Attracting Students to Engineering Through Robotics Camp

Greg Nordstrom[1], Ginger Reasonover[2], Ben Hutchinson[3]

Abstract – This paper presents two years of experience by Lipscomb University's Raymond B. Jones School of Engineering in planning, developing and implementing summer robotics camps. The camps employ a mixture of in-class and studio experiences, coupling lessons in mechanics, machine design, and electronics with guided hands-on experience in designing and constructing working robots. We present curricula for both our "fundamentals" and "advanced" robotics camps. The familiar *requirements-design-build-test-deliver* approach to engineering is used as a framework to guide individual campers and small teams through the robot design and fabrication process. Pre- and post- camp surveys are used to assess camper learning and interest in engineering as a result of attending the camps, and we present these results. Additionally, we show linkages between our robotics camp curricula and various state- and national grade 5-12 scientific, technology, engineering, and math content standards.

Keywords: Engineering, Science, Recruitment, Robotics Camp, STEM

OVERVIEW

Using robotics to interest elementary, middle- and high school students in engineering has gained popularity in recent years. Organized activities often take the form of team-based construction and competition events such as those offered by BEST [1], FIRST [2], and the National Robotics Challenge [3]. Students learn about engineering by experiencing first hand the challenge and excitement of planning, building, and then competing a creation of their own design.

While such competitions are open to all students of a particular age, oftentimes a level of understanding and experience is assumed, making it somewhat difficult for novice students to get much out of these programs initially. Also, when such competitions are not offered locally, these students have few hands-on options for learning about robotics. In an effort to overcome such barriers to entry, and to provide a more introductory approach to robotics, Lipscomb University has developed a summer robotics program designed to introduce students in elementary through high school to engineering through robotics.

BACKGROUND

Beginning in 2006, the Raymond B. Jones School of Engineering at Lipscomb University became involved with BEST (Boosting Engineering, Science, and Technology), a volunteer organization with a mission of exposing middle- and high school students to the practice of engineering through annual robotics competitions. BEST provides teams of students with challenging, hands-on design and construction scenarios and a competitive

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[1] Associate Professor of Electrical and Computer Engineering, Raymond B. Jones School of Engineering, Lipscomb University, Nashville, TN, 37204, greg.nordstrom@lipscomb.edu

[2] Hands-On Science Coordinator, David Lipscomb Campus School, Nashville, TN, 37204, reasonovvw@lipscomb.edu

[3] Dean of the College of Natural and Applied Sciences, Lipscomb University, Nashville, TN, 37204, hutchinsbb@lipscomb.edu

environment within which to demonstrate their efforts. Lipscomb acts as a BEST "hub," providing local teams with materials, engineering expertise, and the competition venue [4]. Faculty members offer their help by becoming BEST "mentors," attending team meetings and guiding students through the engineering process. Lipscomb has also successfully involved its own undergraduate engineering students in the mentorship process [5].

While BEST teams are open to students with diverse backgrounds and experiences, new students are often intimidated by the level of skill and understanding needed to plan, design, construct, and test a working robot. And while the BEST experience is designed to give such students the opportunity to learn these skills, often the reality is that older, more experienced students do the engineering work while the younger, inexperienced students are relegated to non-technical team roles, such as designing t-shirts, constructing the display booth, preparing presentation materials, etc. This situation inspired Lipscomb to consider providing summer robotics camps as a way to raise the experience level of such students in the Middle Tennessee area.

