Robots and Smartphones for Attracting Students to Engineering Education

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Abstract — **The field of Robotics has been around for over half a century. Historically robots have been mostly used for industrial manufacturing applications, although emerging areas in medical, space, security, military, entertainment, and service applications are gaining momentum in the recent years. In the academic community also there have been growing efforts at many K-12 schools to motivate students in STEM education through participation in robotics competitions. A well-known example in this regard is the FIRST, which organizes a number of regional and national robotic competitions. This paper presents a pre-college summer program in robotics and Smartphone programming that is developed for high school students with the goal of attracting them to the field of engineering. The program offers great opportunities for the participants to appreciate the practical value of their academic curriculum and at the same time develop their creativity, problem solving, communication, and team skills.**

Index Terms — **Pre-college program, STEM, Robotics, Programming, Smartphone.**

I. INTRODUCTION

To enhance the competitiveness of the US workforce it is essential to improve the quality of education in the country's K-12 and higher education systems. The government has recognized the challenge in this regard and is leading nationwide effort in raising awareness and improving the standards of education [1][2].

Due to budget shortages, however, many public schools continue to face challenges in finding the resources for quality education. To meet the needs for the 21st century workforce and maintain America's leading edge in technology, the education system has to continue to improve for providing the young generation the necessary skill set. There is increasing demand in highly skilled personnel who have the right preparation in science, technology, engineering and math (STEM) education.

A study has shown that encouraging young people to make a difference in the world through the use of engineering and technology will likely attract them than emphasizing the challenge of math and science skills [3]. Knowing that they can actually make a difference has a powerful impact in their perception about science and engineering education.

Kettering University is a primarily undergraduate institution with emphasis in STEM education. The university has a great history of educating engineers and scientists that have become highly successful in their professional career. The university is well known in its co-operative education that integrates the academic curriculum with professional experience in the industry. So students see the direct applications of their education in the practical world. They also bring back their rich co-op experience to the classroom that further enhances their theoretical understandings.

To offer opportunities and attract highly motivated and talented high school students to pursue college preparation programs, many universities and community colleges offer pre-college educational programs. These are typically run during summer, but some institutions also offer year-round programs.

Kettering University has long recognized the role of pre-college programs in motivating and attracting young K-12 students to higher education in the specific fields of their interest [4]. The programs allow the participants to explore the different career opportunities and help them identify the ones that match their interests.

The rest of this paper is organized as follows. The next section presents the history of the Kettering University Computer Engineering Summer Day Camp. Following that we present the details of the summer camp curriculum, discussing the specific topics covered each day in the program. In the last two sections we present evaluation results of the summer camp and conclusions.

II. HISTORY OF KETTERING UNIVERSITY COMPUTER ENGINEERING SUMMER DAY CAMP

In the past decade there has been increasing involvement by young K-12 students in various robotic competitions. Examples of such robotics competitions are Junior FIRST Lego League (Jr.FLL - grades K-3), FIRST Lego League (FLL - grades 4-8), FIRST Tech Challenge (FTC - grades 7-12), FIRST Robotics Competition (FRC - grades 9-12), that

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***We would like to acknowledge the generous support of the Donald Lee Smith Fund of the Community Foundation of Greater Flint

are all managed by FIRST (For Inspiration and Recognition of Science and Technology) [5]. Such competitions provide great opportunities for the participants to appreciate the value of their academic curricula and develop the skills for problem solving, communication, and teamwork. They further help them explore potential career pathways and learn valuable life and employment skills. In most cases these types of robotic teams and competitions are coached and run by volunteers, who are typically from well-educated and middle class families.

One of the main challenges for kids from economically disadvantaged school districts is the lack of resources to take part in competitions like FIRST. The registration fees and the costs for acquiring kits to enter into such competitions easily run from $1200 to over $6500 [6][7], without the logistics expenses. The high costs become prohibitive for many schools especially in the recent years when education funding is put on the line for major cuts [8].

To address this challenge in the communities surrounding our institution, colleagues in the Electrical and Computer Engineering department developed and started to offer a summer program in Robotics and Smartphone programming. The program was launched in 2010 as a weeklong day camp, with 4 hours of activities per day. The pilot program was primarily focused on building LEGO MINDSTORMS [9] robots and programming them using the ROBOTC [10] language. ROBOTC is a C-based, easy to learn, robotics programming language for educational robotics and competitions.

In addition to the robotics activities, the summer camp also includes short presentations on Introduction to Electrical and Computer Engineering, Mobile Robotics, career opportunities, college degree programs, admissions, and scholarship opportunities.

