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## **AC 2011-616: SUMMER ENGINEERING ACADEMY (SEA), A UNIVERSITY OF ARIZONA STEM INITIATIVE TO RECRUIT HIGH-SCHOOL STUDENTS INTO ENGINEERING AND SCIENCE DISCIPLINES**

### **Ranji K Vaidyanathan, Oklahoma State University**

Dr. Ranji Vaidyanathan is presently the Herrington Professor in Advanced Materials at the Helmerich Research Center at OSU Tulsa. He is also the Director of the New Product Development Center (NPDC) and the Inventors Assistance Service (IAS) at Oklahoma State University. The mission of the New Product Development Center at Oklahoma State University is to link the innovative ideas and capabilities of small manufacturers and inventors with the knowledge and multi-disciplinary expertise of the land grant university faculty, in order to develop and commercialize economically competitive new products that strengthen rural economies, create new and enhanced jobs, capital investment and an increased tax base.

Dr. Vaidyanathan has thirteen U. S. patents and twenty-two pending patent applications. He has developed six different products from concept stage to commercial stage including a product commercially being sold to Airbus, Eurocopter, Lockheed and Boeing.

At Oklahoma State University, Ranji works collaboratively with faculty members from various disciplines and colleges to develop products and solutions for Oklahoma small manufacturers. As the Herrington Professor, Dr. Vaidyanathan works with the Helmerich Research Center faculty to develop a major research and technology transfer thrust in composite materials.

# **Summer Engineering Academy (SEA), a STEM initiative to recruit high-school students into engineering and science disciplines**

## **Introduction**

According to a recent report on K-12 Science, Technology, Engineering and Math (STEM) education by the President's Council of Advisors on Science and Technology (PCAST) to the President, the success of the United States in the 21<sup>st</sup> century will depend on the effectiveness of STEM education priorities of the country.<sup>1</sup> An effective STEM education effort will provide the technical skills and quantitative literacy needed for individuals to earn livable wages and make better decisions for themselves, their families and their communities. In the new global and challenging economy, the country will need a well-educated STEM workforce that is scientifically, mathematically and technologically literate in order to compete against other nations.<sup>1</sup>

Despite its excellent prior record, the United States now lags behind other nations in international comparisons of student performances in science and mathematics. Reportedly, there is an interest and achievement gap among groups such as African Americans, Hispanics, Native Americans and women, who are traditionally underrepresented in many STEM fields.<sup>1</sup> This in turn results in a flat enrollment in undergraduate engineering enrollment. According to a recent National Science Board "Science and Engineering Indicators 2010" report, undergraduate engineering enrollment declined through most of the 1980s and 1990s, rose from 2000 to 2003, declined slightly through 2006, and rose to 431,900 in 2007.<sup>2</sup> The number of engineering degrees awarded by U.S. academic institutions has remained stable at approximately 5% of the total science and engineering degrees every year over the past several decades.<sup>2</sup> However, the number of engineering jobs are expected to grow at an annual rate of 10.4% over the next 5 years.<sup>2</sup> This suggests that there is a potential for a shortage of engineers with bachelor's degrees in the upcoming years and a need to recruit students into engineering disciplines more effectively.

The NSB report goes on to state that an engaging and effective science education should develop student skills to solve complex problems, work in teams, make and recognize evidence-based arguments, and interpret and communicate complex information. The same principles are applicable to education in technology and engineering subject areas.<sup>1</sup> STEM initiatives are also now the focal point for addressing the innovation crisis in the United States.<sup>3</sup> The important lesson that our students need to understand is that they are vital to solving the innovation crisis by trying solve real-world problems while practicing engineers can contribute to this by providing a real-world problems to the students. To be effective, STEM students and teachers, as well as students and teachers from other disciplines such as humanities, arts, social sciences and business need to identify the needs of people and society, critically think and solve problems, generate ideas and rapidly generate ideas and prototype them, work together in multi-disciplinary teams, and finally, effectively communicate those results to the outside world.<sup>3</sup>

The effectiveness of our STEM education will determine whether the United States will remain a world leader and whether we will graduate the scientists, technologists, engineers and mathematicians who will create the new ideas, new products and entirely new industries that will

drive and stimulate the economy and grow the job market. The NSB also reports that of all the patenting activity reported by the US Patent and Trademark office (USPTO) in 2003, Bachelor's degree holders accounted for 41% all the patenting activity. Of those patents issued between 1998 and 2003, 60-65% of the patents awarded to bachelor's degree holders resulted in commercially successful products. One of the important conclusions of the PCAST report to the President is that we need to improve STEM education and we must inspire all students to learn STEM, and in the process, motivate as many of them to pursue STEM careers so that they can create those future innovations by entering engineering professions.<sup>1</sup>

Possible strategies to address the engineer shortage for the future are being developed by several groups.<sup>4</sup> These include development of high school-level engineering courses to high school students to engineering-based First Robotics competitions.<sup>5</sup> Clearly, there is evidence that these programs serve to increase student interest in engineering as a career. However, they may not provide students an opportunity to experience the university setting or exposure to the breadth and variety of engineering projects.<sup>4</sup> Various universities instead may provide summer camps as a means to introduce students to STEM disciplines and create a potential pool of future students.

