



Customer Focused Undergraduate Manufacturing Education Incorporating Middle School Students

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The present paper focuses on a manufacturing education program that exists as a major component of the required undergraduate mechanical engineering curriculum at Lehigh University. Annually, approximately 80 mechanical engineering juniors complete a three-credit course entitled ME 240: Manufacturing. This course exposes them to 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.

General Course Description

The manufacturing course at Lehigh, which was developed in its original form in 1993, attempts to educate students who can transcend traditional disciplinary boundaries. This is done by delivering the course in a way 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 each lecture to assure 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 product design, manual machining, computer numerical controlled (CNC) machining, metal deformation, rapid prototyping, joining, welding, brazing, soldering, thermoforming, injection molding, quality control, measurement and inspection, and composites manufacturing. Throughout the course, students utilize leading commercial computer based design, tool path generation, and process simulation packages to support their activities in the associated physical manufacturing laboratories. Laboratory section sizes are carefully controlled to assure that every student gets individualized instruction. 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 multiple times to accommodate the number of students involved.

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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 Lehigh 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. The student population at Broughal is greater than 50% Hispanic, and generally from lower income families. Providing such 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 both take their studies of math and science quite 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 as well as by the State of Pennsylvania.

The specific collaborative project objective during recent years has been to design and manufacture a toy vehicle similar in size to the common toys sold by *Matchbox* and *Hot Wheels*. The sequence of engineering steps required to do this is presented in Figure 1. During the 2000-2001 academic year, 60 seventh grade students from Broughal teamed-up with the 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 in green in Figure 1.

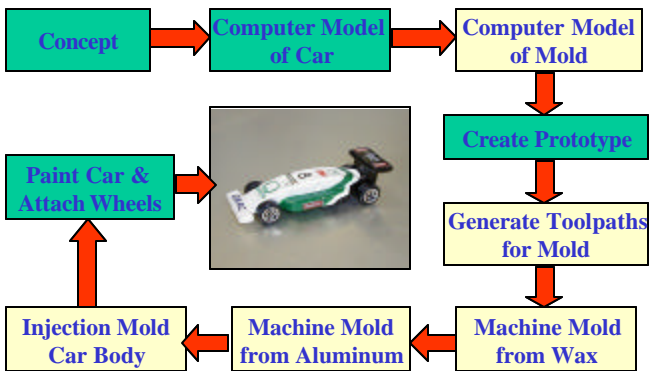


Figure 1: The scope of the Lehigh/Broughal Middle School design and manufacturing experience

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 such as that shown in Figure 2. The conceptual designs were then converted into three-dimensional computer models, as shown in Figure 3.



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



Figure 3: Lehigh and Broughal Middle School students generating a three-dimensional computer model of their selected vehicle design.

The computerized designs were then refined and employed to generate physical rapid prototypes of the vehicles. This is accomplished using a Stratasys fused-deposition based rapid prototyping system recently purchased at Lehigh. A rapid prototype of a resulting vehicle before and after the removal of the dark support structure material is shown in Figure 4. After being



approved by the teams, the rapid prototypes were then painted by the Broughal students for product marketing and advertising purposes.

While the Broughal students were finishing the rapid prototyped vehicle versions, the Lehigh students designed and fabricated aluminum injection molding tooling for actual production using a CNC milling machine. The Broughal students were exposed to CNC machining demonstrations such as that shown in Figure 5 to assure that they understood the total product realization process.

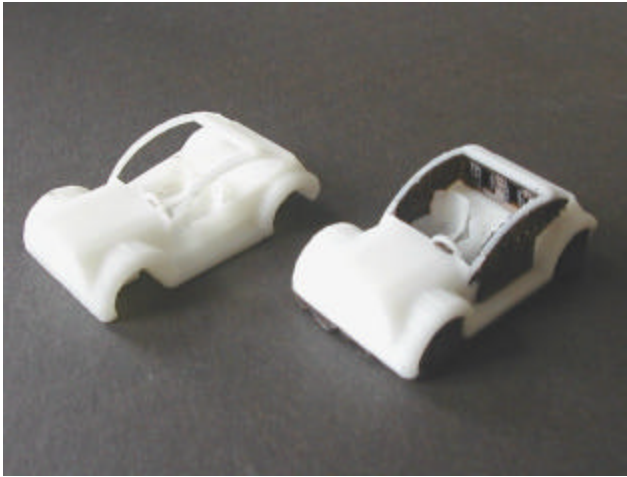


Figure 4: A rapid prototype of a vehicle both before and after the removal of the dark support structure material.



Figure 5: A Lehigh student giving a CNC machining demonstration to visiting Broughal middle school students.

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 vehicle products such as

that shown just prior to ejection from the tooling in Figure 6.

The last stage of the product realization process, which was led by the Broughal middle school students, consisted of the finishing of the final products. The vehicles were painted and wheels were attached. This resulted in vehicles that were fully ready to provide to the marketplace.

Annual Manufacturing Exposition Component

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 and receive an introductory exposure to engineering and the product realization process through a demonstration-based laboratory tour. Since the Broughal project team members are seventh graders, many of the sixth graders become full project participants during the following year. The latest Manufacturing Expo, held on May 4, 2001, was attended by approximately 400 people. The design presentation and poster session was well received, and was followed by the highlight event, which was a head to head downhill race competition involving all of the final vehicle designs. The event was broadcast live over a regional radio station, and covered by a number of television stations, magazines, and newspapers.



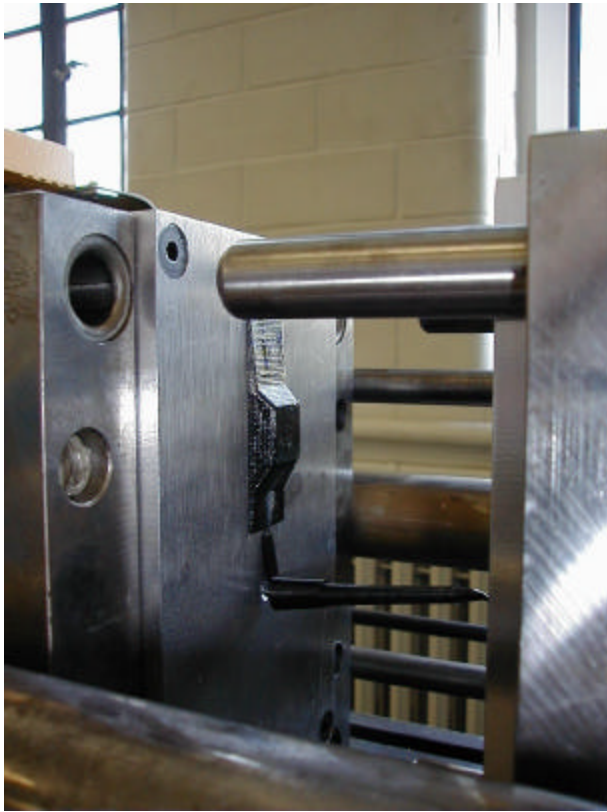


Figure 6: Injection molded vehicle before it is ejected from the mold.



Figure 7: An example final vehicle, in this case “The Shark Car,” developed by a Lehigh/Broughal student team.

Conclusion

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

