

Involving Middle School Students in Customer Focused Undergraduate Manufacturing Education

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Abstract

K-12 engineering outreach programs are gaining in popularity as vehicles for getting students interested in engineering at an early age. This paper presents such a program that is integrated with the undergraduate mechanical engineering curriculum at Lehigh University. Annually, approximately eighty mechanical engineering juniors complete a three-credit course entitled *ME 240-Manufacturing*. This course exposes them to a wide array of manufacturing processes from a scientific, business and social standpoint. The course is innovative in that manufacturing science knowledge is acquired while students simultaneously develop skills in the areas of teamwork, project management, business analysis, and customer focused product realization. An additional innovation is the creative inclusion of approximately 120 local middle school students. These students benefit by developing an awareness of engineering as a potential future career at a critical age. The cooperative university/middle school learning environment has been found to be one that the students enjoy and the ME 240 experience has become a favorite of the Lehigh and middle school students alike.

Introduction

K-12 engineering outreach programs are increasing in popularity and number as universities and secondary schools act to address the shortfall of U.S. students in science and math¹. The rationale for introducing engineering at an early age is described thoroughly in the references and will not be covered presently. Support and impetus for these programs come from the National Science Foundation's Research Experience for Teachers (RET) and Graduate Teaching Fellows in K-12 Education (GK-12) programs, among others.

Many of the K-12 programs involve hands-on work in analyzing an engineering problem and are designed to actively engage the student in the hope of developing an interest in engineering as well as demystifying what is an ominous subject for many students. Scores of universities have begun programs with approaches as diverse as the populations they serve, starting as early as kindergarten. Some programs focus on helping the K-12 teachers improve their teaching of engineering concepts² while others follow a more interactive approach with university faculty and students³ and still others have designed curricula to be introduced by a visiting engineering

professional⁴. Some states, such as Massachusetts⁵ go as far as to require engineering education as part of the K-12 curriculum.

Regardless of the methods used, efforts should be made to follow up on progress made. Poole, et al⁵ describe an assessment plan that was developed for a fledgling outreach program to determine if it was accomplishing its goals as well as to guide future program development. It can certainly be expected that a number of studies will be conducted in the near future to determine if the growing number of outreach programs are indeed having their intended effect—increasing the number of domestic engineering graduates entering the workforce.

General Course Description

The manufacturing course at Lehigh, which was developed in its original form in 1993, attempts to produce graduates who can transcend traditional disciplinary boundaries. This is done by delivering a course that mimics real-life professional situations whenever possible. The course contains a series of 28 lectures that introduce the students to material science, engineering, and business issues underlying the primary manufacturing processes employed in industry today. Specific topics covered include material removal processes, material deformation processes, molding processes, and joining. A large range of material types is discussed including metals, polymers, composites, glasses, and ceramics. In addition, other critical areas such as measurement and inspection, quality control, product quality optimization, production systems, and manufacturing economics are explored. The lectures are provided to the students in an electronic format that enables significant student discussion and active participation in the classroom, as opposed to note taking. Short in-class quizzes are routinely given during lecture to ensure that students are keeping up with the subject matter.

The classroom learning is augmented by hands-on laboratory experiences that students complete each week during the semester. These experiences, which were developed with significant input from industrial advisors to the program, expose the students to a number of specific manufacturing processes as well as the range of activities that take place within manufacturing enterprises. The hands-on laboratories cover the following areas:

- Computer Aided Design (CAD) & modeling
- Numerically Controlled (NC) Machining
- Joining (welding, brazing, and soldering)
- Composites Manufacturing
- Rapid Prototyping
- Manual Machining
- Metal Deformation
- Thermoforming
- Injection Molding

Throughout the course, students utilize leading commercial computer based design, NC toolpath generation, and process simulation software packages to support their activities in the associated physical manufacturing laboratories. Laboratory section sizes are limited to assure that individualized instruction is available to every student. This is made possible by the personal involvement of two faculty members, a full-time professional machinist, and two dedicated and qualified graduate teaching assistants. This level of instructional staff commitment enables each

laboratory experience to be offered four times per week to accommodate the number of students involved.

