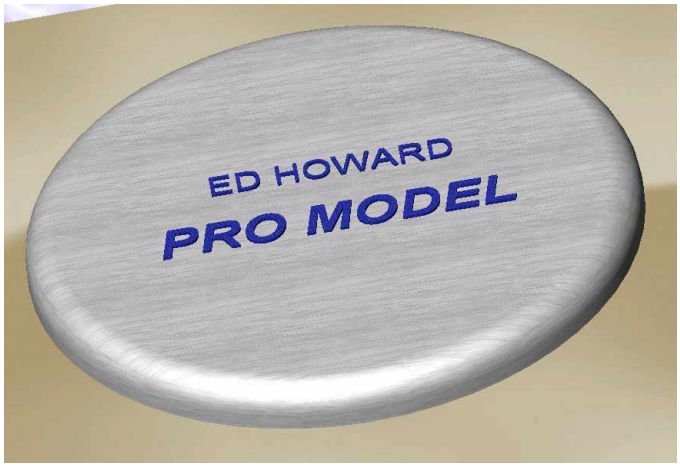

Figure 1
Flying Disk Model

Although the disk is quite simple in geometry, the students go through several steps, including extruding a circular

sketch into a solid shape, filleting edges, shelling the backside of the disk, and adding raised lettering to the front surface. The role of solid modeling in the design process is discussed during this session.

Most of the young women attending the sessions have has no CAD experience. Many may view CAD (and mechanical engineering) as a male-only field. The purpose of this session is to help remove any intimidation the women may feel about exploring such a field, while at the same time show that mechanical engineering has moved beyond the widely-held stereotypes of the profession.

An interesting observation that the authors first made at these sessions was that high school students with no CAD experience at all probably adjusted to solid modeling better than any other group we have worked with. Creating a 3-D model of a 3-D part is a natural process to a person with no 2-D drafting history.

III A Half-Day Outreach Program

Each summer, MSOE sponsors a week-long outreach program entitled *Discover the Possibilities*. The structure of the program allows the participant to receive an exposure to a number of engineering and technical disciplines; a one-day long experience is provided in each of the following disciplines: Mechanical Engineering, Electrical Engineering, Architectural Engineering, and Computer Networking. Therefore, the Mechanical Engineering Department is responsible for programming two four-hour sessions that provide an exposure to the mechanical engineering profession. The sessions that have been implemented are:

- A four-hour morning session, that uses *SolidWorks®* solid modeling software to provide a hands-on part and assembly modeling experience.
- A four-hour afternoon session, that provides a laboratory experience in aerodynamics, material science, or internal combustion engines (based on instructor/laboratory availability).

The four-hour solid modeling exercise was designed with the following goals in mind:

- Provide exposure to the tools, techniques, and terminology used in the mechanical engineering profession
- Provide an opportunity to develop a solid model of a mechanical part
- Provide an opportunity to create a mechanical assembly using the modeled part
- Provide a demonstration of advanced computational tools (photorendering, finite element analysis) using the mechanical assembly

The mechanical component developed for the solid modeling exercise is a flange, as shown in Figure 2. The participants are lead through the solid modeling exercise by the instructor, using an interactive tutorial approach. The important basic skills introduced in the tutorial include:

- Interpretation of an *engineering drawing*.
- Two-dimensional *sketching*.
- Three-dimensional *extrusion*.

- Feature *copying/patterning*.

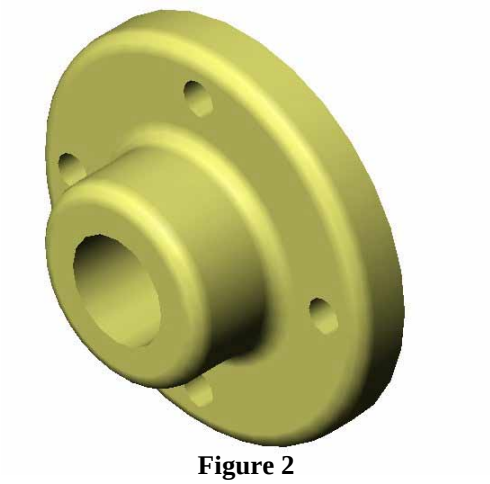

Figure 2

Flange Model

Once the tutorial is complete, participants are provided with the specifications for a second mechanical component. The component, a cylindrical flagpole, is designed to be assembled with the previously modeled flange. Participants are encouraged to model the flagpole on their own, with assistance from roving instructors. The spherical feature at the top of the pole requires the development of a new basic skill: *rotation* of a two-dimensional sketch about an axis to generate a three-dimensional shape.

