RAPID PROTOTYPING AS AN INSTRUCTIONAL AND RECRUITMENT TOOL FOR ATTACTING QUALIFIED HIGH-SCHOOL STUDENTS TO ENGINEERING AS A CAREER OPTION

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Since the summer of 1999, the College of Engineering at the University of Arizona (UA) has been offering a Summer Engineering Academy (SEA) to attract qualified women and underrepresented minority high school students to consider engineering as a career option. In this program, UA and Advanced Ceramics Research, Inc. (ACR) teamed to make the students aware of the state of the art in manufacturing technology. This was done by providing an opportunity for the student teams to design and rapid prototype components for aerodynamic automobiles. Subsequently, these cars were tested in a specially designed wind tunnel and a special prize was awarded for the most aerodynamic design. Students were trained to use SolidWorks™ software and Fused Deposition Modeling (FDM™) for Computer Aided Design (CAD) and rapid prototyping (RP), respectively. The design and model competition results were presented to the parents and faculty members of the College of Engineering. This innovative summer program offered high school students a glimpse of state of the art technology and helped to create excitement towards engineering as a career option.

I. INTRODUCTION

The recent explosive growth in computer power and connectivity is reshaping relationships among people and organizations, and transforming the processes of discovery, learning and communication [1]. Technologies such as computer-aided manufacturing hold much promise for educating and training a workforce for the new millennium. In the 21st century, American competitiveness and worker prosperity will be tied to the education and skill attainment of the workforce [2]. Future workers will need to update their knowledge and skills continuously. Dynamic partnerships and collaborations are essential to ensure that all Americans have affordable and convenient access to acquiring the knowledge necessary for the 21st century economy. The economic health of the Nation and the individual well being rest on the success of this team effort.

Investing in the education and training of the future American workforce will yield significant advantages for individual workers and employers alike, especially given the drive to create high-performance workplaces that emphasize worker autonomy and flexibility [2]. Workers with advanced or upgraded skills are one of the key investments for competitive business performance, which in turn are essential to raising the standard of living for all Americans [2]. The advantages of a highly trained and motivated workforce are clear. For example, one study found that establishments whose workforce had a 10 percent higher than average educational attainment level had an 8.6 percent higher than average productivity level [2]. Apart from productivity improvements, employees with a higher educational attainment level also are rewarded in a variety of ways, since employers recognize that a more skilled and educated workforce perform better.

The most obvious benefit to an employee with skills and education is higher wages. For example, in 1997, the average college graduate made 77 percent more than the typical high school graduate - $40,478 compared to $22,895 [2]. The economic payoff of a better-educated workforce is uniformly higher for both new and returning adult students. The unemployment rates are also lower for a better-educated workforce. A study of the unemployment levels and educational attainment between 1970 and 1997 found that higher educational attainment offers greater employment security [2].

As recently as the 1950s, 20 percent of the workforce was professional, 20 percent was skilled, and 60 percent was unskilled. In contrast, by 1997, while professionals continued to be 20 percent of the workforce, less than 20 percent are unskilled workers, while more than 60 percent are skilled workers [2 and references therein]. The US economy is projected to generate nearly 19 million new jobs in a ten-year period from 1996 to 2006, or 14 percent on average increase per year. Jobs requiring a bachelor's degree will increase 25 percent, nearly double the predicted national average [2]. Although these jobs vary in the type of industries, uniformly and increasingly, these new jobs will require a greater variety and portfolio of skills. These include basic, technical, organizational, and company-specific skills. Basic skills such as reading, writing, and computation are needed in jobs of all kinds. Technical skills would include baseline computer skills as well as computer-aided design and drafting for the manufacturing jobs of the future. As jobs of the future would require a greater degree of employees and customers, communication skills, analytical skills, problem solving, creative thinking, interpersonal skills, the ability to negotiate and influence, and self-management are necessary to be successful [2]. New technology, market changes, and competition drive companies to innovate, constantly upgrade products and services, and focus on continuous improvement of work

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processes. Therefore, in the future, employees must frequently acquire new knowledge and skills specifically relevant to the company's products and services, and their production processes or service delivery modes.