In the spring of 2007, a faculty member discussed the robot camp idea with Bryan Reasonover, a high school student who had recently competed in the BEST robotics competition and was looking for an Eagle Scout project. It was suggested that Bryan plan a one-week summer robotics camp to be held on the Lipscomb campus, and he agreed to pursue the idea. He met with University administrators, presented the idea, and was given permission to use Lipscomb facilities and resources for the camp. The Boy Scouts of America approved his plan, and Bryan acted as camp director, organizing the activities and enlisting the help of Lipscomb faculty and staff to teach robotics classes, work with campers in the design studio, and oversee the use of power tools. He also worked with Lipscomb's public relations office to advertise the camp, and recruited former BEST team members to act as camp counselors. Bryan sought out sponsors to provide materials, and a nominal fee was charged to cover the cost of food, t-shirts and awards. The camp filled up early, was very well received, and laid the ground-work for future camps. Based on the success of that first camp, Lipscomb decided to continue and expand the robotics camp in the summer of 2008.

FUNDAMENTALS AND ADVANCED CAMPS

One point became very clear during our first robotics camp—younger and older campers simply have trouble working together at close quarters for long periods of time. Younger campers lose interest rather quickly and tend to wander, while older campers stay on task and are able to accomplish more in shorter periods of time. Also, peer pressure among older campers tends to keep them from becoming active mentors to the younger campers.

In an effort to better serve the various ages, maturity levels, and skill levels of the campers, while expanding our popular new robotics camp, Lipscomb planned two one-week camps for 2008. The first, a "fundamentals" camp, focused on younger, first-time robot builders while the "advanced" camp was designed to give older, more experienced campers the opportunity to go beyond the basics and increase their robotics knowledge and construction skills. Each camp is described below.

Fundamentals Camp

The goal of fundamentals camp is to give campers a basic exposure to engineering concepts, robotics, electricity, mechanics, and hands-on practice constructing a challenging kit-based robot. The robot used is the OWI-535 Robotic Arm Edge Kit [6], shown in Figure 1 below and currently available for under $30. The OWI-535 can be built by an seasoned kit builder in under four hours, but our experience shows that fundamentals campers require between six and eight hours, with up to two additional hours for test and debug.

- Five degrees of freedom
- Tethered remote control
- Vertical reach: 15 inches
- Horizontal reach: 12.6 inches
- Lifting capacity: 100 grams
- Sturdy construction

Figure 1. The OWI-535 Robotic Arm Edge Kit (photo use permission pending)

The fundamentals camp curriculum is listed in Appendix A. Camp begins with a short welcome session and an ice-breaker activity designed to get the campers interacting with one another, to expose them to brainstorming and the engineering process, and to give them a chance to put that process into practice. We have used activities such as "tallest marshmallow and macaroni" tower, "highest egg drop without breaking," and "strongest paper and clothes pin bridge." The activity can vary, but should have open-ended solutions, limited resources, and end with a short competition.

We motivate the entire week's activities by introducing the robotic arm project on the first day. We also issue each camper a tool kit and have them perform an inventory. Campers don't begin actual construction until they've completed the first mechanics (gears) class and had a session on tools and tool safety. The week continues by interleaving in-class lecture sessions with robot construction studio time. The construction studio consists of two standard sized classrooms, each outfitted with five six-foot folding tables and chairs. This allows each room to comfortably hold 12-15 campers and three or four counselors.

One interesting part of camp is teaching the campers how to solder. Only 25% of our campers have soldered more than once before coming to camp, so it's a new experience for many of them. We have a dedicated lecture on soldering techniques and soldering safety. After that, we distribute solder practice kits (these can be obtained from numerous suppliers for about $6 each) and the campers spend the afternoon building a small electronic device that makes warbling sounds and has a few flashing LEDs. The campers tell us this is one of the most enjoyable activities they participate in while at fundamentals camp.

To show campers first-hand how robots are used in industry, we take them on a one-day field trip to the nearby Nissan automotive plant in Smyrna, Tennessee. By this time the campers are well on the way to finishing their robotic arms, and can immediately see the similarities between what they are building and what Nissan uses on their production floor. Nissan puts on a great tour in general, and they do an especially nice job for our campers.

