The RP Derby: A Design/Build/Test Experience for High School Students

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Abstract

This paper details a weeklong summer session held on the Milwaukee School of Engineering (MSOE) campus for high school students. The design experience, called the *Rapid Prototyping (RP) Derby*, was modeled after the pine car race competitions held by civic organizations; however, it made use of solid modeling and rapid prototyping tools available on campus to allow the students to design, visualize, fabricate, and test their scale model vehicles. Students were initially led through a solid modeling exercise, employing the *SolidWorks®* software package. With faculty assistance, the students were then encouraged to design their own scale model car body, within size constraints. After completing their vehicle design, the car bodies designed by the students were built using Laminated Object Modeling (LOM), a rapid prototyping technology. After receiving the parts from the LOM, the students performed finishing, final assembly, and decoration of their model cars. The testing phase included both wind tunnel testing of scale model vehicles and a race competition.

The design/build/test activities were augmented with theoretical topics related to the design of vehicles; applications of ergonomics, materials engineering, and aerodynamics in vehicle design were discussed. This balance of hands-on design/build/test activities and the exposure to topics in engineering science provided the students with a broad exposure to the field of mechanical engineering. It was well received by the participants, and will be used as a model for future programs at MSOE.

I Introduction

Each summer, Milwaukee School of Engineering (MSOE) hosts a series of one week summer sessions for high school students. The sessions are divided into two different programs: a general engineering program entitled *Discover the Possibilities*, and a discipline-specific program entitled *Focus on the Possibilities*. In the *Discover the Possibilities* program, students rotate daily through the various branches of engineering, receiving lectures and hands-on laboratory experiences in Architectural Engineering, Electrical Engineering, Mechanical Engineering, and Computer Networking. It is intended to stimulate interest in the engineering profession, provide a means to discern between the various branches of engineering, and motivate interest in MSOE. In the *Focus on the Possibilities* program, students select an

engineering discipline of their choice, and spend a week surveying topics specific to their chosen discipline. This program is intended for more academically advanced students, students with highly-focused interests, and previous attendees of the *Discover the Possibilities* program.

The Mechanical Engineering Department at MSOE has participated in the summer program for many years. In previous years, the week-long program in Mechanical Engineering designed for *Focus on the Possibilities* consisted of a series of half-day sessions on topics related to Mechanical and Industrial Engineering, each conducted by a different faculty member in their area of expertise. Example sessions included Materials Testing, Aerodynamics, Internal Combustion Engines, and Spur Gear Mechanics. While the program did provide a broad overview of the diverse topics addressed in a Mechanical Engineering curriculum, many participants felt it lacked cohesiveness.

In the summer of 1999, a new philosophical approach was taken toward the design of the *Focus on the Possibilities*. After reviewing descriptions of successful outreach programs held throughout the country[1-7], it was decided that a design/build/test experience, focused on a unified theme, could provide a more cohesive overview of Mechanical Engineering. The design of automobiles, a popular area of student interest at MSOE, was selected as the unifying theme of the experience. Against this backdrop, topics such as mechanical design, manufacturing, aerodynamics, materials engineering, and ergonomics could be introduced in a unified framework. Rapid Prototyping technology, available through the Rapid Prototyping Center on the MSOE campus, as well as the recently-acquired *SolidWorks®* solid modeling software, facilitated the implementation.

II The RP Derby: An Overview

The design/build/test experience developed for the *Focus on the Possibilities* program was modeled after the pine car competitions often held by civic organizations. The students would be responsible for the design of a scale-model race car; the week would culminate in time trials. The following table details the schedule for the program.

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Morning	*SolidWorks®* Demo	Rapid Prototyping	Manual Processing of Parts	Aerodynamics	Time Trials
Afternoon	Vehicle Design using *SolidWorks®*	Ergonomics	Internal Combustion Engines	Materials Testing	Open House
Evening				Vehicle Decorating and Painting	

A. Day One: Vehicle Design

The first day of the program involved the use of the *SolidWorks®* to design a vehicle body. Wheeled bases were available; the vehicle body would be constrained to dock with the existing bases, shown in Figure 1.

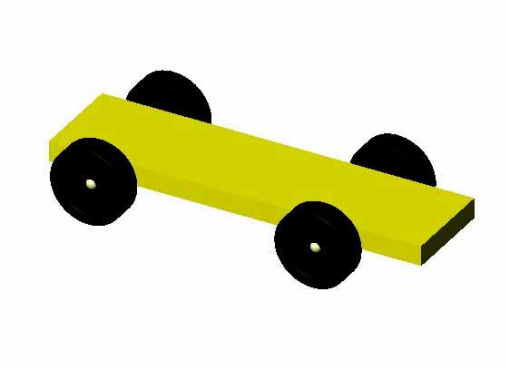

Figure 1: Solid Model of the Vehicle Base

While the students had a wide range of academic backgrounds, few had any solid modeling experience. *SolidWorks®* has proved to be an ideal teaching tool for such environments. In the morning session, the students were lead through the modeling of an example vehicle body. The example vehicle can be seen in Figure 2.

Figure 2: Solid Model of Example Vehicle Body

After stepping through a tutorial, the students had constructed a solid model of the vehicle; in addition, they had acquired the necessary skills to begin developing their own designs. The afternoon session was devoted to allowing the students to either modify the model developed in the tutorial or to develop their own design from scratch.

