Engineering Outreach: A Summer Program Approach

E. Specking[1] and E.C. Clausen[2]
College of Engineering[1]/Ralph E. Martin Department of Chemical Engineering[2]
University of Arkansas

Abstract

Three summer programs were created in the College of Engineering at the University of Arkansas to increase interest in STEM-related fields among rising 6th-12th grade students. Explore Engineering Program 1 (EEP1) and Explore Engineering Program 2 (EEP2) were developed as five-day, daytime-only programs for rising 6th and 7th grade (EEP1) and 8th and 9th grade (EEP2) students to develop interest in STEM concepts and engineering as a profession through interactive hands-on learning. The Engineering Summer Academy (ESA) was designed to attract rising 10th-12th grade students to programs in Mechanical, Electrical, Chemical and Biological Engineering at the University of Arkansas through hands-on departmental programs in a week-long residency program. In 2010 (the first year of the programs), 68 students attended and, in 2011, 135 students applied. Several measurable results were obtained from the three summer programs which demonstrate growth, interest and early success. Perhaps most notable, 25 of the 28 high school senior ESA attendees (89%) in 2010 applied for admission to the U of A in 2011. Fourteen of these 25 new U of A students received academic scholarships from the U of A.

Introduction

According to the National Center for Educational Statistics, Arkansas had the second lowest percentage of STEM degrees awarded in 2009 (8.5%), and was well below the national average of 10.7%.[1] Arkansas Higher Education institutions are not producing enough students to meet industrial needs, and thus Arkansas industry is hiring students from schools outside of Arkansas.

To help close this gap while, at the same time, increasing student interest in STEM-related fields, the University of Arkansas (U of A) College of Engineering has started several pre-college and early-college initiatives. These initiatives include informational visits to high schools, middle schools and elementary schools; K-12 student visits to the university, hosted and coordinated by the College of Engineering Recruitment Office; a variety of summer programs for K-12 students; partnerships with K-12 schools, including the University of Arkansas Engineering and Science Partnership (UAESP); the Engineering Career Awareness Program (ECAP), a diversity recruitment-to-graduation program for undergraduate engineering students; and the Freshman Engineering Program, which helps Freshman engineering students select an engineering major, while also providing much needed assistance to students as they transition from high school to the university. Many universities offer K-12 programs to attract students to engineering. Missouri S & T, for example, offers a variety of pre-college and summer programs including Explosives Camp, It's a Girl Thing and the Summer Research Academy.[2] Schools with similar programs include North Carolina State,[3] Purdue University,[4] the University of Missouri[5] and the University of Iowa[6], just to name a few. Poole *et al.*[7] discuss a method for assessing the quality

of K-12 programs, and Fantz *et al.*[8] note the importance of rigor in preparing K-12 students for collegiate engineering programs. This paper discusses three U of A summer programs created for rising 6th-12th grade students: Explore Engineering Program 1, Explore Engineering Program 2 and the Engineering Summer Academy.

Recruitment of Students

To advertise the summer programs, many resources were used, including verbal advertisements during all engineering tours and school visitations, distribution of flyers and advertisement on the web. In advertising the Engineering Summer Academy (ESA), Enrollment Management at the U of A acquired a list of names from ACT, the College Board and direct inquiries that were used to develop a target audience of high ability students that were diverse and interested in STEM fields. An ESA post card was sent to over 1,000 targeted students.

Financial Arrangements

Each student was charged a program fee to cover camp expenses. Explore Engineering Program 1 (EEP1) and Explore Engineering Program 2 (EEP2) participants were charged $350 to cover daily lunches, two snacks per day, supplies, a t-shirt, insurance and other camp related expenses. College of Engineering scholarships were available for students in need. ESA participants were charged $650 to cover three meals per day, two snacks per day, a t-shirt, insurance, supplies, resident hall costs and other camp expenses. The Razorback Solar Boat Competition was sponsored by the College of Engineering and the Arkansas Science and Technology Authority (ASTA), whose funding for the program came from NSF. Students in the Razorback Solar Boat Competition were awarded scholarships based on need, as either partial or full scholarships. Students in How It's Done—Chemical Engineering Style were awarded scholarships from the Chemical Engineering Academy and the Ray C. Adam Endowed Chair in Chemical Engineering. Each Chemical Engineering student was given a scholarship of at least $300, with some students receiving a full scholarship based on need.

