An Arduino-Based Summer Camp Experience for High School Students

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Abstract

A summer camp for high school students was created at Embry-Riddle Aeronautical University in Prescott, Arizona to introduce them to fundamental concepts involved in microprocessor programming and physical computing. During this intensive five-day camp students were introduced to the Arduino-based Sparkfun Inventor's Kit (SIK) as the hardware platform, along with Arduino's Integrated Design Environment (IDE) for programming. This approach facilitated introducing electronics and programming concepts to high-school students, many of whom had little or no previous programming or circuit construction experience. This paper provides details of the topics, schedule, enrollments, and student evaluations of the Arduino-based Summer Camp conducted at Embry-Riddle Aeronautical University in Prescott, Arizona during summer 2015.

Introduction

With well over 100,000 graduates, Embry-Riddle Aeronautical University (ERAU) continues to lead the way as the world's largest university specializing in Aerospace Engineering. The Prescott, Arizona campus of ERAU focuses on excellence in undergraduate education, with a current enrollment of over 2000 students. The College of Engineering is the largest college on campus and is focused exclusively on undergraduate education. The College strives to provide an environment that facilitates faculty-student interaction, provides a hands-on learning environment, and prepares students for success in industry starting with their first day on the job.

Because the focus of the College is undergraduate education, well-equipped laboratories that feature extensive space dedicated to hands-on student learning are available. Reduced demand for these facilities during summer terms provides the opportunity to repurpose laboratory space to support K-12 outreach activities. Additionally, most college faculty are on 9-month contracts which provides the opportunity to engage in K-12 outreach during the summer. Finally, Prescott is located at an elevation of 5000 feet above sea level which makes for a temperate climate for engaging in summer activities as compared with the rest of the state of Arizona.

In order to understand how this summer experience fits in as an outreach activity, it is worth reviewing the taxonomy of K-12 outreach approaches. Jeffers et al. argues that K-12 outreach approaches can be grouped into one or more of the following categories[1]:

1. Develop classroom material including Web-based resources
2. Offer professional development for K-12 teachers
3. Conduct outreach activities at the K-12 school
4. Conduct or sponsor engineering contests
5. Sponsor teaching fellows or offer service-learning courses
6. Conduct outreach activities on the college campus

Integrative STEM Education provided by the International Technology and Engineering Educators Association (ITEEA) provides an example of resources developed to support classroom insruction[2]. Project Lead the Way (PLTW) is an example of an organization directly focused on professional development for K-12 teachers to support pre-engineering education in America's high schools[3]. At the graduate level, the similarly named Integrative STEM education program at Virginia Tech offers degrees to develop K-16 STEM educators, leaders, scholars and researchers[4]. Massachusetts Institute of Technology Outreach is an example of an organization that is involved in outreach activities conducted at the school itself and sponsoring competitions for students[5]. Teaching fellows or service-learning courses are example of opportunities that partner engineering students with K-12 educators[1]. This paper discusses an Arduino-based summer camp experience for high schools students, which falls under the category of an outreach activity conducted on the college campus.

An Arduino-based Summer Camp

The Arduino Uno is an open-source electronics prototyping platform based on the ATmega 328-P 8-bit microprocessor[6]. The Uno includes 14 digital I/O pins (six of which can produce PWM outputs), 6 analog inputs, a USB mini-B connector that provides power and a serial connection to a PC for programming, a power jack for connecting external power, and a reset button. The Arduino Integrated Design Environment (IDE) contains a text editor for composing code, a message area for displaying information during code compilation and upload, a text console, a toolbar with buttons for common functions, and a series of menus. The IDE connects to the Arduino hardware to upload programs, known as "sketches", and provide basic serial I/O communications capability during program execution.

The SparkFun Redboard is a pin-for-pin compatible version of the Arduino Uno that is produced by SparkFun Electronics[7]. The SparkFun Inventors Kit (SIK) includes a SparkFun Redboard, a small solderless prototyping breadboard, and the components and step-by-step instructions to complete 16 experiments that teach students how to read sensors, display information on an LCD, drive motors, and more. The SIK assumes no previous programming or electronics experience, so it provides an accessible entry point for students with little or no background in electronics hardware or software. Table 1 lists the circuit examples provided with the SIK, while Table 2 provides a list of the components included in the SIK.

Figure 1 provides the schedule for the summer camp. The schedule is quite intensive in order to keep the students busy from arrival Sunday evening (not shown) through the Graduation Luncheon held at noon on Friday. As shown in the schedule, classes normally were held from 8 am to 5 pm with an hour provided for lunch at the campus dining facility. Additionally, as shown in the schedule, several evening technical sessions were provided. During these sessions a faculty member provided presentations on engineering entrepreneurship and a history of the computer.