Yilmaz and others have described the results of a week long summer camp with 30 students at Texas A&M University-Kingsville (TAMUK) held in 2008.<sup>4</sup> TAMUK is a predominantly Hispanic serving Institution (HSI) located in South Texas. This paper described the efforts to expose high school students to STEM concepts through four hands-on engineering projects and three technical activities covering five different engineering fields. The participants were recruited from selected high schools in Texas through class presentations, flyers, personal interactions with counselors, science teachers and principals from those schools that had interacted with TAMUK previously.<sup>4</sup> Family income was used as a primary criterion for selection of the students so as to reach economically disadvantaged students. 30 students were selected and 19 out of the 30 were female. Results suggested that the hands-on nature of the student projects promoted critical thinking, teamwork, writing and leadership skills. The authors suggest that future summer engineering camps should be interdisciplinary in nature with an emphasis on projects with environmental and social concerns while showing a linkage with various engineering disciplines.<sup>4</sup>

A listing of other summer camps in various states directed towards engineering disciplines is given at <http://www.engineeringedu.com/camps/>.<sup>6</sup> These camps vary from being engineering design oriented, covering various engineering fields, short duration (one-week) to long duration (three weeks), requiring fees to being completely free, grade, gender or ethnicity specific, covering specific engineering topics such as robotics or biomedical engineering or requiring writing an essay to maintaining a minimum GPA for admission.<sup>6</sup>

### **Summer Engineering Academy (SEA)**

This paper presents the valuable experiences gained in a weeklong high school summer engineering academy (SEA) at a large four-year, primarily non-residential public university. In this paper, we attempt to share our insights and experiences in engineering student recruitment. The fundamental idea behind the SEA program is to show prospective engineers exactly how an idea becomes reality and the connectivity between a product design and its performance. Due to

student apathy and low attendance in the program from previous years, the college recognized the need to adapt and tailor the SEA program to student interests and aptitudes. The program prior to 1999 consisted of lectures by various faculty members and a bridge building contest with tooth picks. It was seen that prior to 1999, less than 15% of the students who attended the SEA program decided to select engineering majors at either the college of engineering at the university or at other universities. It was clear that the SEA program had to be modified drastically if it was to sustain student interest and support from the college administration.

With the active support of the college of engineering administration, the assistant dean of the college of engineering who also happened to be the director of the Multi-cultural Engineering Program (MEP) program decided to modify the SEA program based on student input and feedback. One of the main goals of the program is to attract high school students including women and underrepresented minorities to enter engineering professions. After researching the program content of the previous years, the MEP director visited several high schools in the state 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 to introduce more hands-on type of activities rather than lectures by the faculty. High school students typically are active and may not be able to sit through long lectures that do not appeal to them, especially when they cannot make the connection to real-life situations.

The MEP director then obtained a \$5000 grant from the state Department of Transportation to rebuild an electric truck belonging to the society of automotive engineers (SAE) student chapter. He also obtained the local utility company's electric vehicle on loan. He also met with local successful high-technology companies run by the college of engineering alumni for their input. The alumni promised to assist the program through funds and materials.

The modified version of this camp has now been conducted since 1999 for over ten years and has offered at least 3 sessions every year, depending on the number of applicants. Session I is a day program for freshman and sophomores. Students in Session II and session III stayed on campus in the dormitories. The program started with approximately 100 students in 1999 and today caters to over 150 students every year. The total number of participants in the SEA program is now over 1800. The SEA program is unique that it has been entirely supported through funds and collaborations with private industry and donations. It has been successful enough that the university considers it to be one of its best outreach programs to the local community. The industry contributions have also enabled the program to award need-based scholarships to students to attend the program.

## **Recruitment**

The Summer Engineering Academy participants were recruited through a number of approaches. These included: i) personal visits by the assistant dean of the college of engineering and director of the MEP to high schools across the state, ii) flyers distributed to the high school counselors, principals, math and science teachers across the state, iii) creation of an official website that is prominently linked to the university website, and iv) providing web links to websites describing summer engineering programs, and v) news articles on the university website, local newspapers and television channels.