After completion of the flagpole model, the concept of mechanical assembly modeling is introduced. The concept of an *assembly constraint* is developed, and participants are led through the assembly of the flagpole with the flange. This assembly is shown in Figure 3.

Completion of the two component models and the assembly generally requires approximately three-and-a-half hours (including a twenty minute break). In the remaining time, the instructor provides demonstrations of some advanced computing tools which are useful in mechanical engineering applications:

- The *SolidWorks® PhotoWorks®* add-in is used to generate a *photorealistic render*ing of the flagpole in service (see Figure 4).
- A *finite element analysis* of the flagpole model subjected load is performed, and the results shown to the class. This motivates the use of engineering analysis, and its relation to solid modeling.

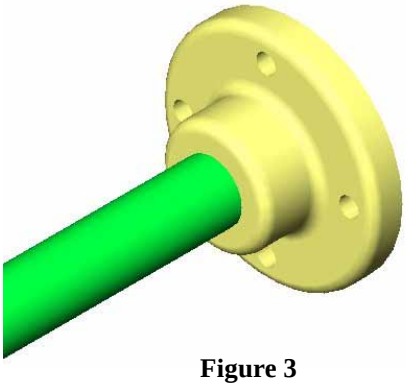

Figure 3

Flange/Flagpole Assembly

Figure 4

Rendering of Final Assembly

IV Integration of Solid Modeling in a Week-Long Design/Build/Test Experience

Each summer, MSOE sponsors a week-long outreach program entitled *Focus on the Possibilities*. It is intended to give participants an in-depth experience in an engineering discipline of their choice. Programs are offered in the disciplines of mechanical engineering, architectural engineering, and electrical/computer engineering. The mechanical engineering offering is centered around an integrated design/build/test experience involving the design and construction of a scale-model racing vehicle. The program, which has been documented in-depth in a previous paper[8], makes use of *SolidWorks®* solid modeling software and rapid prototyping technology to speed the design and construction of the vehicle, as well as to expose the participants to cutting-edge tools available at MSOE. The specific goals of the experience include:

- Provide the students with a pre-professional mechanical engineering experience, including design, realization, and testing of a mechanical device.
- Provide exposure to the tools, techniques, and terminology used in the mechanical engineering profession
- Make use of solid modeling and rapid prototyping technologies available at MSOE

As solid modeling is an integral part of the design/build/test experience, one entire day of the program is devoted to modeling and design. The experience begins with an introductory tutorial; the tutorial used to teach basic *SolidWorks®* operations is the flange exercise described in Section III of this paper. After the basic operations have been presented, a second tutorial is used to guide the participants through the design of a scale-model racer. The vehicle body used in this tutorial is shown in Figure 5.

After completion of the two tutorials, the participants have gained sufficient familiarity with *SolidWorks®* to design and model their own vehicle body. This is done with respect to a set of design constraints, including:

- A maximum envelope of 2.75" x 8" x 1.25"
- A maximum volume of 8-12 cubic inches
- Ability to dock with a standard wheeled vehicle base, for which a solid model and physical part were provided (see Figure 6).

Participants were allowed four hours to design and model their vehicle body; at the conclusion of the session, the participants created a .STL file for use by the rapid prototyping equipment.

The remainder of the week-long session was devoted to the study of engineering topics related to vehicle design, such as aerodynamics, vehicle dynamics, and materials engineering. In addition, time was allotted for assembly, decoration, and testing of the scale-model racers. The experience culminated in a "race-off" tournament.

Examples of vehicle bodies designed and fabricated by the participants can be seen in Figures 7 and 8.