Table 1. List of SIK Experiments

Experiment Number	Description
1	Blink an LED
2	Control LED Brightness
3	Control RGB LED
4	Control Multiple LEDs
5	Read Push Buttons
6	Photo Resistor
7	Temperature Sensor
8	A Single Servo
9	Flex Sensor
10	Soft Potentiometer
11	Piezo Buzzer
12	Spinning a Motor
13	Relay
14	Shift Register
15	LCD
16	Simon Says Game

Table 2. List of SIK Components

SparkFun Redboard	Flex Sensor
Solderless Breadboard	Softpot
16x2 White on Black LCD	USB Cable
74HC595 Shift Register	Photocell
2N2222 Transistors	RGB LED
1N4148 Diodes	10K Trimpot
DC Motor with Gear	Piezo Speaker
Small Servo Motor	330 Ω and 10 kΩ Resistors
SPDT Relay	Pushbuttons
TMP36 Temp Sensor	Jumper Wires

Monday, 6/15/15	Tuesday, 6/16/15	Wednesday, 6/17/15	Thursday, 6/18/15	Friday, 6/19/15
Wake Up Call 6:00AM	Wake Up Call 6:00AM	Wake Up Call 6:00AM	Wake Up Call 6:00AM	Wake Up Call 6:00AM
Breakfast 7:15-7:45AM, Dining Hall	Breakfast 7:15-7:45AM, Dining Hall	Breakfast 7:15-7:45AM, Dining Hall	Breakfast 7:15-7:45AM, Dining Hall	Breakfast 7:15-7:45AM, Dining Hall
Intro To Arduino Camp and Experiment 1,2,3, King 130, 8AM - 11AM, Instructor X	Experiment 8,9,10,11, King 130, Instructor X, 8AM - 11:30AM	Experiment 14 & 15, R&D Project Time, King 130, Instructor X, 8AM - 11:30AM	Project R&D Time, Instructor X, King 130, 8AM - 11:30AM	Project R & D Time, Project Demonstration, 8AM - 11:30AM, KETC 130
Campus Tour, 11AM - 12PM, Admissions				
12PM - 1PM Lunch, Dining Hall	11:30AM - 1PM, Lunch and Dorms	11:30AM - 1PM, Lunch and Dorms	11:30AM - 1PM, Lunch and Dorms	12PM - 1PM Graduation Lunch, Hangar
Experiments, 4,5,6,7, King 130, Instructor X, 1PM - 5PM	Experiments 12 & 13/R&D Project Time. Prelim Design Review, Instructor X, King 130, 1PM - 5PM	Experiment 16 and R& D Time, Intermediate Design Review, Instructor X, King 130, 1PM - 5PM	Project R & D Time, Critical Design Review, King 130, Instructor X, 1PM - 5PM	Check out of Dorms, Hall 7, 1PM - 3PM
Dinner and Dorms - Dining Hall 5:30PM - 6:30PM	Peter Piper Pizza - Dinner and Games 5:30PM - 8PM	Dinner - Dining Hall 5:30PM - 6:30PM	Dinner - Dining Hall 5:30PM - 6:30PM	
6:30PM - 8:30PM, Technical Presentations, Instructor Y, King 126		6:30PM - 8:30PM, Technical Presentations, Instructor Y, King 126	Movie Night/Game	

Figure 1. Daily schedule for Arduino camp students.

During the first day of the camp students were paired up with another student based on experience levels. This reduced the burden on the instructor by allowing more experienced students to assist students with less experience. As shown in the schedule in Fig. 1 and the list in Table 1, students worked through the 16 SIK experiments. These experiments exposed students to introductory concepts like blinking an LED, and then moved on to more advanced topics like controlling RGB LEDs, reading temperature sensors, and driving LCD displays, motors, and servos. At each step students learned basic principles behind digital and analog electronics and microprocessor programming in a language similar to the C/C++ programming languages. The final SIK laboratory experiment involved constructing a relatively sophisticated "Simon Says" memory game in order to challenge the students' circuit construction and programming abilities.

At the completion of each experiment student teams were encouraged to try to modify the program to extend what they had learned beyond what was given in the experiment. This provided students with the opportunity to experiment on their own. For example, after learning how to blink an LED in Experiment #1, students might modify the code to alter the blinking rate so that the on-off period was no longer symmetrical. Additionally, from time-to-time the instructor would provide an in-class tutorial in order to supplement the information provided with the SIK. For example, a discussion of how to apply a transistor as an amplifier to source the additional current necessary to drive a small motor was provided.

During the second half of the camp, students worked in teams of two-to-three to implement designs of their own selection using their SIKs. As they developed their designs, students were introduced to the engineering design process. Students were required to provide preliminary and intermediate design reviews where they discussed the progress of their design, related any issues that were impeding their progress, and then brain-stormed solutions to the problems they encountered. These daily sessions introduced camp participants to the communications and presentation skills so important to practicing engineers.

During the last morning of the camp each team provided a final oral presentation and project demonstration to the entire group. Student projects ranged from digital clocks with alarm functions, to wireless control of a small mobile robot, to a multi-function calculator with memory, to a simple game that measured the speed of human reactions.

Participant Information and Program Evaluation

Summer 2015 was the first summer that the Arduino camp was offered on the Prescott campus. The camp was designed to host sixteen students and the camp sold out well in advance attracting 13 male and 3 female attendees. Summer camps are advertised nationally by ERAU, and therefore the camp attracted attendees nationally as well as from the local area as shown in Table 3. The camp also attracted a diverse range of ages as shown in Table 4.