Starting with 200 applicants/year in 1999, the program (for the three SEA sessions combined) receives about 180 to 200 applications per year. Forty to fifty need-based scholarships are awarded every year, valued at \$20,000 to \$25,000. 6 out of 8 counselors are past SEA graduates.

### **SEA Program Curriculum**

In this innovative weeklong program conducted with generous support from the university, industry and local non-profit organizations, students learn state of the art in computer-aided design and rapid manufacturing technology. The major goals of this effort are to:

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

Every year in the summer, at least three sessions of SEA are conducted at the college of engineering. The three sessions have forty to fifty students each, representing about ten states. During some years, the college also conducts sessions for students sponsored by local non-profit groups such as the Urban League. Each session is one week long. Session I is a day program for freshman and sophomores. Students in Session II and session III stayed on campus in the dorms. Students in all three sessions are taught the use of a 3-D CAD package called SolidWorks™ and asked to design aerodynamic automobiles. They are also asked to use their imagination and design devices under the theme of “Technology in Service of Society”. Students are not allowed to design devices that destroy human or animal life and property.

On the first two days, students attend lectures on fundamentals of aerodynamics, materials used in engineering, industrial applications of rapid prototyping technology and how to prepare for college. On the third day in each session, students based on their area of interest are sent in groups of ten to attend special half-day modules in chemical engineering, electrical & computer engineering, civil engineering, and systems & industrial engineering. Depending upon the level of interest, SEA also offers a refresher course in Algebra and Pre-calculus. High school mathematics teachers are hired for this purpose. One of the teachers presents an hour-long lecture on practical applications or math and science in SEA sessions II & III.

Selected car designs are built using powder injection 3-D printing and stereolithography. In the initial years of the program, the college depended on local businesses to build the prototypes. For the past six years, the college of engineering has procured its own rapid prototyping equipment for building the models designed by the students. These models are then tested in a specially built small-scale wind tunnel. Students take digital photographs of the smoke test. On the last day, student groups in each session make presentations to an audience consisting of parents, grandparents, friends, neighbors and faculty. Prizes are awarded to the best over all designs, best optional project and also to those who solve all the math problems correctly.

One of the unique features of the SEA program is the fact that nearly all the counselors are past SEA graduates. Every year at least six undergraduate students and two graduate students work in the SEA program as mentors. At the inception of the SEA program, a group of women and

minority undergraduate engineering students are selected from the Multicultural Engineering Program (MEP) and are trained to be mentors and counselors. Every year more and more SEA graduates apply for the counselor jobs. Each counselor is responsible for a group of seven or eight students and interacts with them closely and stays in touch with them through the school year. Mentoring takes place during and after the SEA program, covering such important topics as financial aid, scholarships and resources on campus, survival skills, time management and social interactions.

The mentors are trained to use SolidWorks™ software and also taught good communications skills. Would be mentors are given information about college most frequently asked for by high school students. The undergraduate students help the SEA participants with the SolidWorks™ program, run the lunch time mentoring sessions and take part in the evening social activities. The graduate students assist in the wind tunnel tests, digital photography of the smoke tests and preparation of the final presentation.

Concurrent with the development of the technical content of the program, considerable emphasis is placed on the mentoring of the high school students during the week-long SEA program and after they return to their respective schools. Most of the literature on minority participation in engineering education points to poor support systems as the main contributing factor for low retention and graduation rates among these students. In the SEA Program, the mentors and counselors are mostly women or minority students currently enrolled in engineering at the university. The mentors spend time with SEA participants in small groups and address the following specific issues:

1. Preparing for college and taking all the available math and science courses in the high school junior and senior years.
2. Provide information on financial aid and scholarships.
3. Take the high school students on tours to visit various cultural centers and minority student clubs such as SHPE, NSBE, AISES and SWE.
4. Provide information on engineering related careers.
5. Provide information on time management skills and good study habits.
6. Teach them to seek help from counselors and advisors.
7. Talk to parents during and after the SEA final presentation.

In addition, the director of the program maintains contact with the parents to ensure that the students are on track to graduate and also to offer information on new scholarships and programs.

