

Summer Engineering Academy (SEA), an innovative university- industry partnership to improve the recruitment of qualified high-school students into engineering disciplines

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Abstract

To improve the number of qualified high school students entering into engineering disciplines, the University of Arizona (UA) and local businesses have created a program called the Summer Engineering Academy or (SEA). The SEA program has proven to be highly successful during the summers of 1999 and 2000. The idea behind the SEA program is to show students how a concept becomes reality. On this program, student teams designed and rapid prototyped aerodynamic vehicles using SolidWorks™ and Fused Deposition Modeling (FDM™) for Computer Aided Design (CAD) and rapid prototyping (RP), respectively.

In 1999, two groups of 35 freshmen-sophomores and 47 junior-seniors participated, while in the 2000 program, 52 freshmen-sophomores and 40 junior-seniors attended. Out of the students who attended the program in 1999, 27 students from the senior batch have enrolled in the University of Arizona engineering programs. In both of the programs, 68 female students and 57 students from under-represented groups participated. The students were taught concepts of materials science, aerodynamics, CAD, and rapid prototyping by faculty from UA. The students visualized and modeled to prepare CAD files of the cars. The parts were built using a Fused Deposition Modeler. The vehicles were then tested in a wind tunnel and prizes were awarded for the best aerodynamic design. The students also toured the ACR and Raytheon rapid prototyping facilities during the weeklong program. The design and model competition results were presented to the parents and faculty members of the College of Engineering.

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 millenium. 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, even for those who are fired, laid off or downsized [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 interaction between 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 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).

A recent report of the National Science Board (NSB), the governing body of the National Science Foundation discusses the importance of preparing and providing the necessary background for our children to face the workplace of the future [3]. In another report, NSB also said quote “urge 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” and “In the global context, a scientifically literate population is vital to the democratic process, a healthy economy, and our quality of life” end quote [4]. It is evident that 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. 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]. 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. Due to student apathy and lack of interest in the programs from previous years, the College recognized the need to adapt and tailor the SEA program to student interests and aptitudes. With the active support of the College of Engineering Administration, 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, many students asked, “How does a design idea become a reality?” which strongly suggested that the

SEA program could include Computer-aided Design (CAD) and Rapid Prototyping (RP). The SEA program also follows the high school students who attended the SEA program to evaluate the added motivation on the students due to their participation in the SEA program.

The university has several joint research programs with Advanced Ceramics Research Inc. (ACR), who is 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.

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 1999, two groups of 35 freshmen-sophomores and 47 junior-seniors participated, while in the 2000 program, 52 freshmen-sophomores and 40 junior-seniors attended. Out of the students who attended the program in 1999, 27 students from the senior batch have enrolled in the University of Arizona engineering programs. In both of the programs, 68 female students and 57 students from under-represented groups participated. In this program, the students, separated into teams, were asked to design aerodynamic cars that were to be tested later in a wind tunnel for measuring the coefficient of drag.

Specifically, the students were taught the concepts of materials selection and materials science, aerodynamics, CAD, and rapid prototyping by mechanical engineering and materials science faculty from the University of Arizona College of Engineering. Under the materials science topic, the students were taught about the three classes of materials such as metals, ceramics, and polymers and where each type of material might be appropriate to be used. Materials selection fundamentals was taught by a representative of Raytheon Missile systems to provide an understanding of how to select a material for a specific application, based on the design requirements of a given component. In this case, the example selected was a component for space application where the importance of weight savings had to be matched against the component property requirement. The students were asked to compare the weight of a component made from tungsten and a ceramic material. Next, they were asked to calculate the cost of a space payload in terms of its weight and the cost savings that they might achieve by reducing the weight of the payload. In the aerodynamics area, the students were taught the fundamentals of an aerodynamic design, with an example of aerodynamic car. Teams of students were asked to design the most aerodynamic car based on the engineering principles that were taught to them. According to the feedback from the students, the most interesting topic was materials selection, due to the manner in which it was addressed.

Five undergraduate guidance counselors trained the students in the use of 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 figure 1. 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 that they had conceptualized and designed were being built in their presence. A photograph of the cars made for the 2000 SEA is shown in figure 2.

The model prototype cars were then tested in a specially designed and built wind tunnel at the University of Arizona College of Engineering. The students obtained a 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. 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 on a full scale. Additionally, program managers from the Department of Transportation presented concepts for a transportation system of the future.