After the successful run of the pilot offering of the robotics camp, the following year in 2011 the program was further expanded to a week long full-day camp. Besides the robotics material, activities on Smartphones and their programming are added. Students learn how to use graphical based MIT App Inventor [11] to create applications for Android based Smartphones and tablets. The kids find it interesting and fun creating apps with increasing levels of complexity in such a short training period. They even have more fun when they are able to program their phones to remotely control the robots in a competition setting.

III. Computer Engineering Summer Day Camp Curriculum

The curriculum has two major components:

1) Mobile Robotics – Build mobile robots using Lego or other kits, program robots, learn different types of sensors and integrate them with robots, control robot with programs running on a phone.
2) Smart Phone Programming - Learn App Development environment, use phone devices such as GPS and Bluetooth, and create Map App, control robot through Bluetooth.

Program outcomes - students who successfully complete this summer camp are expected to demonstrate:

- Practical application of STEM to basic Computer Engineering topics including mobile robotics, programming, and Mobile Apps development.
- Problem solving skills
- Team-work skills

The summer camp is typically run around the middle to end of July. The program hours are from 9:00 AM to 4:00 PM, with one-hour lunch break. Table 1 shows the program schedule, showing the split of activities between Robotics and Mobile Apps development.

TABLE I
Computer Engineering Summer Day Camp Program Schedule

	Mon	Tue	Wed	Thurs	Fri
Morning I	Robotics	Robotics	Robotics	Robotics	Robotics
Morning II	Mobile Apps	Mobile Apps	Mobile Apps	Mobile Apps	Mobile Apps
Afternoon I	Robotics	Robotics	Robotics	Robotics	Robotics
Afternoon II	Mobile Apps	Mobile Apps	Mobile Apps	Mobile Apps	Mobile Apps

The list of topics and hands on activities planned for the Robotics part of the program are presented below. Figure 1 shows a model of the basic LEGO MINDSTORMS NXT robotics platform that the students build and program. In the final day's soccer competition challenge the teams also add accessories that enable the robot to grab and kick a ball.

Fig. 1. Basic setup of the LEGO MINDSTORMS NXT robot used in most of the camp activities

Day 1:
- Introduction to mobile robotics.
- Building your first Lego robot.
- NXT Hardware and intro to programming.

Day2:
- ROBOTC programming.
- Basic movement commands.
- Improved movement.
- Programming challenge.

Fig. 2. Students building their robot

```
task main()
{

    motor[motorC] = 50;
    motor[motorB] = 50;
    wait1Msec(4000);

    motor[motorC] = -50;
    motor[motorB] = 50;
    wait1Msec(800);

}
```

Fig. 3. ROBOTC programming example

Day 3:

- Introduction to Sensors.
- Sense-plan-act paradigm.
- Touch sensor.
- Obstacle detection using touch sensor.
- Obstacle course programming challenge.

Day 4:

- Ultrasonic sensors.
- Obstacle detection using Ultrasonic sensors.
- Ultrasonic programming challenge.
- Encoders.
- Movement control using encoder functions.

Day 5:

- Light sensor.
- Movement control using light sensor.
- Major programming challenge (using Bluetooth and Android app).

The Mobile Apps Development module is developed for Android based Smartphones and tablets. The programming environment is a web-based graphical tool that is easy to learn for people without any previous programming exposure. The list of topics and hands on activities planned for the Mobile Apps Development part of the program are presented below:

Fig. 4. AppInventor Designer. The user interface design tool for AppInventor.

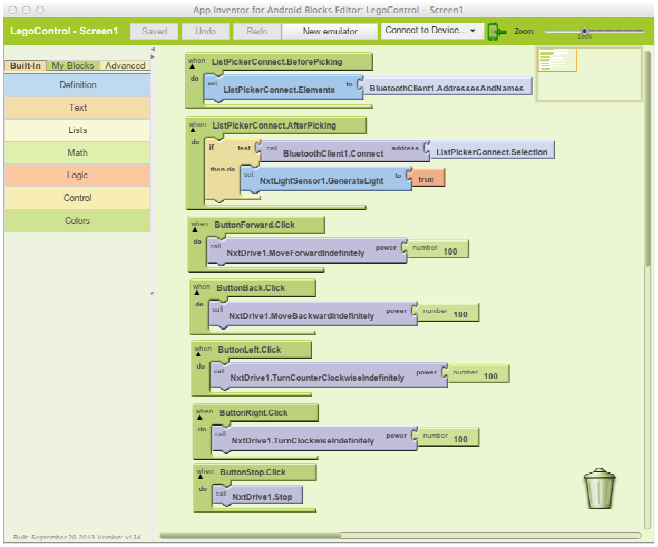

Fig. 5. Blocks Editor for AppInventor. Blocks Editor is the programming tool based on blocks that can be dragged and dropped on top of the canvas.