### **SEA Projects**

On day 1, SEA participants learn SolidWorks™ in teams of 3 and start the design of automobiles. All the initial designs looked like UPS vans or milk trucks (Figure 1). On day 2, students continue aerodynamic car design, using SolidWorks™. The Ferraris and Mustangs start coming out (Figure 2) after the lecture on Aerodynamics! The actual models built for the students are shown in Figure 3. On day 3, the student teams work on the optional projects and

also attend the half-day modules at the different departments. As soon as the designs are completed, the mentors have them built in the rapid prototyping machine now available in the MEP office. On day 4, the prototypes are tested in a specially built wind tunnel for evaluating their aerodynamics (Figure 4). On day 5, the students prepare their presentations and present that in front of friends, family and faculty members. Each team member speaks about a particular part of the design process and their impressions of the academy. At the reception, SEA program counselors, mentors and program director meet with parents and answer questions.



Figure 1. Initial designs by the SEA program participants

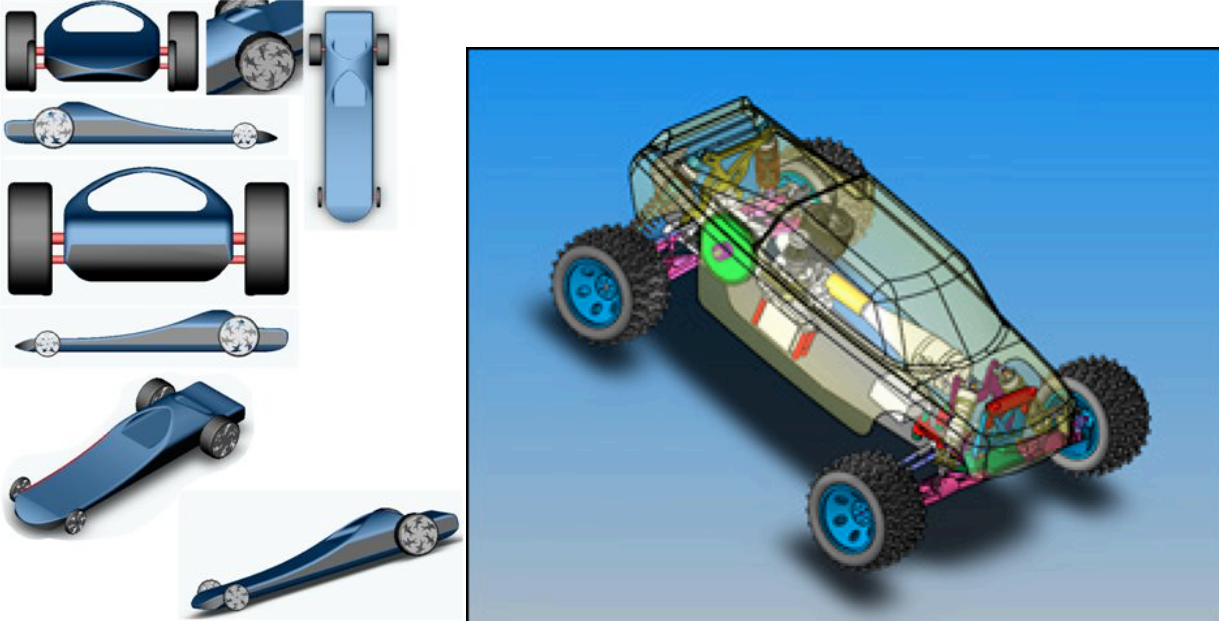


Figure 2. Improved models designed by the SEA program participants



Figure 3. Some of the actual prototype models built by the SEA program participants



Figure 4. Prototype models being tested in the wind tunnel

### **Student statistics from the SEA program**

In the past ten years, more than 1800 high school students have participated in the SEA program, with approximately 30-35% of those attending being women, 55-60% Hispanic, 6% African American, 6% Native American, 25-30% White and remaining Asian. The overall student enrollment data from 1999-2010 is shown in Figure 5. The breakup of the student population is shown in Figures 6, 7 and 8. It was also observed that after attending the SEA program, more than 80% of the rising juniors and seniors decided to attend engineering at the college of engineering of the university or at other schools (Figure 9). This compares favorably with less than 15% students deciding to attend engineering majors prior to the modification of the SEA program. These students represented approximately ten states including Alaska. A group of SEA program participants is shown in Figure 10.

Complete data for student enrollment since the change in the SEA program is not available. Based on partial data (Table 1), it can be seen that the enrollment data shows an increase in minority student numbers since 1999. It can also be seen that the number of students applying to the SEA program increased since 1999, although it has been difficult to increase the number beyond what it is currently due to budget constraints.