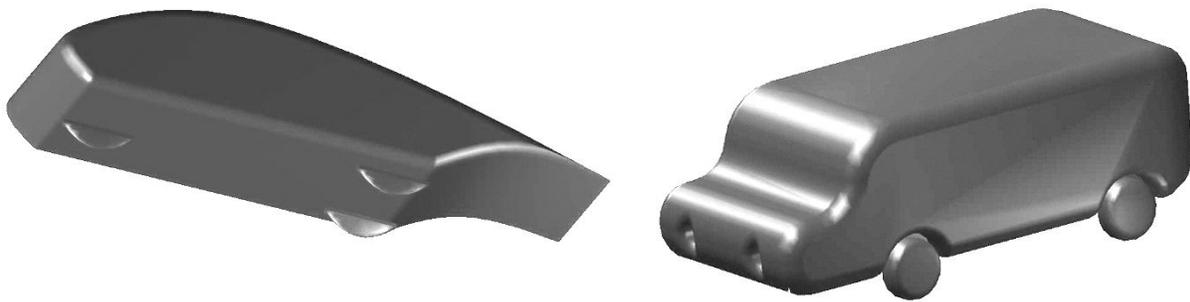


Figure 1. Solid models prepared by participants in the SEA program

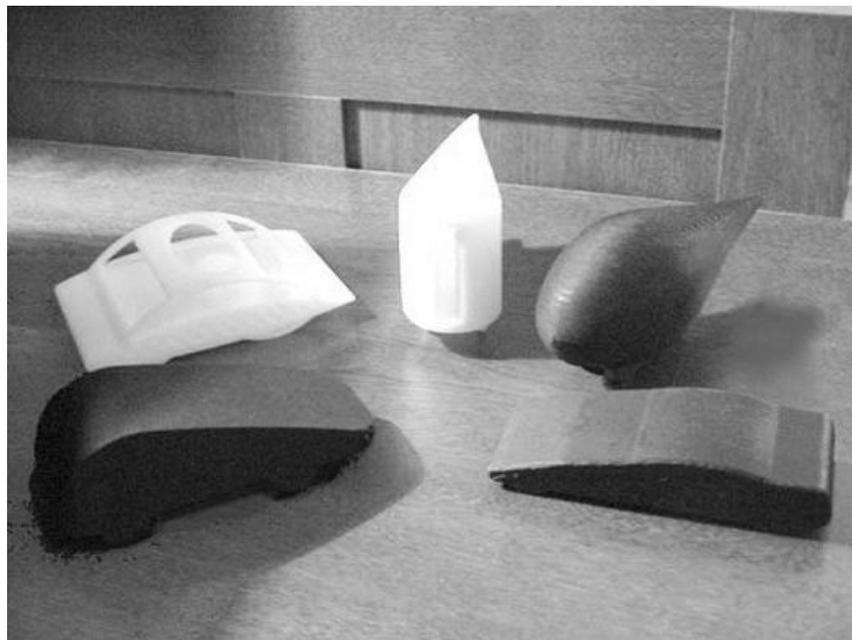


Figure 2. Examples of the cars manufactured during the 2000 SEA.

At the conclusion of the SEA, the students were asked to evaluate the SEA program and provide feedback. Overall, the students were found to have enjoyed the Summer Engineering Academy a

great deal. Their enthusiasm has also spread and as demonstrated by a record 390 applications for the 2000 program, up more than 100% from the 1999 program. More than 90% of the SEA program participants showed an interest in enrolling in engineering programs, based on the evaluations. For the upcoming program in 2001, the number of applicants has increased by more than 100% compared to the SEA program in 2000. Additionally, the number of sessions has been increased to three, with 40 science and math teachers from around the country to participate in a special SEA session in July 2001.

As mentioned above, 27 senior high-school students from the 1999 SEA program have joined the UA engineering programs. Their progress is being followed closely by the SEA program to evaluate the effect the SEA program has had on their academic choices. The authors are fully aware that since the SEA program is new, the data to support some of the assumptions given above are lacking. The authors believe that continued collection of student responses over the next few years and follow-up with the students in the program would help to rectify this problem.