Day 1:

- Introduction to Smartphone applications.
- App Inventor for Android Setup.
- Making your first Android app.

Day2:

- How to create Android apps.
- Creating a Painter app.
- Installing your app on a Smartphone.

Day 3:

- Using GPS and Text To Speech.
- Creating Map app.
- Automatic Text Messaging app.

Day 4:

- Using TinyDB, and GPS.
- Creating an app for your Mom or Dad.

Day 5:

- Using Bluetooth.
- Controlling Lego MindStorms NXT through Bluetooth.

Figure 4 and 5 show screenshots of the AppInventor screen for the Smartphone programming activities.

The students work in groups of two, so that they can collaborate, learn from one another, and develop teamwork skills. One of the goals of the program is to cultivate creativity and problem solving experience. When each new topic is introduced the students are challenged to work on related practical problems that demonstrate the applications of the topic.

On the final day of the summer camp program the participants take part in a competition, by working on a project that combines several of the concepts introduced throughout the week. They program their Smartphones or tablets to remotely control the robots and achieve the given competition challenge. An example of a final challenge is to build remotely controlled robot (using Smartphone or tablet as the remote control) and to play in a soccer game between two teams of robots. Figure 6 shows a diagram of the soccer arena. Figure 7 shows various attachments from student teams built to allow the robot grab and kick a ball. Teams of two to three robots play on each side. This was indeed found to be a fun way to conclude the summer camp program.

IV. Program Evaluation

This computer engineering summer day camp is a work in progress. The program is open to students who are ready to enter high school grades 9 to 12, by the fall of the same year. The first offering of the program as a pilot was run in July 2010, with only 7 students. Within just one year the enrollment grew to 24, which was actually more than the maximum capacity of 20 initially set. From the post-program surveys completed by the 2011 participants we learned that 92% of the survey respondents were satisfied with the program and that they would recommend it to others.

From the survey conducted at the end of the 2012 summer camp offering, we also obtained satisfactory results as displayed in Table II. In the survey questions there are five options to choose from, in the range 1 to 5. A choice of 3 is considered neutral; while 4 and 5 are considered positive responses; 1 and 2 are considered negative responses.

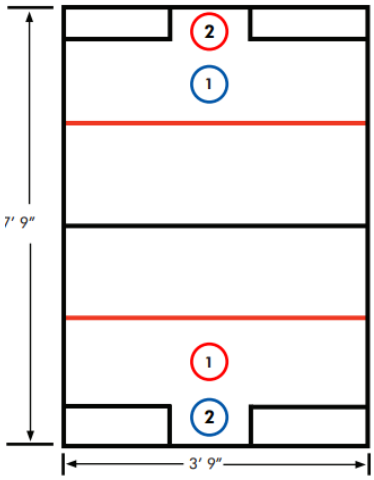

Fig. 6. Soccer arena used for the final day robotics competition. (1) in red is the starting area of team A. (2) in red is the goal scoring area of team A. Similarly, the blue circled colors correspond to team B.

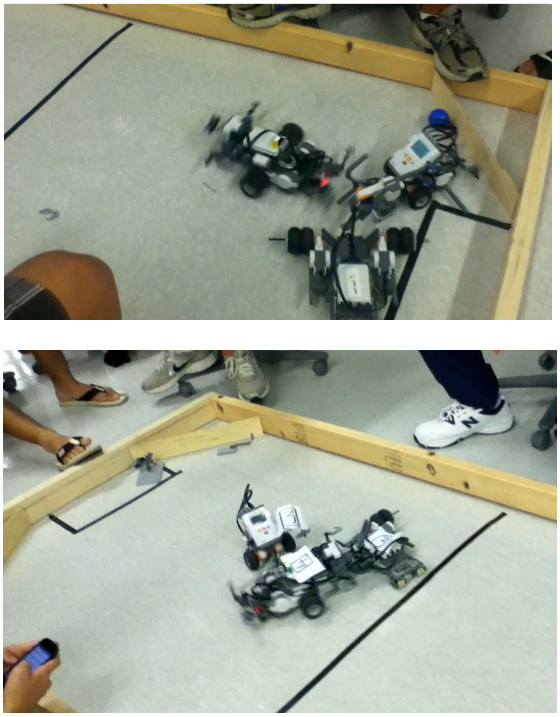

Fig. 7. Various attachments built by student teams to allow their robots play soccer.