The morning of the fifth day is spent finishing up the robots and testing them before the final competition. Parents and friends are invited for lunch and the afternoon competition. The competition is a "pick-and-place" race that centers around a six-foot long conveyer belt with a large collection bin at one end. For each round of competition, six robots are placed near the conveyer belt, three on each side. Surrounding the robots are blocks of various sizes, shapes, and colors. Each camper is assigned a color, and must use their robot to pick up as many blocks of their color as possible and place them on the conveyer belt in three minutes. At the end of the round, blocks that made it to the output bin are counted and scores are tallied. Higher points are awarded for heavier and irregularly shaped blocks. We are able to complete eight such heats in about an hour. From these preliminary rounds six campers advance to the finals round. The finals round lasts another hour and determines the final order of the top six finishers. Fundamentals camp concludes with an awards ceremony and a picture session.

Advanced Camp

The second camp we offer is an "advanced" camp designed to take more experienced campers beyond the kit-building activities of fundamentals camp and increase their understanding of engineering and robotics through the design and construction of a robot from raw materials, similar to what is done in BEST.

As with the fundamentals camp, advanced camp exposes campers to engineering concepts, robotics, mechanics and electronics, but provides more depth, involving the campers in planning, designing, and constructing a robot that meets a set of predefined design criteria. The robot must be capable of forward-, backward-, left- and right-hand motion, at variable speeds, under remote control. At least three 8" balloons must be mounted on the robot at heights between 12" and 30", and each robot must include a robotic arm mechanism to aid in the popping of opponents balloons during competition. Given these constraints, the design decisions are left entirely to the campers. Typical robots are shown in Figure 2.

As seen in the advanced camp agenda in Appendix B, the approach of using an icebreaker activity, introducing the final project early on the first day, and interleaving lecture and studio sessions is similar to that used in the fundamentals camp. However, advanced camp lecture sessions are more in-depth, covering topics such as transmitters and receivers, speed controllers, and manipulator arm design, and includes more time for planning, designing, and constructing the robot itself.

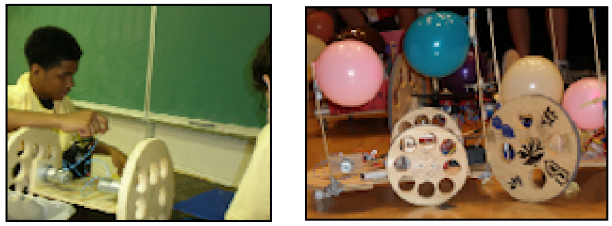

Figure 2. Building and battling advanced camp robots

Due to the short amount of time, the high cost of materials, and the relative complexity of the final project, campers are assigned to design teams of three to four. They must organize themselves into a team and assign each member various pre-defined team roles including project lead, motion base designer, manipulator arm designer, test engineer, and graphics designer. Camp counselors and engineering faculty act as mentors and technical advisors to the teams, taking them through the design process one step at a time. A machinist from the engineering department machine shop also acts as a mentor, overseeing the use of the drill press, the lathe, the milling machine, the band saw and other large power tools. Several smaller hand- and power tools are available in the studio rooms and campers are taught how to use them.

As with fundamentals camp, the week culminates in a final competition. For the advanced camp, this takes the form of a large ring (the "ring of doom") where up to four robots at a time compete head-to-head in a series of three-minute heats attempting to pop as many of their opponents balloons as possible (scoring positive points) while defending their own balloons (which count negative points if popped). Both intermediate- and final round competitions are held, and camp ends in an awards ceremony and picture-taking session. Because the robots remain behind after camp, counselors disassemble the robots immediately after camp and store the reusable parts (motors, servos, sensors, transmitters and receivers) for future use.

STEM STANDARDS

Lipscomb's robot camps have proven to be extremely popular. But more than being fun, these camps supplement and reinforce experiences required by Tennessee grade 5-12 scientific, technology, engineering, and math (STEM) curriculum standards [7] and suggested by federal STEM initiatives and guidance [8]. While we used the curriculum standards provided by the State of Tennessee to guide us, standards provided by other states are quite similar. A list of 14 Tennessee STEM curriculum standards covering Embedded Technology and Engineering, Embedded Mathematics, Energy, Motion, and Forces in Nature are listed in Appendix C. All are applicable to robotics camp.

