EDUCATING ENGINEERS OF THE FUTURE

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ABSTRACT

This paper reports on the latest efforts of the Center for Science and Mathematics Education and the Department of Electrical and Computer Engineering at Stony Brook University to provide high school students with an early exposure to engineering activities. Several programs, events and activities have been offered over the last few years and here we discuss the *Engineering Summer Camp*. This two-week residential camp for high school students in their sophomore or junior years exposes them to hands-on electrical and computer engineering research and educational activities. Students participate in exercises that range from fabricating a fiber voice link to developing an embedded processing system for measuring temperature. The purpose of this effort is to attract, inspire and educate engineers of the future.

Index Terms— K-12 education, electrical and computer engineering, summer camp.

Fig. 1. The Stony Brook Engineering Summer Camp has run annually since July 2009 with nearly 60 participating students, and has proved to be extremely successful.

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1. INTRODUCTION

America is suffering from a shortage of engineering talent [1, 2]. While unemployment remains a major problem across the country, the engineering sector is experiencing the reverse: the inability to find enough skilled engineers. The main reason for this demand is the rapid evolution of technology and the constant need to solve new technological challenges. At present, there is a clear disconnect between successful undergraduate-level and precollege-level engineering education, especially since there is no established tradition of engineering in the K-12 curriculum [3, 4, 5]. Although significant progress has been made in past years towards integration of engineering into K-12 classrooms [3, 6], there are still many inroads that must be made to reach the ideal literacy in precollege programs [7, 8].

The Center for Science and Mathematics Education (CESAME) and the Department of Electrical and Computer Engineering (ECE) at Stony Brook University (Long Island, New York) have established a strong link with the purpose of highlighting the "E" in STEM (Science Technology, Engineering and Mathematics) education and raising public awareness and excitement for engineering. During the past six years, CESAME and ESE have offered a variety of engineering programs, events and activities and have established collaborations with the Women in Science and Engineering (WISE) program and the National Science Foundation-funded project MARIACHI,[1] to attract, inspire and educate students at all levels in science and engineering, so they will be committed to the highest standards of leadership, scholarship and service [9, 10, 11]. Moreover, the offered activities have focused on promoting diversity in the field of engineering in the form of WISE courses (WSE 187), MARIACHI summer workshops for high school students and teachers, engineering summer camps for high school students and research opportunities for students at all levels. As a result of these efforts, several female students have continued into an engineering career path.

In this paper we describe in some detail the latest efforts related to the *Engineering Summer Camp*[2] offered for high

[1] MARIACHI stands for Mixed Apparatus for Radar Investigation of Cosmic-Rays of High Ionization.

[2] stonybrook.edu/cesame/students/EngineeringCamp/engsummercamp.shtml

school students, which has run for the past three years. We report on the novel format of the camp as well as on the particular activities that the students carry out. We also describe the involvement of undergraduate and graduate students as well as student societies' in the running of the camp, and we describe how the camp is evaluated and disseminated.

The remainder of the paper is as follows. The next section gives an overview of the camp. In Section 3 the camp activities are explained in detail. Section 4 discusses the evaluation and dissemination, and finally, Section 5 includes some concluding remarks and details of future plans.

2. AN OVERVIEW OF THE CAMP

The *Engineering Summer Camp* is a two-week residential program for sophomore and junior high school students. The camp consists of a series of engineering activities that combine theoretical classes with hands-on practice involving soldering or programming. Each activity targets a different area in the fields of electrical and computer engineering and has the innovative approach of teaching students to build different "gadgets," such as AM receivers, metal detectors or temperature sensors. Faculty, other campus instructors, graduate and undergraduate students deliver all activities. Competitions are regularly carried out to foster teamwork, the thrill of competition, and to recognize the students who make significant contributions.

During lunch students share their experiences with students or staff and faculty from different University departments including some of the engineering student societies or the Career Center and they get first hand information about life on campus. At the end of the day, the students update an online diary in the form of a *wiki* page where they describe their daily learning adventures and provide feedback to instructors and staff. During the evenings students are exposed to additional educational activities, which include visits to the campus radio station or an astronomy night.

Several grants and corporate partners have partially sponsored the program and have provided financial aid to underrepresented groups and high-needs students who participated in the camp.