Table 1. College of engineering student enrollment 1997-2001

Sum of count	Ethnic origin				Grand total
	African-American	Hispanic	Native American	Others including women	
1997	4	39	9	24	76
1998	9	53	13	39	114
1999*	12	66	16	41	135
2000	15	68	15	41	139
2001	12	107	20	60	199
<b>Grand total</b>	<b>52</b>	<b>333</b>	<b>73</b>	<b>205</b>	<b>663</b>

\* SEA program started

Anecdotally, based on student response, the SEA program has contributed positively to the student decisions to attend the college of engineering either at the university or at other universities. This can be seen in the student responses given below.

### Student responses and evaluation

Typical student responses ranged from complete engagement to increased curiosity. Some of these comments were:

- “Much more interesting than hanging out”
- “I did not know this was engineering”
- “Selection of variables is every thing”
- “This is how they design good cars”
- “Computers have real uses”

Students have written personal notes to the MEP director explaining the value of the SEA program in helping them to become engineers. A female student wrote that she wanted to become a fighter pilot as a result of attending the SEA program. She wrote: “I would like to thank you very much for helping me to get in to the Summer Engineering camp. This Camp was very helpful in my decision to become an Engineer. Everyday I met someone new, that was interested in the same great field; Engineering. I really enjoyed the lectures that we attended almost every morning. I loved going to computer lab to apply my new technical skills. There is so much I don't know about Engineering, and the computer programs helped me realize how much knowledge is involved in this field. Through out the course, I used the four computer programs to design and create my aerodynamic vehicle. I applied the knowledge I gained from the Professors, to design the high tech car. Then when we went to the huge wind tunnel, where I learned that not only was the looks important, but the aerodynamics needed to be considered. Soon after I replaced my first creative idea, and put the air intake into consideration to cut down on drag. After the changes, my design was finalized. Then I went to the rapid prototyping laboratory and before my eyes, my vehicle was being produced. I was so happy to see that my car was one of four that were created. Next, my partner and I put together a power point

presentation, and submitted it to a highly attentive audience. I have learned so much from this experience, and at the same time I had a lot of fun. I learned how to apply my technical skills, and how to simply operate four Engineering programs. I experienced life in a college dorm, and loved it. I also learned what is expected of an Engineer, in a real job setting. Thank you again for making awesome experience possible.”

Results are seen in the student evaluations as well as the data on participants then selecting engineering as a major. In student evaluations, the program receives consistently high scores of eight or higher for academic content. Many participants also find summer jobs and internships as a result of their new skills. A former student wrote: “I wanted you to know that you are the reason my brother and I decided to become engineers. We participated in the Summer Engineering Academy in the summer of last year and we fell in love with this interesting and exciting career, engineering. I will be going into mechanical engineering this fall and my brother will be going into aerospace and optical engineering next fall. Even my youngest is looking forward to participating in SEA in the summer two years from now. The university can be sure to expect three more dedicated engineers in the near future.”

Another student wrote: “Thank you for inspiring me to follow my dreams and become the best I can be and making my family's wish come true. My mother and father came to the United States from Mexico many years ago and they have both worked extremely hard to make sure that we do not have to go through the hardships that they had to experience. I cannot thank you enough for opening the doors to a better future.”

Over the last ten years the SEA program has been in existence, there have been many such responses from students who have appreciated what the program has been able to do for them in terms of motivating them to enter into engineering professions. However, it is not an easy task to evaluate how the student attitudes have changed since the SEA program modification, since the students are already interested in STEM careers to an extent and the hands-on nature of the SEA program only helps to reinforce the interest.

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 exploring materials science and mechanical engineering disciplines. Many parents have taken time from their busy schedules to write and inform the college how much the SEA program has benefited their son or daughter. 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.

Based on individual follow-up with the students, it was observed that after graduation, these students received excellent job offers from various small and large engineering companies in the state or outside. However, it is difficult to separate the effect of the SEA program on the employability of the engineers who entered the college of engineering after attending the SEA program. The only peripheral evidence is the fact that the minority enrollment increased considerably after the SEA program was modified in 1999.