Cooperative Design and Manufacturing Experience

As the semester progresses, the course builds toward an independent and competitive design and manufacturing project that students complete in small groups. To expose the Lehigh students to product realization in a customer focused environment, the project has been designed to include collaboration between the university and Broughal Middle School. Broughal was selected in an effort to expose engineering as a potential and realizable career option to students that today are underrepresented in American universities in general and engineering schools in particular.

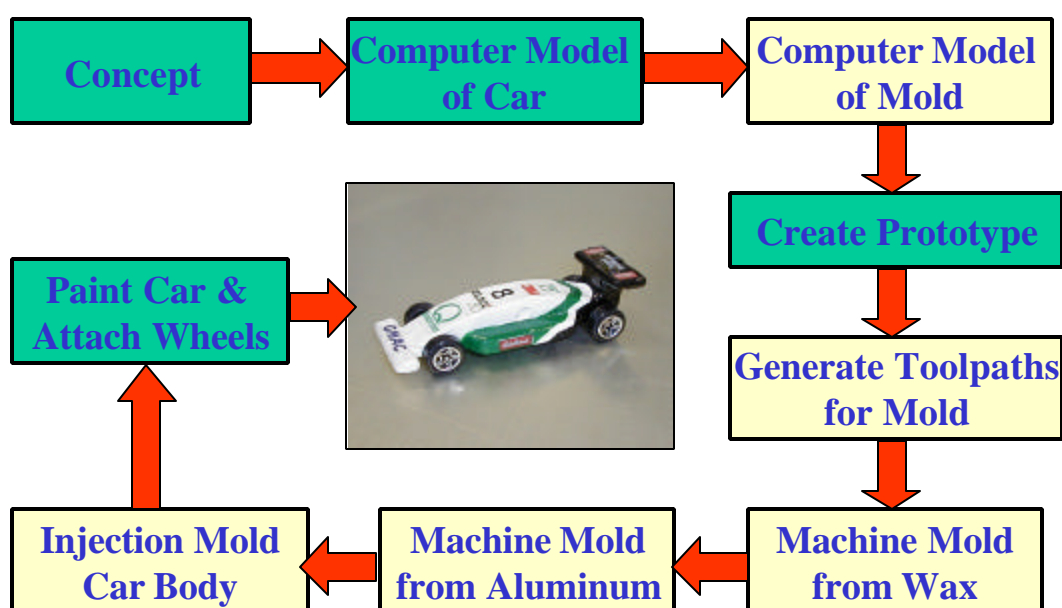


Figure 1 – The scope of the Lehigh/Broughal design and manufacturing experience.

The student population at Broughal is approximately 75% Hispanic, and generally from lower income families. Providing the middle school students with an early awareness of engineering develops an interest in and appreciation of engineering as a career, which subsequently motivates them to take their studies of math and science seriously, and make critical college preparatory decisions during their early high school years. In addition, students at Broughal also satisfy the criteria for several applied learning standards set by the school district and the State of Pennsylvania.

The collaborative project assignment during recent years has been to design and manufacture a “Matchbox” sized toy vehicle following the sequence of engineering steps presented in Figure 1. This progression from concept to finished project is intended to mimic the product development cycle one might encounter in industry. During the 2001-2002 academic year, approximately 60

eighth grade students from Broughal teamed-up with nearly 80 Lehigh students to complete the project. The students were split into 26 teams working competitively against each other. Each group had five or six members, typically three Lehigh students and two to three Broughal students. The members from Lehigh on each team assumed the detailed design and manufacturing responsibility, while the students from Broughal participated as customer representatives, concept designers, and finishing experts. The project teams were formed early in the semester, with significant team collaboration continuing throughout a three-month period. The middle school students were heavily involved in the completion of the tasks shown shaded in green in Figure 1.



Figure 2 – Lehigh and Broughal Middle School students discussing initial product concept ideas.

As shown, each team started with the development of concept sketches and ended with the delivery of final vehicles. The concept sketches were drawn by the Broughal students and modified during initial team meetings that took place mid-semester (Figure 2). The conceptual designs were then developed as three-dimensional computer models during the first lab week of the project. Middle School students came to the Lehigh CAD lab to watch and learn the process of creating a CAD model as well as to provide some input to their Lehigh teammates on its progress (Figure 3).

The CAD model of the vehicle body was refined (Figure 4) and then used to generate physical prototypes of the vehicles. This was accomplished using a Stratasys fused-deposition modeling (FDM) rapid prototyping system recently purchased by Lehigh. After being approved by the teams, the rapid prototypes were then painted by the Broughal students to be used as marketing tools (also Figure 4).