The reasons for this demand are many. Many products manufactured today incorporate advanced technologies such as digital circuits and advanced materials. Their manufacture relies on an array of automated technologies that control production and check quality. Materials delivery and product distribution also require understanding and applying sophisticated computerized information systems. Technology and knowledge are used increasingly to raise the value of services and products. The ability and availability of a modern workforce fully knowledgeable in such advanced technologies can help a business differentiate its service from that of its competitor and provide an edge in the marketplace. The primary market for such a workforce with the necessary technological background is from our children who are currently in secondary school (grades 9-12).

The importance of preparing and providing the necessary background for our children to face the workplace of the future can be understood from a recent report of the National Science Board, the governing body of the National Science Foundation [3]. In a previous report, the National Science Board (NSB) also urged "all stakeholders in our vast grass-roots system of K-12 education to develop a nation-wide consensus for a common core of knowledge and competency in mathematics and science" [4]. This report also states, "In the global context, a scientifically literate population is vital to the democratic process, a healthy economy, and our quality of life" [4]. The future of the Nation is maintained through a continuous flow of talent into its science and engineering workforce – talent that consists of certain core skills and competencies derived from education and training shaped by the highest standards of quality [3]. The NSB believes that the Nation's economy would be best served by those people who are prepared for careers that produce the next generation of knowledge, products and processes in all sectors of the economy [3]. The two NSB reports [3, 4] specifically discuss setting content standards for improving math and science education. However, it could be argued that the issues raised by these two reports are equally relevant to the issue of motivating and enhancing student recruitment into engineering careers. Only students trained in the new technologies will be able to meet the challenges of the industries of the future.

An education system that has science, mathematics, engineering and technology education as its essential components is important to prepare our children for the future workplace. The NSB report goes on to say that, while US graduate education remains the envy of the world, the declining interest and participation of domestic students in science and engineering must be taken as a disturbing sign that K-12 mathematics and science education is failing to renew, expand and prepare our talent pool [3 and references therein]. The implication is that new innovative solutions must be found to prepare and motivate our youngsters to enter and be successful in the workforce of the future. These are perhaps best achieved through local strategies that promote academic achievement in mathematics and science with help from the federal level from agencies such as the Department of Education and the National Science Foundation [3].

The University of Arizona has been active in increasing the recruitment of qualified high school students into its engineering programs using its Summer Engineering Academy (SEA) and involvement in the Math, Engineering, and Science Achievement (MESA) program with the area schools. The Multi-cultural Engineering Program (MEP) at the College of Engineering, University of Arizona conducts the SEA for recruiting qualified high school students nationwide. This is used primarily as recruiting tool for the College of Engineering. In order to create excitement and interest in various engineering disciplines, the College recognized the need to adapt and tailor the SEA program to student interests and aptitudes. The Director of the MEP program decided to modify the SEA program based on student input and feedback. He visited several high schools in Arizona and met with students as well as high-school administrators and teachers. The student input suggested a need to radically change the SEA program content. For example, the Director asked the students, "How does a design idea become a reality"? The response from the students strongly suggested that the SEA program could include Computer-aided Design (CAD) and Rapid Prototyping (RP).

The university has several joint research programs with Advanced Ceramics Research Inc. (ACR), a local small business with expertise in rapid prototyping (RP) technology and advanced materials. The university requested ACR's assistance in developing a program to allow high school students to become familiar with engineering design, rapid prototyping and materials. The goal of this effort was to:

- Give high school students a look at the opportunities and experiences that engineering offers,
- Expose prospective engineers to a college campus and a manufacturing organization, and
- Create innovative cooperative partnerships between academic and industrial institutions.