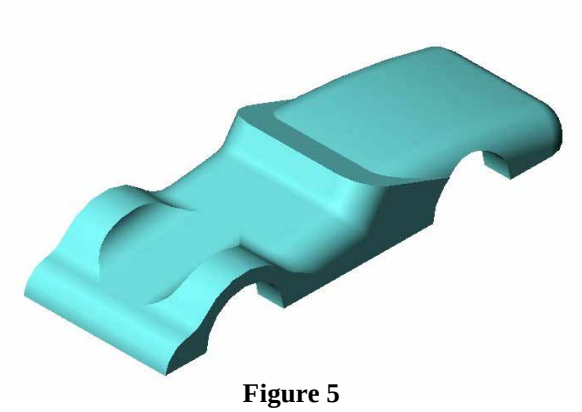

Figure 5

Car Body from Tutorial

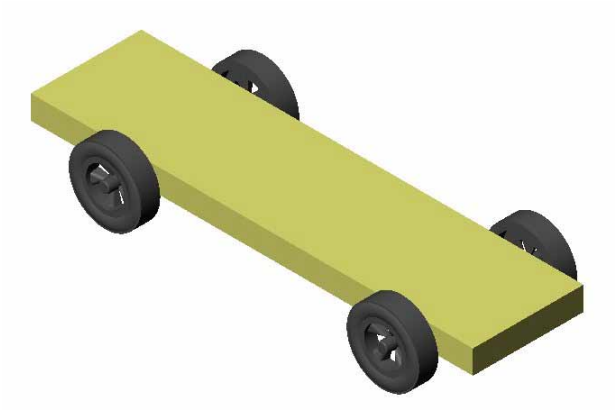

Figure 6

Standard Base for Racer Models

Figure 7

Student-Designed Racer

Figure 8

A Group of Student Racers

V Ongoing Outreach in Solid Modeling and Rapid Prototyping

With a grant from Ameritech Corporation, MSOE has participated in a program with three area high schools under which parts modeled by high school students are made in MSOE's Rapid Prototyping Center. Examples of some of the parts modeled by students are shown in Figure 9. The grant covers machine time for building the parts. The authors believe that this type of program can encourage prospective engineering students. As rapid prototyping equipment becomes less expensive to own and operate, this type of program could become popular.

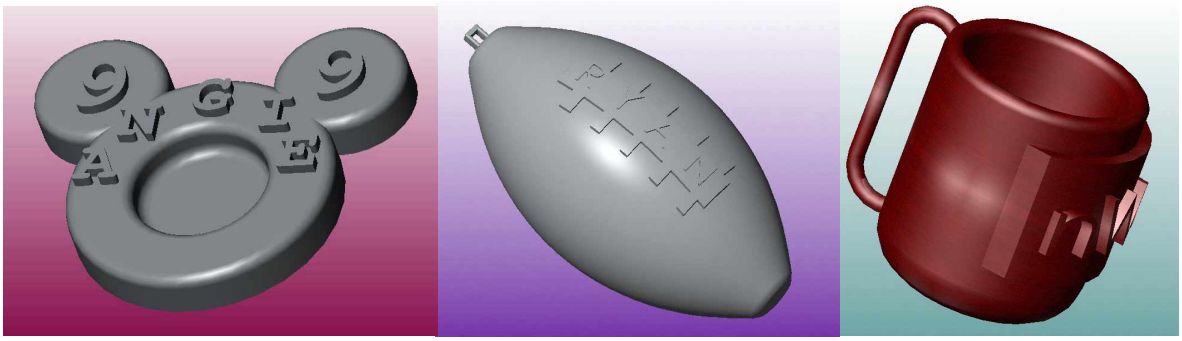

Figure 9

Parts Modeled by High School Students

VI Conclusions and Recommendations

Solid modeling with the *SolidWorks* software package has been successfully implemented in a variety of high school outreach programs at MSOE. Using this technology, outreach efforts have been transformed from passive "lecture/demonstration" experiences to active hands-on activities. Participants are able to gain experience with the tools and techniques of mechanical engineering, and in the case of programs that are integrated with rapid prototyping technology are able to realize and test their design efforts.

Based on the two years of implementation of the redesigned outreach efforts discussed in the paper, the following conclusions can be drawn:

- With carefully guided instruction, high school students can become minimally proficient with the basic features of the *SolidWorks* solid modeling package in as little as an hour. For this reason, it is an ideal choice for outreach experiences.
- Participant surveys indicate that the hands-on solid modeling activities are among the favorite activities of outreach programs.
- The solid modeling exercises are particularly popular and effective when they are coupled with the use of rapid prototyping technology. Participants appreciate the ability to realize and test the parts they have designed.

- A participant-to-instructor ratio of no more than 10:1 is recommended for implementation of a solid modeling-based outreach program. Participants with limited computing experiences need individualized attention, and a ratio on this order allows for such attention.
- In recent implementations of these programs, up to 15% of participants have had some previous solid modeling experience. With solid modeling vendors increasingly marketing their products to high schools, this percentage is expected to grow. Therefore, outreach efforts based on solid modeling must continuously adapt to provide an interesting and challenging experience for more technically sophisticated participants.

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