Figure 3 – Lehigh and Broughal students generate a three-dimensional computer model of their selected vehicle design.

Photos of the prototypes, images from the CAD system, concept sketches and descriptions of the process were combined to produce presentation posters and t-shirt designs, which were on display during an annual Manufacturing Expo (see next section).



Figure 4 – CAD model of a vehicle and the corresponding painted rapid prototype.

While the Broughal students were finishing the prototype vehicles, the Lehigh students designed and fabricated injection molding tooling from aluminum plates using an NC milling machine. The Broughal students were also exposed to rapid prototyping, NC machining and injection molding demonstrations (Figure 5) during their time at Lehigh to ensure that they understood the total product development and realization process.

Once the students finished their production tooling, actual final vehicles were injection molded using one of Lehigh's injection molding machines. Accomplishing this required the selection of

an appropriate material and the optimization of injection molding processing conditions using commercial molding simulation software. The end result of this was the molding of the actual vehicle products during the last week of the project.



Figure 5 – A Lehigh instructor gives an NC machining demonstration to visiting Broughal Middle School students.

The last step prior to product launch was to paint and finish the vehicles. This was accomplished by the middle school students using model paints, decals and wheels supplied by Lehigh. The students' imaginations once again went to work to create many unique and colorful designs (Figure 6) with some teams producing multiple finish designs for their vehicle. The vehicles were now ready for unveiling at the Manufacturing Expo.

Annual Manufacturing Exposition

To celebrate the Lehigh University/Broughal Middle School educational partnership, the project culminates each year with a MANUFACTURING EXPO, which is a design competition and vehicle race held at the end of the semester. The itinerary for this public event includes a poster session and presentation of the finished vehicles. The final products are judged primarily by a group of 60-80 Broughal sixth graders who attend the event. These sixth graders also receive an introductory exposure to engineering and the product realization process through a demonstration-based laboratory tour and many of them become full project participants during the following years. The latest Manufacturing Expo, held on May 3, 2002, was attended by approximately 300 to 400 people. The design presentation and poster session was well received, and was followed by the featured event—a spirited, head to head downhill race involving all of the final vehicle designs. The event was broadcast live over a regional radio station, and covered by a number of radio, television and print media outlets.

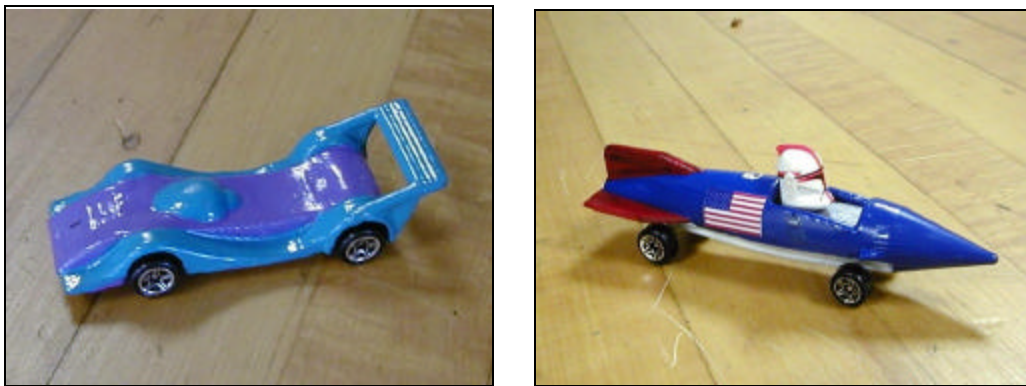


Figure 6 – Examples two final vehicles—“Team Fyre” (left) and the “Rocket Car” (right)—developed and produced by Lehigh/Broughal student teams.



Figure 7 – Two middle school students cheer their vehicle to victory at the annual Manufacturing Expo race.

Conclusion

An innovative manufacturing education program has been successfully developed and implemented at Lehigh University. It is unique in that it serves the dual role of effectively training college students while simultaneously exposing enthusiastic middle school students to engineering as a potential career. The program has been well received at both Lehigh and the Broughal Middle School and can be readily adopted by other universities. Further information related to the development, implementation and enhancement of this educational concept can be obtained by contacting any of the above authors.

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