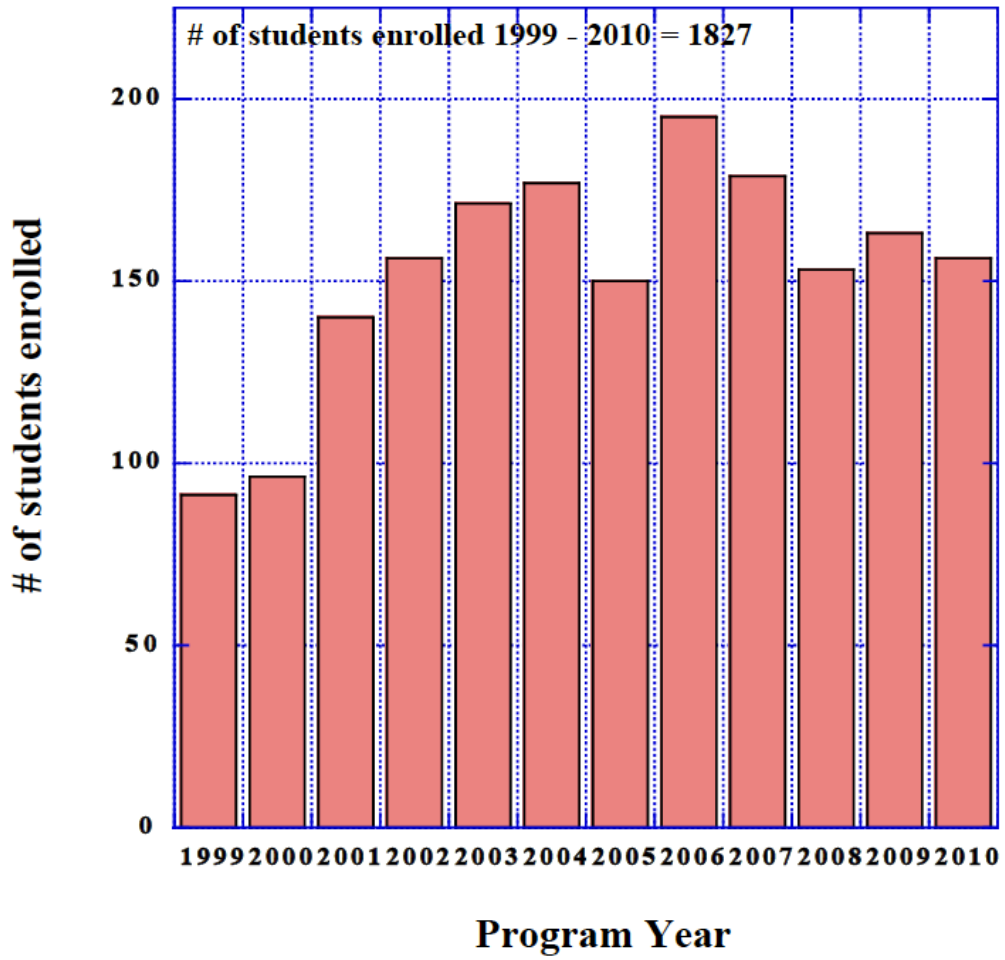


Figure 5. SEA program student enrollment statistics 1999 – 2010

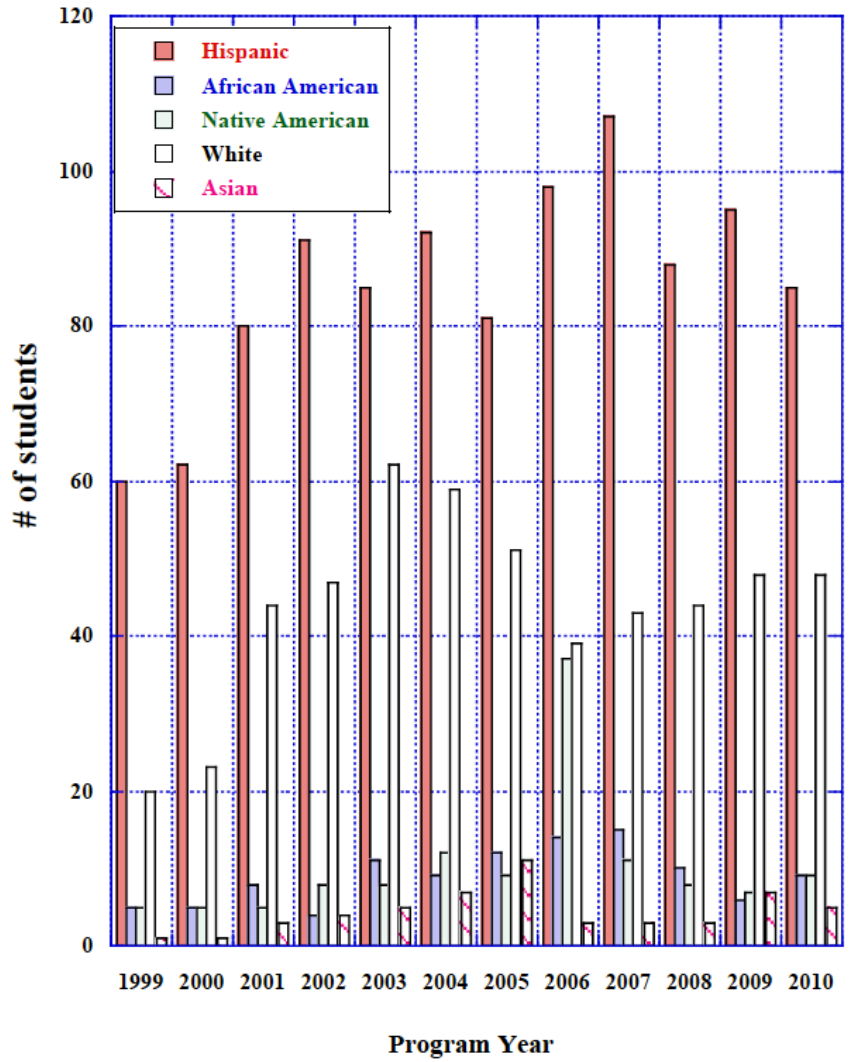


Figure 6. Detailed break-up of the SEA program student enrollment statistics 1999 – 2010