3. THE ACTIVITIES

The *educational activities* run every day from 9AM to 5PM with a break for lunch. Most of the activities are completed in one day and all of them involve the building of an engineering product. Below we describe some of them:

- *Changing frequencies:* A series of experiments help students grasp the concept of frequency in everyday signals, mainly in speech and music. The experiments are performed in real time, on dedicated digital signal processing chips, using a visual programming environment. Audio clips and the students own voices are taken as inputs via microphones, and loudspeakers are used as the main outputs. The experiments enable the students to create sound effects on their own.
- *Exploring, and exploring with, sonar:* Sonar range finding is a widely used technique, employed by fishermen, bats and submariners. The basic idea of active sonar is simple: "ping" the target and measure properties of the reflected sound to characterize the object. Students use an ordinary computer sound card and speakers plus a directional microphone to form an active sonar system. With the computing environment MATLAB they create and control the ping and then digitize and display the reflection. Issues like resolution and sensitivity of the system as well as measuring Doppler sonar are addressed.
- *Discovering the radio:* Students learn the basic theory of amplitude modulation and detection as used in the transmission and reception of AM radio signals. Students build a TRF (tuned-radio-frequency) one-chip AM radio from a dedicated kit. In the process of building the radio kit, students become familiar with circuit components such as variable capacitors, air-wound inductors, electrolytic capacitors, resistors, and the single IC chip used for detection. They also learn about transistor audio amplifier stages. Students become acquainted with the notion that the job of engineers is to design and build properly functioning circuits and learn the processes of AM tuning, detection, and audio amplification as they complete the various stages of the kit.
- *Persistence of vision clock:* Our vision plays tricks on us. Many types of visual displays take advantage of these optical illusions. One example would be film movies where we perceive full motion and constant illumination of a scene, but we actually are being shown a sequence of still pictures alternating with darkness. The heart of this activity is a small microcontroller that students custom program in assembly language. The microcontroller is capable of executing millions of instructions each second, and is responsible for flashing the LEDs at the required speed. The LEDs are moved across our field of vision leaving a trail of flashes that appear as text floating in space. Th activity requires soldering skills in the assembly of the system. Most of the computer code is pre-written, but the student needs to make a few changes to customize the unit to for example display the desired text.
- *Creating prototypes:* This topic is essentially "Microcomputers 101." Students learn and utilize fundamental microcomputer system design techniques, resulting in the construction of a fully working design prototype. The design is a simple ambient temperature monitoring system. This activity has a lecture/laboratory format. The lectures present important theoretical descriptions of the hardware and software utilized for the implementation of the system, and the

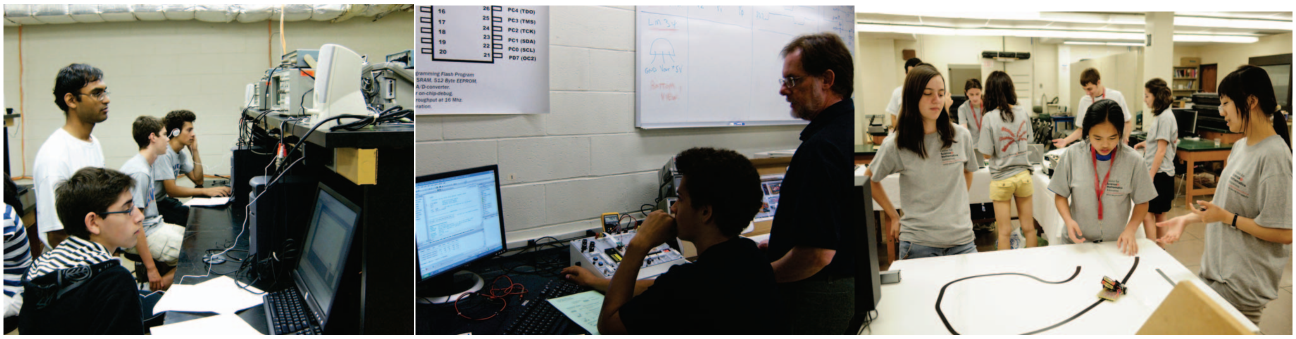

Fig. 2. Pictures from the activities. Left: Changing frequencies; Middle: Creating prototypes; Right: Line following robot.

lab periods are spent constructing, testing, troubleshooting, and verifying proper system operation of their prototype. A full design overview is provided, and by the end of the activity, each student has constructed and fully tested the system prototype.

- *Building a line following robot:* A line following robot is a mobile machine that automatically follows a specified path without the need for human steering. The machine has various applications in areas such as industrial automation, warehousing and automatic guided vehicles on roads of the future. Students build and improve a line following robot based on three main components: a sensing system, a drive system and a microcontroller. The sensing system consists of 6 reflective optical sensors and the drive system for the robot has two small DC motors. The shafts of the motors are coupled to rubber wheels that are attached to axles connected to the main body of the robot. The torque generated by the motors is transferred to the wheels to give motion to the robot. Finally, an Atmel Atmega8 microcontroller is used and a control algorithm is implemented to control the speed and direction of the robot. Students explore three types of algorithms: bang-bang control, proportional control and proportional-derivative-integral control. Based on the observed results of the line following, they tune the control parameters of these algorithms to achieve better performance.