B. Day Two: Prototyping/Ergonomics

1. Rapid Prototyping: The Rapid Prototyping Center (RPC) on the MSOE campus proved to be an invaluable resource for the design/build experience. STL files generated by the students using *SolidWorks®* were transmitted to the RPC. Laminated Object Modeling (LOM), a rapid prototyping technology in which three-dimensional models are built up from heat-laminated, laser-cut paper sections, was used to construct the models. The students were able to tour the RPC, and received an overview of such technologies as stereolithography, fused deposition modeling, and selective laser sintering; in addition, they were able to observe their parts being fabricated on the LOM machine.

Laminated object modeling proved to be an ideal choice for this application. The large build area allowed the construction of all of the vehicle bodies in a single machine run; this proved to be both a time-efficient and cost-effective operation. In addition, the parts fabricated on the LOM require a moderate amount of post-processing; parts must be removed from surrounding material (a process called "decubing"), sanded, and sealed before they can be used. This would allow for the introduction of additional hand-on manufacturing techniques.

2. Ergonomics: The scale model vehicle designed in this program were 1/20 scale; ergonomic aspects were ignored in the design. However, the design of automobile bodies involves the design of ergonomically correct seats, displays, and control devices. Students were encouraged to apply these principles to a hypothetical full-scale version of their vehicle design.

C. Day Three: Manufacturing/Internal Combustion Engines

1. Parts Post-processing: After fabrication of the basic part shape on the LOM, the students were required to perform a number of hands-on post-processing operations to complete the manufacturing process. These included:

- Decubing: This involves the removal of excess material around the basic part, which is a function of the rapid prototyping process. Simple tools, such as screwdrivers and hobbyist knives, are required. Figure 3 details this process.
- Sanding and Sealing: The decubed parts would eventually be painted and decorated by the students. A necessary preliminary process involved a light hand-sanding operation, followed by the brush application of an acrylic sealant.

These hands-on activities allowed the students to experience the hands-on laboratory component to the engineering profession, while also allowing the students a chance to work and socialize in an open environment.

2. Internal Combustion Engine Fundamentals: In keeping with the automotive theme of the design/build experience, the students were introduced to the fundamentals of internal combustion engines. The model of a piston as a slider/crank was shown, allowing for applications of principles of simple trigonometry in the development of a simple model. An engine test cell was shown, and the effects of ignition timing on power output were discussed.

Figure 3: Decubing of a part fabricated on the LOM

D. Day Four: Aerodynamics/Materials

1. Aerodynamics: The design of a vehicle body is an ideal application for introducing concepts of aerodynamic drag. The basics of aerodynamics were introduced; in addition, a wind tunnel and smoke tunnel were available for conducting aerodynamic tests. Scale model vehicles, available from the Society of Automotive Engineers competition teams at MSOE, were used in wind tunnel and smoke tunnel demonstrations.

2. Materials Engineering: The need for strong, lightweight materials in automotive design was used to motivate a discussion on materials engineering. Tools such as tensile test equipment and a scanning electron microscope were demonstrated for the students.

3. Vehicle Painting/Decoration: Students were encouraged to include aesthetically creative and decorative elements in their vehicle designs. An informal session was held the night before the time trials to allow the students to decorate and perform final assembly of their vehicles. Spray paints, decals, and detail paints were provided. Figure 4 shows a completed car body.

E. Day Five

1. Time Trials: A single car track, instrumented with reflective photoeyes and a microprocessor, was constructed. Student time trials were held, to allow for the testing component of the experience. In addition, the principles behind the timing system were introduced, and simple principles of statistics were applied to the time trial data.

2. Open House: In the afternoon of the final day, parents were invited to tour the laboratory areas. A slide show detailing the events of the week was available.

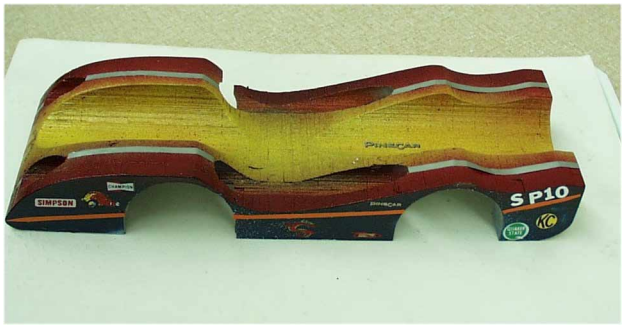

Figure 4: Completed car body

III Conclusions

Based on the first implementation of the RP Derby, the following conclusions have been drawn:

- *SolidWorks®* is an invaluable tool for this type of short program. In just a few hours, the high school students were able to gain sufficient proficiency to design a simple scale model vehicle body.
- Rapid prototyping technology is an ideal tool for a design/build/test experience. Students can bring their designs to realization without having to use shop facilities, or resorting to alternatives such as the use of prefabricated blocks or cardboard models.
- The use of a design/build/test experience provides an ideal unified theme upon which to build; topics such as solid modeling, manufacturing, aerodynamics, materials, and ergonomics could be introduced in context, providing an additional level of interest and understanding.

Participant surveys confirmed that the design/build/test experience was viewed as a success by the students. A summary of the survey follows:

Rating:	Excellent	Good	Average	Poor	No Opinion
Number of Respondents:	6	2	1	0	0

Positive student comments focused on the use and application of *SolidWorks®* as the most enjoyable experience in the summer program.

This design/build/test experience proved to be an innovative and successful summer program implementation. Future summer programs in the Mechanical Engineering area will continue to follow this model.

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