Table 3. Student States of Residence

AZ (4), CA (3), CO (1), FL (2), MN (1), NV (1), NY (1), OR (1), TN(1), WA (1)

Table 4. Ages of Attendees

14 (1), 15 (4), 16 (6), 17 (5)

Table 5. Office for Summer Programs Survey Questions and Results

Questions:	Arduino	Aero	Astro	Average
1. How would you rate your overall camp experience?	8.8	8.8	8.4	8.7
2. How would you rate the overall performance of the student coordinators/staff members?	9.2	9.4	8.6	9.1
3. The student coordinators/staff members were approachable and made you feel welcome.	9.2	9.6	8.7	9.2
4. The camp schedule was adequately involved.	8.8	8.5	8.2	8.5
5. The food provided was satisfying.	7.8	7.5	6.1	7.1
6. How would you rate your housing experience?	8.1	8.3	7.5	8.0
7. The curriculum was interesting and helped you learn.	9.4	8.9	8.8	9.0
8. The in-class lessons were applicable to your projects and any assignments.	9.6	9	8.6	9.1
9. The professors were engaging and easy to understand.	8.6	8.6	7.4	8.2
10. How would you rate your opportunities and experience here at ERAU?	9.3	9.3	8.9	9.2

The Office for Summer Programs at the Prescott campus of ERAU surveys attendees to determine their satisfaction with each camp prior to their departure at the end of the week. This survey is general and queries attendees not only on academic aspects of the camp, but also on housing, meals, and extracurricular aspects of the program. Table 5 contains the survey questions as well as the results for the Arduino camp and the other academic camps offered during the summer. The rating scale ranges from 1 (low satisfaction) to 10 (high satisfaction). The last four questions in the survey relate to student satisfaction with each camp's curriculum. It is interesting to note that the ratings for these four questions for the Arduino camp equal or exceed the ratings of the other academic camps, despite the fact that this was the initial offering of the Arduino-based camp and the other camps have been offered for a number of years.

Table 6. Results of Student Evaluation of Arduino Camp

Questions:	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. The activities conducted during the week met or exceeded my expectations for the camp.	6	9			
2. The SIK guide provided sufficient information for me to complete the experiments.	9	6			
3. The SIK experiments were interesting and challenging to me.	6	8	1		
4. The schedule of the class provided a good balance between structured time and project time.	6	7	2		
5. The in-class tutorials improved my understanding of hardware and software concepts.	6	9			
6. The evening presentations were informative and educational.	7	4	4		
7. The team presentations provided me an opportunity to communicate what I had learned to an audience.	5	5	5		
8. I am more interested in studying computer, electrical, or software engineering as a result of this camp than I was before.	3	6	6		
9. I would recommend this camp to others.	7	6	2		

In addition to the survey conducted by the Office for Summer Programs, the instructor also surveyed the camp attendees at the conclusion of the camp. This survey focused on student satisfaction with the curriculum, the SIK and the experiments, team presentations of the design projects, and how much the camp increased their interest in studying computer, electrical, or software engineering. Table 6 reports the number of responses in agreement with each category from the 15 students taking the survey (one student departed early before the survey was administered).

The results of the student evaluations in Table 6 confirm the success of the camp as an outreach activity design to stimulate student interest in STEM topics. In responding to the evaluation all of the students either *Agreed* or *Strongly Agreed* with the statement "The activities conducted during the week met or exceeded my expectations for the camp." Student responses indicated that 9 out of 15 either *Agreed* or *Strongly Agreed* with the statement "I am more interested in studying computer, electrical, or software engineering as a result of this camp than I was before." The remaining 6 students indicated a neutral response to the question. This is an encouraging result given that many of the students had little or no previous exposure to programming, circuit construction, or any of the other technical topics covered during the camp.

As part of the evaluation process, students were provided an opportunity to give written responses to the following questions:

1. The one thing I like best about the camp was
2. The one thing I like least about the camp was
3. The one thing I wish had been done better during the week is
4. The one thing I wish we had spent more time on during the week was
5. The one thing I wish we had spent less time on during the week was
6. If I could change one thing to make this a better camp for next year it would be
7. Is there anything else you'd like to add?

These questions drew a number of related, as well as unrelated responses, but generally indicated strong student satisfaction with the concept behind the camp: combining experiments in the SIK with the opportunity to participate in individual and team-based design projects.

Summary

A new summer camp for high school students was created at Embry-Riddle Aeronautical University in Prescott, Arizona in order to expose them to fundamental concepts involved in microprocessor programming and physical computing. The results of student responses confirm the success of the camp as an outreach activity designed to increase student interests in STEM topics. All 15 student responses *Agreed* or *Strongly Agreed* with the statement "The activities conducted during the week met or exceeded my expectations for this camp." Additionally, 9 out of 15 student responses either *Agreed* or *Strongly Agreed* with the statement "I am more interested in studying computer, electrical, or software engineering as a result of this camp than I was before." This student feedback and other lessons learned will be incorporated to improve the next iteration of the Arduino summer camp scheduled for June, 2016.

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