It is important to highlight the involvement of the local IEEE Student Chapter, the honors' society Eta Kappa Nu and the Computer Engineering Society, which provide the participants a direct interaction with undergraduate students from the ECE department. One of the educational activities is indeed instructed by students of the IEEE Student Chapter.

As part of the *extracurricular activities*, the Stony Brook Career Center offers a two-day working luncheon where students learn how to build a successful college resume and practice presentation skills. Faculty from other departments such as Mechanical Engineering or Biomedical Engineering participate in round-tables to introduce students to other engineering disciplines. Additional activities include visits to other engineering departments' labs or to the newsroom or the radio station on campus.

During the final day, students prepare a fair with the prototypes that they have built. A panel of judges formed by ECE faculty who are not instructors during the camp, faculty from other departments, staff, alumni and graduate and undergraduate students get to know the students and ask questions about their experiences and projects. At the end of the day a closing awards ceremony concludes the camp.

4. EVALUATION AND DISSEMINATION

A *wiki* page has been set up for the camp to allow for downloading of materials and supporting documents. The *wiki* is one of our most popular tools and serves as a knowledge database. On one hand it has been an excellent tool for the dissemination and collection of information related to the activities. On the other hand, it is also used to keep record of the students' progress and feedback. At the end of the day, each student updates their own *wiki* page as a diary with questions, comments and results of the ongoing activities and exercises. Faculty members from the department, or other participants like the Career Center also use the *wiki* to have their information and materials posted and upload their own contributions.

The progress of the educational plan has been continuously assessed by small surveys and feedback from the students. Entry and exit-level surveys have been carried out to assess the knowledge acquired by the students and their level of satisfaction. The data collection measured baseline variables, such as knowledge of the subject matter, academic self-efficacy, valuation of competence, competence expectancies and subjectively perceived competence. The pre- and post-data for each participants subject knowledge for the 18 participants in the 2010 camp are shown in Figure 3.

Two main results were found: There was a highly significant increase in knowledge about engineering, measured by the quiz that was conducted at the beginning and at the end of the camp. Average score of correct answers in the pre-test was 39% and went up to 60% after the completion of the camp. In addition, subjective perception of competence in-

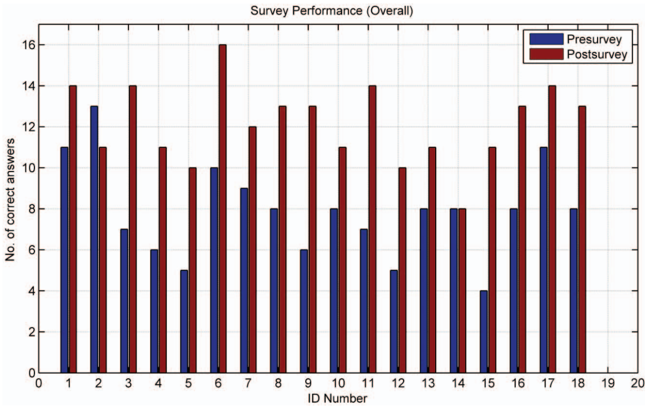

Fig. 3. 2010 performance analysis.

creased from an average score of 1.8 on a 5-point rating scale at the beginning of the camp to 3.9 at the end (these data are not shown for lack of space). The data indicate that the participants started at a high level at the beginning and stayed high until the end. This probably reflects the high standards in selecting the group of students who participated.

In summary, the results indicate that the participation in the *Engineering Summer Camp* had a strong impact on knowledge acquisition. The results are especially noteworthy given the fact that a two-week intervention has such a big effect on central psychological variables. Follow up emails reveal that many of the participants have chosen to pursue engineering as career option.

5. CONCLUSIONS AND FUTURE WORK

In this paper we describe the Engineering Summer Camp offered by Stony Brook University (NY) through the Department of Electrical and Computer Engineering and the Center for Science and Mathematics Education. This is a two-week residential program where sophomore and junior high school students participate in hands-on activities related to the fields of electrical and computer engineering. After its third offering, the success of the program is revealed by the comments of the students in the wiki pages that they created and the emails of students and parents acknowledging and congratulating our team.

We will scale-up this effort by adding new engineering disciplines (mechanical and biomedical) and expanding the camp from two to four weeks.

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