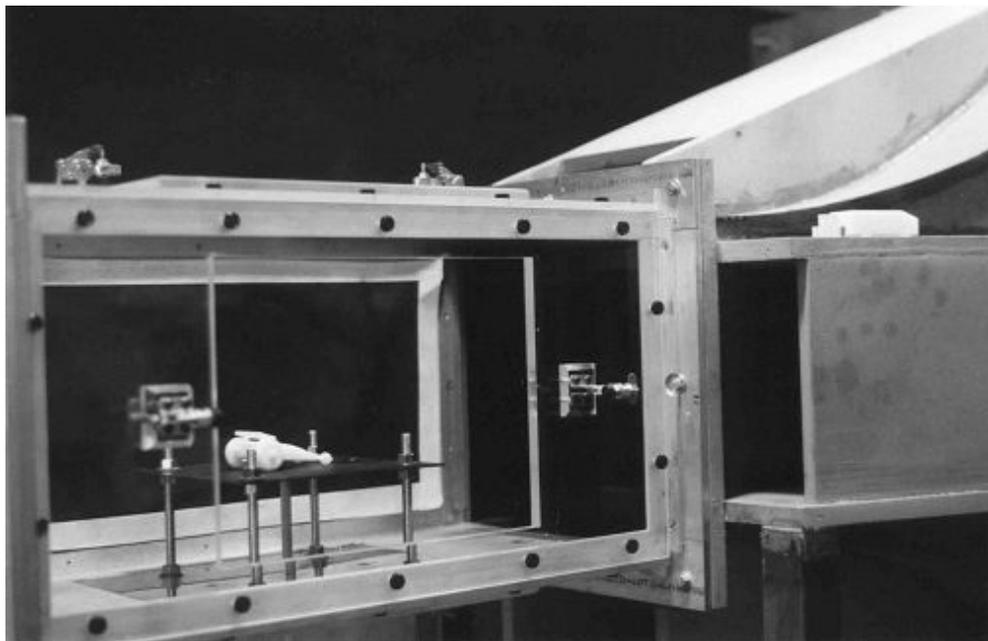


Figure 3. An image of a prototype car inside the wind tunnel

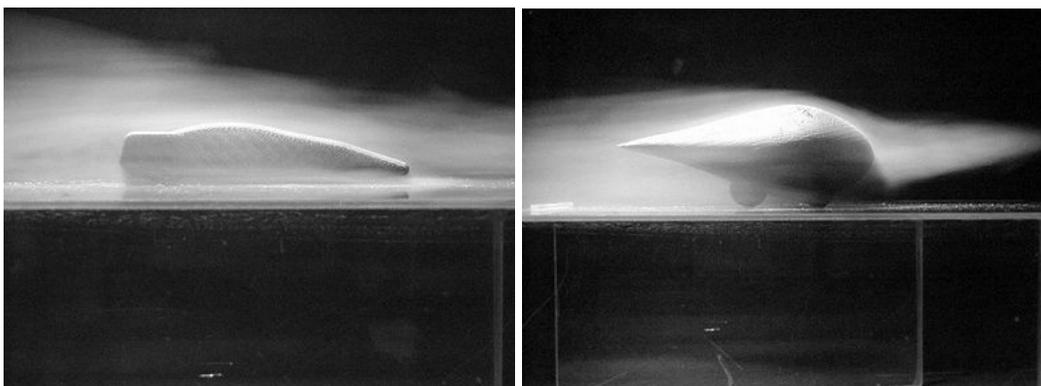


Figure 4. Close-up view of two prototype cars being tested inside the wind tunnel.

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 and expressed an interest in joining engineering disciplines in the future.

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Biographical Information

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Todd Anderson is an Assistant Professor in the Department of Aeronautics and Astronautics at the University of Washington. Formerly, as an Assistant Research Professor in the AME Department at the University of Arizona, Dr. Anderson instructed CAD for the department and SEA. Dr. Anderson received his Mechanical Engineering degrees from the University of Vermont (B.S.) and the University of Arizona (M.S., and Ph.D.).

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Greg Artz is a senior rapid prototyping technician at ACR. Greg is responsible for all commercial applications of ACR's rapid prototyping business. Greg also collaborates with UA for teaching computer-aided design and rapid prototyping to undergraduate students by building prototype models of CAD files sent by the students to ACR.

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Christopher Choi is an Assistant Professor in the Department of Agricultural and Biosystems Engineering of the University of Arizona. Dr. Choi has established the Instructional Computer Laboratory and developed a course entitled Introduction to Computer Aided Design and has introduced Rapid Prototyping in conjunction with the state-of-the-art CAD technology. Dr. Choi received a Ph.D. degree in M.E. from Colorado State University.

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