To illustrate how the robot camp experience relates to state curriculum standards, consider one of the activities the campers participate in—designing wheels for their robots. Applicable Tennessee STEM curriculum standards are shown parenthetically. Robots have an overall height limit, and campers are given a choice of wood or plastic for their wheels. Such size limits and materials choices represent design constraints in the engineering process (CLE 3202.T./E.2). Campers are encouraged to build prototype wheels of both plastic and wood to test for weight and traction (CLE 3202.T./E.3), and had to justify their material choice based on these tests. Next, final wheel size is calculated (CLE 3202.Math.2 and CLE 3202.Math.6) based on game strategy (speed vs. maneuverability) and the wheels designed. Once designed, wheels are built and tested, and test results used to determine which wheel size best solved the problem at hand (CLE 3203.3.1). Of course, the entire exercise reinforces the use of the engineering process (CLE 3202.T./E.2).

Throughout the course of robotics camp, several other STEM-based curriculum standards are reinforced by robot camp activities as well, as suggested by a review of Appendix C. In addition to giving campers hands-on experiences in STEM-related activities, robot camp activities can also help them meet certain ACT College Readiness Standards [9] in mathematics and science as well as National Science Foundation's Science and Technology Standards [10]. Overall, robot camp provides many STEM-based experiences that will benefit the campers when they return to the classroom.

RESULTS AND EVALUATION

It's clear to all of us involved in the Lipscomb robotic camps that the students thoroughly enjoy themselves. We observe their enthusiasm first hand, and we hear about it from them, their parents, and even their grandparents. However, in an effort to quantify the amount of experiential learning that occurs during robotics camp, we ask the campers to complete both a pre- and a post-camp survey. In addition to basic demographic data (including data on how well they do in math and science in school), we gather data on the camper's understanding of what engineers do, their past experience with using tools, and measure their self-reported increased or decreased interest in math, science, engineering and robotics as a result of attending camp. The same survey is given to fundamental and advanced campers. The summer 2008 survey results are presented below. No attempt was made to distinguish between data coming from fundamentals campers vs. advanced campers.

2008 Robotics Camp Pre-Camp Survey Results

In 2008 we had 53 camper attend robotics camp at Lipscomb University. Six were female and 47 were male. Campers ranged normally in age from 10 to 17 years old, with the majority being aged 13. All reported getting good grades in math and science, with 28 responding that getting such grades was "easy" compared to 11 who said they had to "work hard" to achieve good math and science grades. At the beginning of camp, 17 campers said they "definitely understand what engineers do" while 21 said they were "not too sure what engineers do." None reported having "no idea what engineers do."

A portion of the pre-camp survey asked detailed questions about the campers' construction experiences (clamping, gluing, marking for cuts, sanding, finishing, disassembling mechanical and/or electrical devices, and measuring electrical characteristics such as voltage, current, and resistance). In all cases, a relatively small number (8% to 25%) had never done these activities, and in all cases except the electrical measurements, 48% to 72% said they had done the activities "many times." Almost half had made electrical measurements "at least once."

Campers also answered survey questions regarding experience with various tools. Over 95% had used hammers and screwdrivers "many times" and the rest had used them "at least once." 64% reported using wrenches, pliers, and wire cutters "many times" with less than 8% reporting having "never used" them. Many (62%) had used hand saws and hand-held power drills "many times" but few (less than 26%) reported using them "many times." Only 17% had used a drill press "many times" with a majority (over 56%) reporting having "never used" a drill press.