TABLE II
POST-PROGRAM SURVEY RESULTS FROM THE SUMMER CAMP PROGRAM OFFERING IN 2012

Survey question	Response
Satisfaction of initial expectations	91% satisfied, 9 % neutral
How much fun the students have while learning	95% positive response, 5% neutral
Appropriateness of the course material to the grade levels	91% appropriate, 9% neutral
Whether they will continue learning the topics on their own	86% positive response, 5% neutral
Whether they like Kettering University's educational environment	95% positive response, 4.5% neutral
Whether they recommend this summer camp to others	86% positive response, 14% neutral

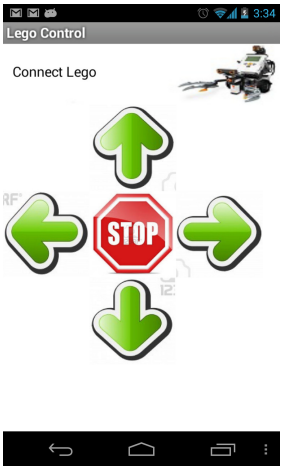

Fig. 8. Smartphone running the robot remote control program (via Bluetooth interface)

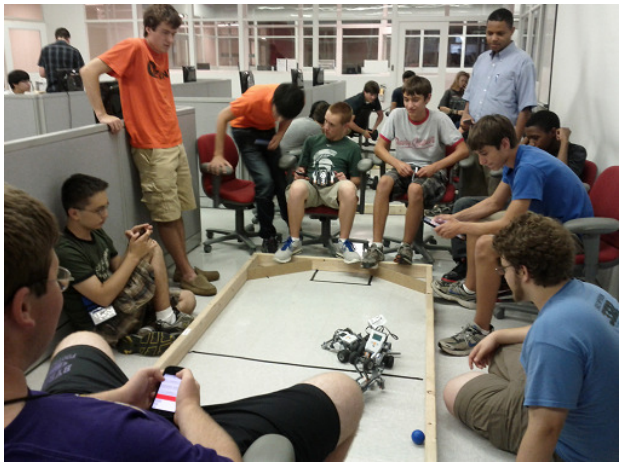

Fig. 9. Soccer challenge in action.

Due to the continued success and popularity of the Computer Engineering Summer Day Camp program, we were able to attract external funding from a community foundation. The program received a generous grant support from the Donald Lee Fund of the Community Foundation of Greater Flint, for three years (2013 to 2015). We are grateful to this support, which motivates us to further expand our offerings by adding a new program targeted for intermediate to advanced level students.

Beginning in the summer of 2013 we have introduced a second program that employs Arduino [12] microcontroller for 11th and 12th grade high school students. The focus of the program is about embedded systems, their applications (such as in automotive, consumer electronics, and industry), and the basic concepts on hardware and software of embedded systems. Topics on microcontrollers, input/output interfacing, sensors, actuators, communications and programming are covered. The activities employ an open robotic platform that the students assemble, and they use the Arduino microcontroller, motor control shield, motors and sensors to drive and control the robot. Bluetooth communication technology is also introduced to allow remote control of the robot using Smartphone.

V. CONCLUSION

This paper presented the effective use of robots and Smartphones for attracting and inspiring students to STEM education. The long-term objective of this summer program is to increase awareness about the Computer Engineering and related fields of study, for high-school students in our surrounding region. The impact will be measured by conducting surveys that look at the number of applicants for our program, the number of those who participate, their diversity in gender and ethnicity, and its impact in their perception about the summer program, Computer Engineering, and STEM in general.

Even though it may take a few more years to see the actual long-term impact of the program, the preliminary survey results from two years in a row demonstrate that there is high level of satisfactions with the program. High percentage of students liked the educational environment provided by the camp and Kettering University in general, and most of them highly recommend our summer camp to others.

Through this summer program Robots and Smartphones are shown to be effective, fun and engaging tools for motivating and attracting students in to STEM programs. It gives the students great satisfaction when they are able to build their robots, program them to perform specific tasks, and give their robots capabilities to sense the environment to detect and avoid obstacles, or navigate in a maze. Also, the practical activities the students perform on robots, sensors, programming, and the Smartphone apps they develop give them excellent exposure into the fields of Computer Engineering, Electrical Engineering, Computer Science, and other related STEM fields.

We will continue to improve the Computer Engineering Summer Day Camps in the years ahead to further enhance its impact in attracting more and more talented students to Computer Engineering and other STEM programs, and Kettering University.

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