Using Future Engineers Camps to Advance STEM in Western North Carolina

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Abstract– Ask – Imagine – Plan – Create – Improve. These five words were at the center of all activities introduced during Future Engineers summer camps held at the North Carolina Center for Engineering Technologies. Using the Engineering Design Process, the students learn about engineering through hands-on activities led by licensed public school and college teachers. Beginning in 2010, these camps were developed as a collaboration between the North Carolina Center for Engineering Technologies, Catawba Valley Community College's Champions of Education, and NC State University's College of Engineering. The four camps offered in the summer of 2012 added to the previous four camps make a total of 8 camps offered over the past three years. These camps were attended by 339 students ranging from rising 3rd to rising 8th graders. Special care was taken to ensure participation by females and minorities. Students participated in a week-long intensive immersion into engineering design and fabrication techniques. The application process was competitive and students from 12 counties were invited to apply. Applications have exceeded the available slots each year, as the program continues to grow. The primary goal of the camps is to introduce elementary children to the engineering design concept through hands-on activities using math and science skills.
This paper highlights the history, development, and implementation of the summer camps, and their impact on the community. In addition, results from parent surveys will be presented as an impetus for further development in STEM in the public schools. Other institutions should be able to utilize lessons learned in their respective communities.

Keywords: STEM, K-12 education, Engineering Technology

INTRODUCTION AND BACKGROUND

The United States continues to slip in the world rankings for student's performance in science and math. In a recent report, the World Economic Forum ranked the United States 52nd in the quality of mathematics and science education, and 5th (and declining) in overall global competitiveness [1]. This issue is particularly pervasive among minority and female students. There also appears to be an ever decreasing interest in math, science, engineering and technology among our youth at a time never before faced in history. The United States currently ranks 27th in developed nations in the number of college students receiving undergraduate degrees in science or engineering [2]. We face an Information Age of exploding technological advances in a world dominated by technological innovation created by scientists, engineers and technicians. Yet, we do not appear to have sufficient interest and motivated students in the pipeline to fill the need for future scientists, engineers and technicians. That lack of interest seems to resonate from the middle schools in the US all the way to the graduate schools. In fact, foreign students studying in US graduate schools currently outnumber the US students [3]. Equally disturbing, is the fact that over 2/3 of the engineers who receive Ph.D.'s from US universities are not United States citizens [4]. In a recent report released by the U.S. Congress Joint Economic Committee, demand for high tech jobs will continue to climb, while the number

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of students pursuing degrees in STEM- related areas will continue to drop [5]. The report was very specific in its assessment of reasons for the US trailing in STEM education. Simply stated,

> "Of particular concern are the persistent STEM participation and achievement gaps across different demographic groups. In particular, women are less likely than men to pursue degrees in STEM, and black and Hispanic students are less likely than white students. If these disparities were corrected, the United States would be better able to fulfill the demand for STEM workers." [p5].

The interest level of the students continues to be low in the mid elementary grades through middle school and high school. In order to prepare for our STEM career demands in the future, there must be more students following a path of education that will prepare them for these positions. In a recent US News and World Report story, President Barak Obama hopes to fill the gap by pushing the country to produce 1 million college graduates with STEM degrees over the next decade [6]. In order to continue to compete in today's global economy, The US must ensure that interest and awareness of STEM continues to grow.

While there are a number of issues in the educational system in the US that could lead to a shortage of STEM professionals, there are a few that stand out. First and foremost, there is a scarcity of early STEM programs in the elementary and middle grades. There are a number of proposals currently being considered at the federal level that would alleviate that problem. Secondly, there is a lack of qualified professionals to teach STEM in the elementary, middle and high schools. Thirdly, the benefits of STEM have not been marketed well to potential students. Math and science courses are considered difficult and undesirable. And finally, our culture has determined that STEM related areas are not "cool." [5].

Why is it important to address STEM now? The answer is simple: jobs. With the national unemployment rate currently at 7.9% [7], there is still much work to do. North Carolina currently ranks 47th in the nation with an unemployment rate of 9.6% [8]. In order to alleviate high unemployment rates, we must prepare a workforce that is capable of qualifying for and keeping the jobs of this century. The US Bureau of Labor Statistics projects that 7 out of the 10 fastest growing occupations in the US will be STEM-related [8]. The US Department of Commerce reports that STEM occupations have grown 8% in the last 10 years (2000-2010) and are expected to grow twice as fast (17%) in the next ten years [9]. In addition, 16 of the 25 highest-paying jobs in 2010 require STEM preparation and STEM workers earn 26% more than their non-STEM peers [10].