2008 Robotics Camp Post-Camp Survey Results

The post-camp survey used four questions to determine what changes in interest and understanding of engineering had occurred as a result of attending robotics camp. Table 1 below summarized this data. Questions pertaining to demographics, the ability to get good math- and science grades, and prior skill with tools and construction techniques are not repeated.

When it comes to understanding what engineers do...	73% had **more understanding** about what engineers do	27% had the **same understanding** about what engineers do	None had **less understanding** about what engineers do
As a result of camp…	59% had **increased interest** in math, science and engineering	41% had the **same interest** in math, science and engineering	None had **less interest** in math, science and engineering
As a result of camp…	86% had **more interest** in robotics than when camp started	14% had **the same interest** in robotics as when camp started	None had **less interest** in robotics than when camp started
As a result of camp…	77% had an **increased interest and ability** in using tools	23% had the **same interest and ability** in using tools	None had a **decreased interest and ability** in using tools

Table 1. Summary of changes in interests and skills as a result of camp

CONCLUSIONS

Notionally and empirically, the data are quite encouraging. Campers have a lot of fun at robotics camp and, in large majority, credit attending camp with an increase in their interests, skills, and understanding of mathematics, science, engineering and robotics. Especially encouraging is the fact that not a single camper reported a decrease in any of these areas as a result of attending robotics camp. It had the desired effect—the campers are attracted to engineering!

Lipscomb University sees this as a successful program and plans to continue and grow the camps in the future. Currently there are plans for a Robotics Academy during the summer of 2009 which will focus on programmable platforms to create robots with autonomous behavior. Also, many of the campers from our 2007 and 2008 robotics camps have joined or formed BEST teams, doubling of the number of Lipscomb hub teams registering for BEST 2008 when compared to BEST 2007 (eight in 2007 vs. 16 in 2008). We foresee continued growth of our BEST hub due to student involvement in robotics camps.

Finally, Lipscomb sees these robotics camps as a community outreach effort. To that end, we are pursuing sponsorship of disadvantaged and minority campers from local businesses, as well as seeking funding for additional camps targeting at-risk children in the local community.

APPENDIX A – FUNDAMENTALS CAMP AGENDA

Monday	
0830-0900	Registration
0900-1030	Welcome session
1030-1045	Break
1045-1130	Intro to Robotics and the Engineering Process
1130-1200	Lunch
1200-1215	Introduction to the "Robotic Arm" project and competition
1215-1300	Mechanics I: Introduction to Gears
1300-1315	Construction I: Tools and tool safety
1315-1330	Break
1330-1500	Kit build
Tuesday	
0900-0945	Mechanics II—Real-World Design Constraints
0945-1000	Break
1000-1130	Kit build
1130-1200	Lunch
1200-1245	Electricity I: Batteries, Lights, and Switches
1245-1300	Construction II**:** Soldering Safety
1300-1330	Soldering Project
1330-1345	Break
1345-1500	Soldering Project (cont)
Wednesday	
0900-0945	Mechanics III—Gravity, Forces and Loads
0945-1000	Break
1030-1130	Kit build
1130-1200	Lunch
1200-1315	Kit build
1315-1330	Break
1330-1445	Kit build
1445-1500	Field trip preview
Thursday	
0800-1400	Field trip to Nissan plant in Smyrna, TN
Friday	
0900-1015	Kit build
1015-1030	Break
1030-1145	Trial runs and testing (finish kit if necessary)
1145-1215	Lunch
1215-1330	First round competition
1330-1345	Break
1345-1430	Final round competition
1430-1500	Awards, pictures, camp survey and wrap-up