Explore Engineering Program 1

The Explore Engineering Program 1 was developed as a five-day, daytime-only program to introduce rising 6th and 7th grade students to STEM concepts through interactive hands-on learning, and thereby develop an early interest in these areas. In the summer of 2010, the first year of the program, 11 students applied and all were selected to participate. In 2011, 25 students were selected for the program from 31 applicants. The program was primarily staffed by hourly undergraduate and graduate students, with program content mostly provided by College of Engineering faculty. Two staff members were assigned to the student group for the entire week to assist the students and build relationships. In addition, two staff members and a faculty member from each participating engineering department were used to help present the daily programs.

Table 1 shows the major activities from the summer of 2010. The students worked in groups of 3-4 students. Each day, the activities began with an ice breaker as a "wake up" and an opportunity to meet other participants. Following the ice breaker on Day 1, the student groups

performed three problem solving activities. Subsequent days focused on a branch of engineering by performing projects that required critical thinking/problem solving skills. Tours were often used to introduce the middle school students to engineering research.

Table 1. Highlights of EEP1 2010

Day	Major Activities
1	Overview of engineering; puff mobile; stick 'em up project; marshmallow launcher; protect the pill
2	Mechanical Engineering: patrol robot; mining robot
3	Computer Science/Engineering: two programming robotics activities; tours
4	Electrical Engineering: electromagnet launcher; windmill; tours
5	Chemical Engineering: chemical reaction powered car experiments

One of the more interesting projects was the marshmallow launcher. Each group of students was given 20 tickets to be used to acquire materials that individually "cost" one or more tickets. The students then designed and built a launcher using purchased materials. The goal of the project was to launch a marshmallow, achieving the longest distance at the lowest cost. Thus, an inch was added to the launched distance for every left over ticket. The launchers were restricted to secondary motion, which prevented the students from making the easiest design, a slingshot. One group enjoyed the project so much that, when they returned home, they had their parents take them to Lowes to buy better supplies. The next day they brought in a device that launched a marshmallow 200 feet.

Explore Engineering Program 2

Explore Engineering Program 2 was designed to introduce rising 8th and 9th grade students to STEM concepts but, in addition, perhaps stimulate student interest toward a branch of engineering, as well as science and engineering in general. In the summer of 2010, 14 students applied and all were selected to participate. In 2011, 25 students were selected for the program from 29 applicants. Staffing for the EEP2 program was identical to the EEP1 program, and the content of the program was very similar to EEP1.

Table 2 shows the major activities for the EEP2 program from the summer of 2010. Once again, the students worked in groups of 3-4 students. Each day, the activities began with an ice breaker. Following the ice breaker on Day 1, the students were introduced to engineering as a career before beginning departmental activities. The program then focused each day on a branch of engineering by performing projects that required critical thinking/problem solving skills. Tours were used to introduce the students to engineering research.

Table 2. Highlights of EEP2 2010

Day	Major Activities
1	Civil Engineering: water distillation (environmental), concrete (transportation), earthquakes, tours
2	Mechanical Engineering: patrol robot; mining robot
3	Computer Science/Engineering: two programming robotics activities; tours
4	Electrical Engineering: electromagnet launcher; windmill; tours

5	Chemical Engineering: chemical reaction powered car experiments; tours

The robotics activities of Days 2 and 3 were a highlight of EEP2. The students were exposed to different aspects of robotics using modified labs from Lego® Mindstorms®.[9] The first day of the robotics activities focused on mechanical/construction aspects by using drag and drop programming software to program the robots. On the second day, the students used java to program the robots to do completely different activities to do other activities, including running a maze. The students learned basic programming fundamentals and, by the end of the day, were trying new things by changing the pre-developed code.