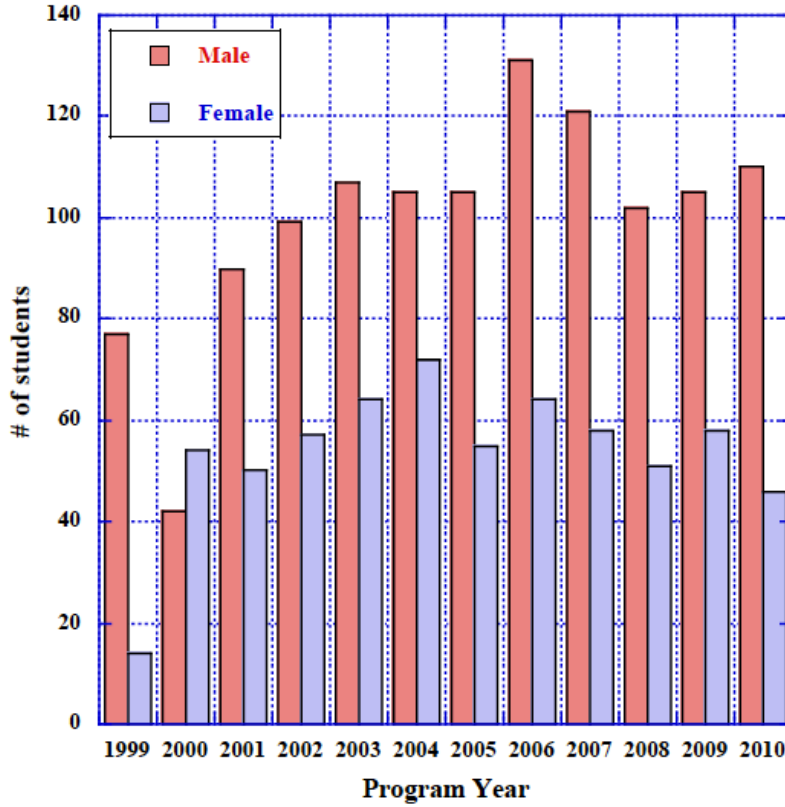


Figure 7. SEA program enrollment 1999 - 2010 - male/female distribution

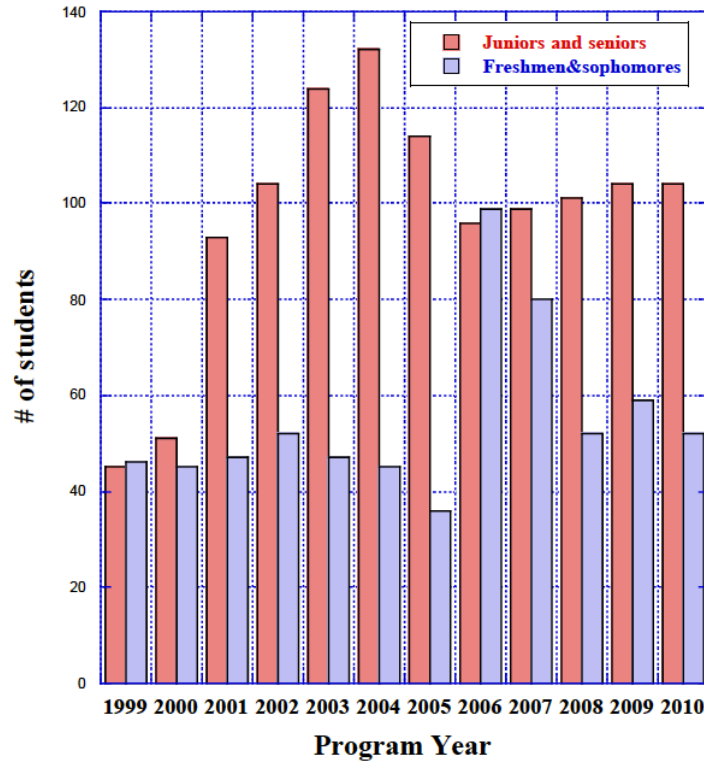


Figure 8. SEA program enrollment – distribution between freshmen/sophomores and juniors/seniors