II. Results of the Summer Engineering Academy (SEA) Program

The fundamental idea behind the SEA program was to show prospective engineers exactly how an idea becomes reality. In the current year program, two groups consisting of 35 freshmen and sophomores and 47 juniors and seniors participated. Among the juniors and seniors, there were 14 female students and 17 male students from under-represented groups. In this program, the students, separated into teams, were asked to design aerodynamic cars whose coefficient of drag would be determined in a wind tunnel. The students were taught the general concepts of materials science, aerodynamics, CAD, and rapid prototyping by selected faculty from the University of Arizona College of Engineering. Five undergraduate guidance counselors trained the students to use Solidworks™ to design the models. The students visualized and modeled aerodynamic cars and prepared .stl files of the cars using Solidworks™. Examples of model cars are shown in figures 1 and 2. The .stl files were emailed to ACR, who prepared the .sml files for building the parts using an in-house FDM 1600 machine. The students toured the ACR rapid prototyping facilities while the models were being built. They were excited by the fact that the models they had conceptualized and designed were being built in their presence.

The prototype cars were then tested in a specially designed and built wind tunnel at the University of Arizona College of Engineering. The students obtained first-hand experience of the principles of aerodynamics by actually seeing their concept models tested in the wind tunnel. The wind tunnel is shown in figure 3. A close up image of a model in the wind tunnel is shown in figure 4. The wind tunnel data was analyzed and interpreted by the students.

This provided them a feedback as to how their cars would perform if they were built to full scale. Additionally, program managers from the Department of Transportation presented concepts for a transportation system of the future.