Engineering Summer Academy

The Engineering Summer Academy was designed to attract rising 10^{th}-12^{th} grade students to engineering programs at the University of Arkansas through hands-on departmental programs in a week-long residency program. In 2010, two programs were offered:

- The Razorback Solar Boat Competition Program, an effort of Electrical Engineering and Mechanical Engineering, created and coordinated by the College of Engineering Recruitment Office, and
- How It's Done—Chemical Engineering Style, a program offered by the Chemical Engineering Department

In 2011, Green Design—Sustainability, a Biological Engineering Department offering, was added to ESA. In 2010, 43 students applied to ESA and, in 2011, approximately 85 students applied (see demographics in Table 3). All of the students were accepted, although some of the students were moved from a "full" program to another. The applicants were mostly male, and most of the attendees were from the State of Arkansas. Minorities represented 45% of the attendees in 2010 and 32% of the attendees in 2011.

Table 3. ESA Demographics, 2010 and 2011

	2010	2011
No. of applicants	43	85
Male/female	Male: 74% Female: 26%	Male: 66% Female: 34%
Home state	Arkansas—35 Texas—3 Tennessee—1 Georgia—1 Missouri—1 Oklahoma—1 North Carolina—1	Arkansas—64 Texas—10 Louisiana—3 Tennessee—2 Florida—2 Georgia—1 Missouri—1 Kansas—1 Oklahoma—1
Race/ethnicity	Caucasian—55% African American—33% Asian/Pacific Islander—7% Hispanic/Latino—5%	Caucasian—68% African American—12% Asian/Pacific Islander—7% Hispanic/Latino—5% Multi-racial—5%

		Native American—3%
Average ACT	27	26
Average gpa	4.02	3.74

Because ESA was a residency program, both night and day staffs were required. A Resident Director was hired to create and carry out the night activities, which included activities such as scavenger hunts, obstacle courses, activities at the U of A recreational center and cook-outs. The Resident Director also managed four Resident Assistants (three male, one female) who built relationships, managed problems and helped in executing the night activities. In 2010, The Razorback Solar Boat Competition was developed and run by four College of Engineering staff and students. How It's Done—Chemical Engineering Style was developed and run by five faculty from the Department of Chemical Engineering.

The objective of the Razorback Solar Boat Competition was to develop three foot, solar-powered boats from polystyrene foam that were suitable for racing. These boats were smaller versions of boats used in Solar Splash,[10] a solar boat competition involving engineering students from 12 universities, who put the boats through four days of sprint, slalom and endurance races. Solar Splash teams come from as far away as the University of South Carolina and Washington State University, with international competition provided by the University of Southampton, England, and Tecnologico de Monterrey, Mexico.

Table 4 shows highlights of the Razorback Solar Boat Competition from the summer of 2010. Twenty-seven students attended: 13 worked as electrical engineers, and learned some of the principles of electrical engineering, built the solar panels and worked on the wiring of the boats; and 14 worked as mechanical engineers, and learned some of the principles of mechanical engineering, while designing and building the three foot hull. After check-in on Day 1 (Sunday afternoon), the activities officially started on Day 2 with introductions and an ice breaker. The students then travelled to Lake Fayetteville to observe a solar boat demonstration from the U of A Solar Splash team. After the demonstration, the group was divided into groups (ME or EE), and began receiving instruction for boat assembly. Much of the subsequent camp time was then spent in constructing, wiring and testing the smaller boats. Tours of research labs were also given throughout the week to expose the students to different opportunities within their selected program. The final boat race was held at Lake Wedington on Day 6 in conjunction with a picnic. Check-out occurred on Day 7 (Saturday morning).

Table 4. Highlights of the 2010 Razorback Solar Boat Competition

Day	Major Activities
1 (Sun)	Check in
2	Introductions; ice breaker; travel to Lake Fayetteville to observe solar boat demonstration; begin smaller boat construction
3	Warm up activity; small boat construction; lab tour
4	Small boat construction
5	Small boat construction; lab tour
6	Small boat construction; test boats in pool; Lake Wedington Boat Race
7 (Sat)	Check out

Table 5 shows highlights from the major activities of How It's Done—Chemical Engineering Style from the summer of 2010. Sixteen students attended. After check-in on Day 1, the activities began on Day 2 with an ice breaker to better introduce the student participants and the faculty, and a general overview of Chemical Engineering as a profession. Each day of the program was devoted to hands-on activities in a different aspect of Chemical Engineering, including separation (with an emphasis on the use of membranes), biomedical engineering, energy and food. The activities were performed in groups of 3-4 students. Plant trips to Immunovision, a local biopharmaceutical company, and Kraft Foods were included. Day 6 included a general information session, where student questions about Chemical Engineering, the U of A, scholarships, housing, etc. were answered. Each day ended with students completing evaluation forms. Check-out occurred on Day 7.