The case has been made from multiple sources that the introduction of STEM into elementary, middle, and high schools is prudent. In a 2012 study, Thompson showed that adding manipulatives and multimedia during the teaching of a STEM subject increased learning of that subject (math/geometry). The largest increases were seen in minority students and girls [11]. Other studies found that boys started outscoring girls in the same subjects. There is much agreement that educators need to introduce STEM at an early level. The use of non-traditional methods certainly could not harm the process. The best way to do that would be to use higher order technologies that are normally found at the college level; thus, there is a need for sustained partnerships between post-secondary and K-12 institutions. If the sharing of technology is done effectively through those K-12 partnerships, there would be a noticeable decrease in the gender and race gap [11].

One proven method of introducing STEM to K-12 student is through the implementation of Science Camps or Future Engineers Camps. One of the most prominent camps of this type is SPACE CAMP®. SPACE CAMP was founded in 1982 as an outreach program of the US Space and Rocket Center in Huntsville, Alabama. The main goal of the program is to promote the study of math, science, and technology. The program couples classroom instruction with hands-on activities and teaches teamwork, decision-making, and leadership. The inspiration for the program came from Dr. Wernher von Braun. SPACE CAMP has become known as one of the premier STEM educational programs in the United States [12].

Other states, universities and partnerships have followed suit and developed K-12 partnerships to offer opportunities for students to explore STEM subjects. For example, at Purdue University, the College of Science K-12 Outreach program was initiated in 1989 to increase interest and achievement in science and mathematics at the pre-college level. That partnership includes camps, visits, teacher training, personal contact, and engagement [13]. Other universities have formed partnerships to promote STEM at the K-12 level. Those include Auburn University, University of Central Florida, UMASS Lowell, and the University of Minnesota.

THE ROLE OF THE NORTH CAROLINA CENTER FOR ENGINEERING TECHNOLOGIES

The North Carolina Center for Engineering Technologies (NCCET) was created to provide a facility for applied research in engineering related fields in the Unifour region of North Carolina. The center serves as a conduit to baccalaureate engineering education delivered by University of North Carolina system schools, including Appalachian State University, Western Carolina University, East Carolina University, and the University of North Carolina at Charlotte. Instructional delivery is multifaceted and includes face-to-face, online, hybrid, interactive television (ITV), and laboratory instruction via a Virtual Computer Laboratory (VCL).

Conceived as a community supported higher education effort in technical and engineering disciplines, the NCCET was established through a collaboration of business, government and higher education organized as the Future Forward Economic Alliance. This collaboration resulted in a major public-private capital campaign, which raised enough money to purchase and renovate the current building. Once completed, the building was presented to the University of North Carolina system for its intended use. The NCCET opened in 2008 with Western Carolina University's Engineering Technology curriculum as the resident degree program. Since that time, the center has served an average of 50 students per semester in engineering related disciplines and currently serves an additional 100 students per semester in other programs (13) McDaniel

As a part of its mission, the NCCET has partnered with public school systems in the region to assist with labs, field trips, and guest lectures. In 2009 , an idea was proposed to bring students to a summer camp that would give those students knowledge of STEM disciplines, experience in working though problems and challenges related to STEM careers, and a basis for maintaining their interest in the STEM disciplines. And so, the NCCET's Future Engineers Camp was born.

FUTURE ENGINEERS CAMPS AT THE NCCET

Beginning in 2010, the inaugural Future Engineers Camp was developed as a collaboration between the North Carolina Center for Engineering Technologies, Catawba County Community College's Champions of Education, and NC State University's College of Engineering. The first year's camp served 96 students and was a great success. The application process was competitive and students from 12 counties were invited to apply. The applications have exceeded the available slots each year even though the number of camps has increased. The primary goal of the camps is to introduce elementary children to the engineering design concept through hands-on activities using math and science skills.

Another goal of the camps has been to expose regional public school teachers to engineering concepts using classroom math and science activities created by North Carolina State University and Appalachian State University faculty and staff. Forty-two teachers have served as camp leaders and received lesson plans that they may use in their classrooms with other students. The 21 teachers hired for the 2012 camps represent 10 school districts and were selected from 68 applicants. Teachers attend two days of intensive training at NCSU to prepare for the activities presented at the camps. They also received training at NCCET for the robot and CAD activities. Each teacher served as the lead instructor for one or more of the activities during the camp.