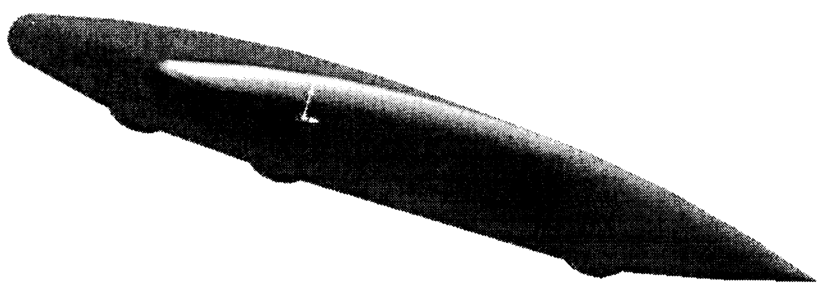

FIGURE 1. A SOLID MODEL PREPARED BY PARTICIPANTS IN THE SEA PROGRAM

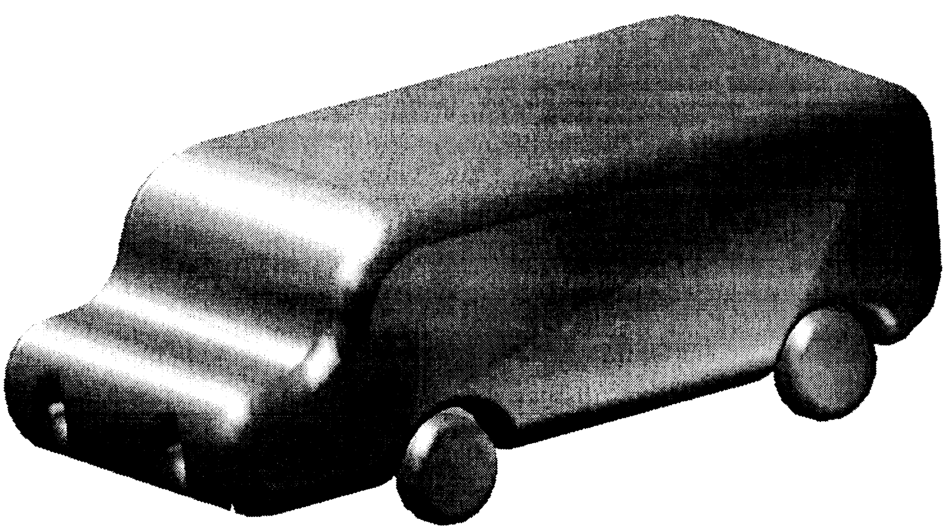

FIGURE 2. A SOLID MODEL OF A SCHOOL BUS/VAN PREPARED BY PARTICIPANTS IN THE SEA PROGRAM

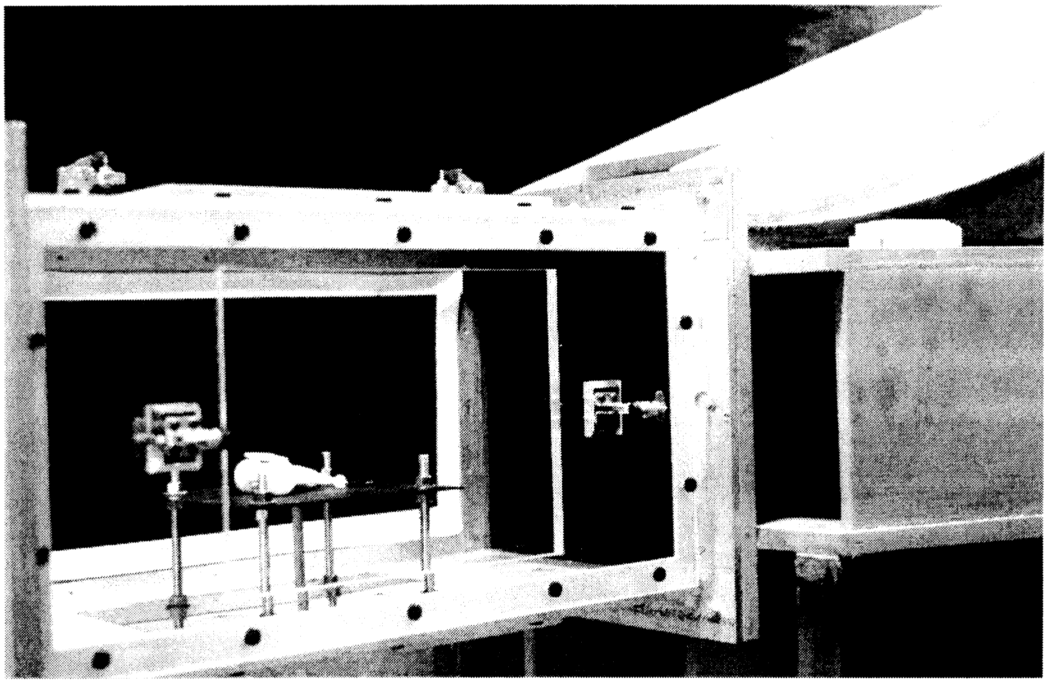

FIGURE 3. AN IMAGE OF A PROTOTYPE CAR INSIDE THE WIND TUNNEL

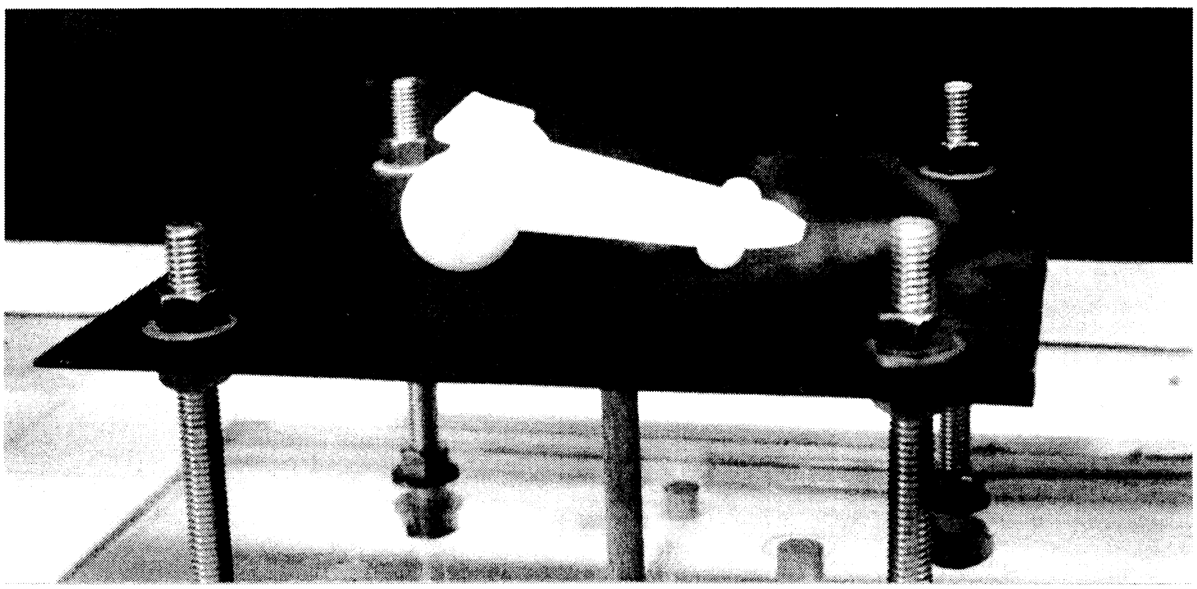

FIGURE 4. CLOSE UP VIEW OF THE PROTOTYPE CAR INSIDE THE WIND TUNNEL

III. Discussion

The results from the SEA program were encouraging to both ACR and the University of Arizona. The response from the high school students and their parents were overwhelmingly positive and showed that this innovative educational experiment combining CAD and RP was successful in showing how exciting engineering careers of the future could be to potential engineers. The SEA program introduced high school students to many different engineering disciplines. All the students loved working with the CAD software, since it was user-friendly and intuitive. A large number of students expressed an interest in joining materials science and mechanical engineering disciplines. The program was so successful that the College of Engineering has already received many inquiries from the parents of high school students interested in attending the SEA program in 2001. Future program information can also be obtained by contacting Cecilia Gaxiola, Engineering Bldg. Room 200, P. O. Box 210020, AZ 85721-0020, Tel: 520-621-4018. E-mail: Gaxiola@engr.arizona.edu

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3. "Preparing our children: Math and Science Education in the National Interest," available at http://www.nsf.gov/nsb/documents/1999/nsb9931/nsb9931.htm.
4. National Science Board, Failing our children: Implications of the Third International Mathematics and Science Study, July 31, NSB-98-154, hereafter referred to as the "July Statement".