APPENDIX B – ADVANCED CAMP AGENDA

Monday	
0830-0900	Registration
0900-1015	Welcome session
1015-1030	Break
1030-1100	Review of Robotics and the Engineering Process Introduction to the final project
1100-1145	Electronics I: Transmitters, Receivers, Motors and Speed Controllers
1145-1215	Lunch
1215-1230	Construction I: Tools and tool safety
1230-1345	Robot build
1345-1400	Break
1345-1500	Robot build
Tuesday	
0900-0945	Mechanics I: Wheels, Axles, Speed and Torque
0945-1000	Break
1000-1130	Robot build
1130-1200	Lunch
1200-1245	Mechanics II—Manipulators and Arm Design
1245-1345	Robot build
1345-1400	Break
1400-1500	Robot build
Wednesday	
0900-1000	Soldering project (line/sound tracker project)
1000-1015	Break
1030-1145	Soldering project (move to robot build as finished)
1145-1215	Lunch
1215-1245	Electronics II: Servo-driven switches
1245-1345	Robot build
1345-1400	Break
1400-1500	Robot build
Thursday	
0800-1400	Field trip to Nissan plant in Smyrna, TN
Friday	
0900-1015	Robot build
1015-1030	Break
1030-1145	Trial runs and testing (finish Robot if necessary)
1145-1215	Lunch
1215-1330	First round competition
1330-1345	Break
1345-1415	Final round competition
1415-1500	Awards, pictures, camp survey and wrap-up

APPENDIX C – APPLICABLE TENNESSEE STEM STANDARDS

Embedded Technology and Engineering:

CLE 3202.T./E.1	Explore the impact of technology on social, political and economic systems.
CLE 3202.T./E.2	Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.
CLE 3202.T./E.3	Explain the relationship between the properties of a material and the use of the material in the application of technology.

Embedded Mathematics:

CLE 3202.Math 2	Utilize appropriate mathematical equations and processes to solve basic physics problems.
CLE 3202.Math.5	Interpret results of Algebraic procedures.
CLE 3202.Math.6	Model real-world phenomena using functions.

Energy:

CLE 3202.2.4	Probe the fundamental principles and applications of electricity.
CLE 3202.2.9	Solve problems related to voltage, resistance and current in a series circuit.
CLE 3202.2.10	Investigate Ohm's law to design and build a simple circuit.

Motion:

CLE 3203.3.1	Investigate the relationships among speed, position, time, velocity and acceleration.
CLE 3202.3.2	Investigate and apply Newton's three laws of motion.

Forces in Nature:

CLE 3202.4.1	Explore the difference between mass and weight.
CLE 3202.4.2	Relate gravitational force to mass.
CLE 3202.4.3	Demonstrate the relationships among work, power and machines.

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Greg Nordstrom

Greg Nordstrom is an Associate Professor of Electrical and Computer Engineering at Lipscomb University where he teaches courses in embedded systems, microprocessors, and digital computer design. He holds a Bachelor of Science in Electrical Engineering from Arizona State University, a Master's degree in Electrical and Computer Engineering from the University of Tennessee, and a Ph. D. in Electrical and Computer Engineering from Vanderbilt University. His research interests include techniques for automating the growth and analysis of protein crystals, the development of graphical meta-languages for use in software and hardware modeling, and the use of robotics to motivate K-12 STEM education.

Ginger Reasonover

Ginger Reasonover has been employed by Lipscomb University since 1996, serving both the elementary school and the university. She develops and implements hands-on science experiences for PK-4th grade students and prepares labs for the university biology department. Reasonover is currently pursuing a BS degree through Lipscomb University's Institute for Sustainable Practice. She has received training from Project Learning Tree, Project Wild, and Flying Wild. Reasonover has presented sessions on science and robotics at the National Science Teacher's Association Convention and the National Conference on Aerospace and Space Education. She founded the David Lipscomb BEST Robotics team and helped create the Lipscomb University BisonBot Robotics camp.

Ben Hutchinson

Dr. Ben Hutchinson is the Dean of the College of Natural and Applied Sciences at Lipscomb University, as well as a Professor of Chemistry, teaching both general and inorganic chemistry. He holds a Bachelor of Science, a Master of Science, and a Ph.D, all in Inorganic Chemistry. His research interests include molecular spectroscopy, photocatalysts, and science education.