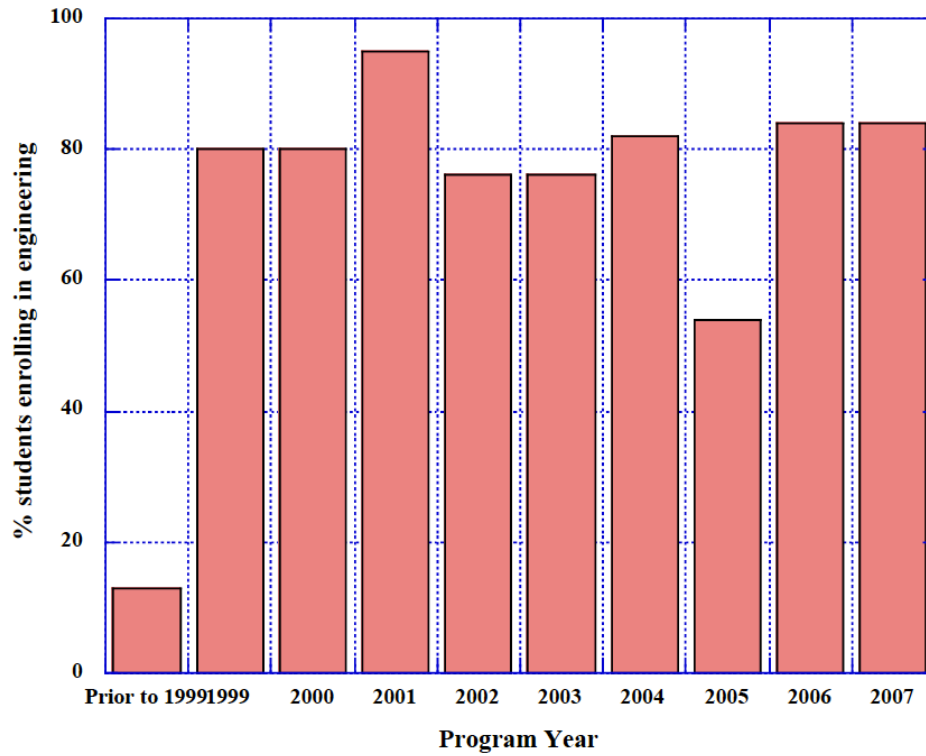


Figure 9. Percentage of students entering engineering after attending the SEA program



Figure 10. A group of SEA program participants

## Conclusions

The students were able to obtain first-hand experience of the principles of aerodynamics and real-world engineering by actually seeing their concept models tested in a wind tunnel. The wind tunnel data was analyzed and interpreted by the students with the help of their mentors. This provided them feedback as to how their cars would perform if they were built to full scale. The Summer Engineering Academy has now become a program of choice among young women and men from underrepresented groups attending the university because of the hands on activities, mentoring from engineering students and need based scholarships. The SEA program has attracted students from as many as ten states, including Alaska.

The results from the SEA program were encouraging to both the students and the university. The response from the high school students and their parents were overwhelmingly positive and showed that this innovative educational experiment combining computer-aided design and rapid prototyping 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 exploring materials science and mechanical engineering disciplines. Many parents have taken time from their busy schedules to write and inform the college how much the SEA program has benefited their son or daughter. 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.

Anecdotally, the SEA program was shown to have a major impact on how young people perceive engineering as a profession and career. The hands-on design and manufacturing experience was shown to create interest for engineering and the results were seen in the student evaluations as well as the data on the number of high school students selecting engineering as a major. In the student evaluations, the program received consistently high scores of eight or higher for academic content and teamwork and this aspect is important to many students. Students also expressed surprise that engineering can be fun and that they never realized fields such as materials engineering and systems engineering even existed. Based on individual follow-up with the students, it was observed that after graduation, these students received excellent job offers from various small and large engineering companies in the state or outside. However, it is difficult to separate the effect of the SEA program on the employability of the engineers who entered the college of engineering after attending the SEA program. The only peripheral evidence is the fact that the minority enrollment increased considerably after the SEA program was modified in 1999.

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