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SCHEDULE OF ACTIVITIES:

Day 1.

- Introduction to Engineering by Ray Umashankar, Director MEP
- Lecture on Fundamentals of Computer modeling & Design by Professor Chris Choi
- Demonstration of design software package SolidWorks by UA Engineering Students
- SEA participants start learning SolidWorks in teams of 3 and design automobiles.

Day 2.

- Lecture on Fundamentals of Aerodynamics by Professor Al Ortega
- Tour of large wind tunnels
- Demonstration of Aerodynamic solar car project by UA Solar car club
- Lecture on Materials in engineering and rapid Prototyping by engineers from Advanced Ceramics Research and Raytheon
- Students continue aerodynamic car design, using SolidWorks

Day 3.

- Continuation of Aerodynamic car design
- Lecture on Finite Element Analysis and use of ANSYS software by Professors Erdogan Madenci and Todd Anderson
- Student car designs sent to Advanced Ceramics Research by e-mail

Day 4.

- Visit to Advanced Ceramics Research and Raytheon for tour of facilities and witnessing the Rapid Prototyping process.
- Students testing their car designs in the specially built wind tunnel and taking digital photographs.
- Students learning to use PowerPoint for their final presentations.

Day 5.

- Students fine tuned their final presentations.
- Students make their presentations to an audience of nearly 300 people consisting of Deans, department heads, invited guests, family and friends.
- Each team member speaks about a particular part of the design process and the academy.
- Awards given to best design, completion of problems.
- Reception and awards ceremony: Overall best design award went to a team of three women high school students.
- Evaluation: In the written evaluations, many students indicated that for the first time they understood what real world engineers did, what tools were available and finally their own decisions to pursue engineering were firmed up as a result of this program.