Teachers leave the camp energized to take these activities into their classrooms. Most of the past camp teachers have already used one or more of the activities with their students. From straw rockets to silly putty, teachers are able to introduce the engineering design process to their students and also to the other teachers in their school. The camps are making a difference in the lives of our children. The Camp mission of keeping students interested in STEM curricula appears to be successful. The Camp steering committee hopes to do a longitudinal study to follow these kids into their post-high school studies.

Unlike many STEM camps and activities throughout the country, the Future Engineers camps at the NCCET focus on the "E" in STEM. The engineering design process is utilized in all the camp activities. Students learn how ask appropriate questions regarding a problem; imagine possibilities for solving the program, then make a plan towards a solution to the problem, then they create their solution into tangible, testable product/process, then they test their solution and collect data to improve their process/product. Students work both independently and in groups to complete this process. They are able to develop and practice a process that will help them in any problem solving

situation, but most importantly they are working with problems, materials and processes that are appropriate for engineers.

Students have experienced activities related to multiple engineering disciplines including Civil, Mechanical, Electrical, Nuclear, Chemical and Industrial Engineering. Students are able to identify the engineering discipline related to a particular problem

Implementation of the Camps

Appalachian State University, Catawba County Champions of Education and NC State University have partnered together to offer four summer camps in 2013. There will be two elementary school Future Engineers camps (rising 3rd through 5th grade students) as well as one middle school Future Engineers camp and one Robotics Camp (rising 6th – 8th grade students) during 2013. In addition a new camp for rising 9th and 10th graders will be offered in product development. This camp will allow students to use the design process to create and develop a product using engineering processes.

Program Costs

Registration for the camp is $325. A limited number of partial scholarships (up to $275) are available for students needing financial assistance. Information about how and where to make payments and the cancellation/refund policy will be provided to students who are accepted to camp. The application process is highly competitive and students should take great care in writing their reason for attending the camp on the application form. The application process requires a recommendation from a teacher and much weight in the review process is given to the student essay and the teacher recommendation.

Program Overview

The camps are non-residential and students attend each day from 9:00 am to 3:00 pm. The programs provide students with a fun and positive introduction into various fields of engineering by using hands-on, creative investigations and real-world building activities. Students are led in activities during the week by licensed elementary and middle school teachers along with Appalachian State University faculty and students. The teachers serve as team leaders throughout the week and also lead some of the activities.

There are hands-on activities introducing various engineering concepts in all the camps. Campers work in groups and individually to design and create solutions to various problems. The elementary and middle school camp activities are different each year, so campers are encouraged to return! On the final day of camp, students will spend the morning working on final displays and challenges that incorporate activities from the camp. Students will demonstrate their work in a public competition/demonstration. Families and the community are invited to attend this final presentation.

Each 3rd - 5th grade Future Engineers camp follows the same agenda. A typical day is:

- Brief large group gathering to introduce the theme for this part of the day;
- Activity (depending on length, may be one or several different activities)
- The activity will be introduced and instructions will be given. The students then go to their team areas and conduct the activity on their own, using the Engineering Design Process. Adult team leaders are present to provide help as needed, but they provide assistance more than direction for the students.

  If appropriate, there will be a mini competition at the end of the activity.
- A debriefing of the activity is completed to help facilitate learning.
- Lunch (provided)
- Daily awards ceremony

The middle school camp follows a similar schedule to the elementary camps with more advanced activites. The final day, families will come to see what their child has been doing throughout the week. The campers will lead the presentations.

Lego Mindstorms robots are built and programmed during the Robotics camps and introduced in the elementary camps. The robotics camp will result in a competition in front of the families on the final day. The students will compete in a scenario of their choice in front of the parents.

The product development camp will teach the students the processes involved in taking a new or existing product from the idea/concept phase to a fully functional prototype, ready for introduction to the market place. Students will study various design concepts along with how to effectively and universally communicate these ideas in detailed Engineering 2D drawings and 3D solid models. Students will work in teams of two or three to address real world opportunities. The final day will result in presentations of the camper's product ideas and the process followed to create the product/prototype. This presentation will demonstrate the camper's knowledge and skills of the design process learned in the camp.

The most popular activity based on parent surveys was the Robotics lab. This activity, unlike the other labs through the week, is repeated on a daily basis. The scenarios used for the Robotics labs have centered on current news events. For the past several years these were based on disasters that have occurred around the world. The first year was based on the oil spill in the gulf; the second year was based on tornados in Missouri, while the past year focused on the earthquake and radiation disaster in Japan. The students built and programmed Lego MindStorm Robots to accomplish tasks related to the humanitarian and cleanup efforts in the wake of these disasters. A course (map) was laid out providing several scenarios. The students would build and program a robot capable of accomplishing the tasks of securing the injured or trapped personnel, moving debris, and delivering relief supplies. Using these current events, the students are provided an opportunity to develop and apply their critical thinking skills to real world situations.