Table 5. Highlights of the 2010 How It's Done—Chemical Engineering Style

Day	Major Activities
1 (Sun)	Check in
2	Ice breaker; the Chemical Engineering profession; water desalination, emphasizing membrane filtration
3	Biomedical engineering; electrophoresis
4	Plant trips to Immunovision and Kraft Foods
5	Energy; extracting sugars from algae for fermentation to biofuels
6	Food; making the best cup of coffee; studying at the U of A
7 (Sat)	Check out

A highlight of the week was Day 4, when students competed to extract the most sugar from dry algae. The key to obtaining the highest yield of sugars from algae is to balance the extraction of sugars from easily converted starch with the more difficult extraction of sugars from cellulose, all without degrading the sugars. The student groups were first briefed on the carbohydrate content of algae and how it might be extracted, and then were given time to locate techniques on the internet for extracting sugars from biomass. The student groups each decided on a plan of attack within the constraints of available materials, implemented the plans, and then submitted samples for sugar analysis. Procedures ranging from mild acid or base hydrolysis to enzymatic hydrolysis (from human saliva) were tried. While waiting for sample analysis, the students played with a remote-controlled car that was fueled with biobutanol.

Results from the Programs

Several measurable results were obtained from the three summer programs which demonstrate growth, interest and early success:

- In 2010, EEP1 had participation from four academic departments in the College of Engineering. In 2011, participation increased to six departments. EEP2 had participation from five academic departments in 2010, and participation increased to six departments in 2011. As was mentioned earlier, ESA added a sustainability program in 2011.
- In 2010, 11 students applied to the EEP1 program and all were accepted. In 2011, 31 students applied and 25 were accepted.
- Fourteen students applied to the 2010 EEP2 program and all were accepted. In 2011, 29 students applied and 25 were accepted.

- In 2010, 43 students applied and were accepted to the two 2010 ESA programs. In 2011, 85 students applied and were all accepted to three programs, although some students had to be moved to less "popular" programs.
- Eleven of the 68 summer program attendees in 2010 re-applied to EEP1, EEP2 and ESA in 2011.
- Twenty-five of the 28 high school senior 2010 ESA attendees (89%) applied for admission to the U of A for the 2011-2012 school year.
- Fourteen of these 25 new U of A students received scholarships from the U of A upon their admission to the university. Six of the students received prestigious Chancellor's Scholarships and one received a very prestigious Bodenhamer Fellowship (only six awarded in 2011).

Future Efforts

Several new initiatives will be employed in the future to continue to improve the summer programs. The recruitment efforts will be expanded to increase enrollment in all of the programs, including:

- Developing an improved summer program flyer and summer program website
- Distributing the program flyer to visiting groups/students
- Sending the program announcement and other program information to teacher contacts
- Creating a targeted list of high ability students for summer program contact
- Advertising on the University Newswire system and radio
- Posting program information on Macaroni Kids (an online event website)
- Sending e-mails through U of A Admissions to at least 30,000 contacts
- Advertising through social media (Facebook and Twitter)
- Advertising on departmental websites

To improve the program offerings, feedback has been collected from students, parents, faculty and staff to target areas for improvement. In the future, the programs will have more faculty involvement, and existing program content will be enhanced. Each year, an additional academic program will be added to the Explore Engineering Program, until all departments are on a biannual schedule or each department is doing a half-day program. The goal for the Engineering Summer Academy is to add an additional program each year. The Green Design program was added in 2011, and a civil engineering program will hopefully be added in 2012.

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Biographical Information

ERIC SPECKING
Eric Specking serves as the Assistant Director of Recruitment for the College of Engineering at the University of Arkansas. He directs the engineering recruitment office and most of the College of Engineering's K-12 outreach programs.

EDGAR C. CLAUSEN
Dr. Clausen currently serves as Professor, Associate Department Head and the Ray C. Adam Endowed Chair in Chemical Engineering at the University of Arkansas. His research interests include bioprocess engineering, the production of energy and chemicals from biomass and waste, and enhancement of the K-12 educational experience. Professor Clausen is a registered professional engineer in the state of Arkansas.