Application Process

The application process is the same for each camp. Potential students must complete an application on paper or online. A letter from teacher, school counselor or principal recommending the student must be submitted also.The recommendation letter should be written by a teacher or other school official and speak on behalf of the student. The letter should address the student's interests and abilities, as well as the student's character and suitability for attending the camp. Scholarships can be requested for need-based students. If applying for a need-based scholarship, the student must obtain a letter of demonstrated financial need from the school counselor. The NCCET does not intend to receive financial information from individual students, so the school system will be relied upon to indicate if a student has a demonstrated need. Generally, participation in the free and reduced lunch program is an indicator, but a school counselor or other school official may be able to speak to other factors influencing financial need without providing specific financial information.

All application materials must be postmarked no later than March 1 of each year. Applications received after the March 1 deadline will be considered only if there are openings in the chosen camp. Approximately 48 students will be selected for each Future Engineers camp. The Robotics camp will be limited to 24 middle school students. The product development camp is limited to 12 students. A number of factors are considered in selection of attendees from the pool of applicants. The steering committee will rely heavily on the teacher recommendation and the student statement about why they want to attend camp to make selections. Students selected will represent a cross-section of backgrounds and geographic areas. Selected students may be interested in engineering careers, but have little or no background as well as students who have some previous experiences. Students will be notified no later than April 1 if they have been accepted to the camp or placed on a waitlist.

SUMMARY AND LESSONS LEARNED

Historically, the United States has produced scientists and engineers responsible for many of the world's breakthroughs in technology and innovation. That innovation ushered in an era of economic growth unsurpassed in history. That is not the case any longer. As stated earlier in this paper, the United States continues to slip in the world rankings for student's performance in science and math. The interest level of the elementary, middle and high school students continues to be low. In order to prepare for our STEM career demands in the future, there must be more students following a path of education that will prepare them for these positions. In Western North Carolina, the utilization of summer Future Engineers Camps seems to be an excellent way of promoting STEM.

The NCCET, in partnership with local school systems and universities has offered a total of nine (9) camps over the past three years. These camps were attended by 386 students ranging from rising 3rd to rising 8th graders. The camps have been a work in progress each year, with each year getting larger and more involved than the last. There have been many lessons learned. The best indicators of success are results of parent surveys from each camp. These surveys (Appendix A) indicate that students have a much better understanding of engineering after attending the camp. Ninety-two (92) percent of parents surveyed strongly indicated that the camp had a positive impact on their student's attitude about science and math. Parents also indicated that the application process, registration, and payment were easy processes. An overwhelming majority of parents surveyed (95%) would recommend the camp to others. Finally, the vast majority of parents agreed that teachers at the camp did a great job instructing the students.

Parents were also asked this open-ended question on the survey: If your child talked about the camp, what did he/she say about the experience?" The responses were impressive. Students were clearly affected by their exposure to STEM activities. The students talked very positively about learning CAD, Robotics, Problem Solving, and Programming. Below are a few representative comments:

- *"Said it was the best week of camp he has ever had. Very excited about the possibility of becoming an engineer."*
- *"He loved it and has already asked if he could go back next year."*
- *"Talked about it all the time. Absolutely loved it. Explained root cause analysis to his brother just yesterday, including an example about the Jefferson Memorial."*
- *"My child enjoyed every day learning more about engineering the process and it really made him think. He has spoken about the camp to anyone who will listen."*
- *"They enjoyed the opportunity and hope to attend again next year."*
- *"He said that he learned a great deal about math and science and that it will help him later in school."*
- *"He absolutely loved this camp. He enjoyed the speakers and all of the projects. Robotics is not offered at his school as an afterschool activity; however, he would be the first to sign-up if given the opportunity. He is now considering all of the types of engineering and has made several AutoCAD drawings."*

It is easy to see the excitement and lasting impressions that the camp has made on the students after just one week. In all, 386 children have attended the camp over a three year period. Twenty three percent (23%) of the attendees were female, 25% of the attendees were on free and reduced lunch and received a scholarship to attend camp, and 25% were African-American, Asian, Hispanic or Multi-racial. Camp enrollments increased by 26% from the first to the second year and almost 40% from the second to the third year of camp offerings. The planned enrollment for 2013 will be more than 88% higher than the first year of camp attendees. While the numbers of students are only a fraction of the total number of students enrolled in Western North Carolina schools, it is not difficult to assess the effectiveness of the Future Engineers Camps.

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