

Sustainability of K-12 Engineering Outreach Activities beyond the Grant Period

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Abstract – We describe the successful implementation of a pipeline of engineering outreach activities for K-12 students based on funds made available by a Texas Engineering and Technical Consortium (TETC) Texas Youth in Technology Demonstration Project Grant. In addition to educating K-12 students about the engineering discipline we also aim at improving our electrical and computer engineering undergraduate student retention rate by employing undergraduate students as mentors. We show how key investments and partnerships built during the grant period enable us to continue and grow our outreach and mentoring programs.

Index Terms – K-12 engineering outreach, robotics student mentors, sustainability.

INTRODUCTION

In this paper we describe how we are able to continue and grow engineering outreach activities that we started in 2006 with funds received through a Texas Engineering and Technical Consortium (TETC) Texas Youth in Technology Demonstration Project Grant [1]. The awarded grant “Integrated Outreach, Mentoring, and Placement of Texas Youth in Engineering Careers”, focused on pipelining pre-university students through a series of robotics-based engineering outreach programs with interlocking elements. At the same time it proposed to provide early hands-on experience to freshman level engineering students at Texas Tech University in order to improve retention of these students within their major.

Lubbock, TX, the location of Texas Tech University, has traditionally an agricultural economy based on cotton and a large Hispanic population. With the university and two major hospitals it serves as the academic and medical hub for a radius of about 200 miles. However, not many engineering job opportunities exist in Lubbock and its surroundings, which has two major impacts: first, K-12 students are unlikely to have a parent pursuing a career in engineering and therefore are largely unaware of the engineering profession and qualifications needed to successfully become an engineer. Second, engineering undergraduate students only have limited access to part-time work opportunities within their area of interest and most of them are working in jobs unrelated to their major. While juniors and seniors are generally successful in securing

industrial summer internships or semester-long co-ops out of town, the opportunities for engineering freshmen to gain experience in their major outside the classroom are limited thus not allowing them to underpin their choice of major through practical experience that at the same time provides financial support. Our motivation to install a pipeline of engineering outreach activities was thus twofold: to introduce K-12 students to the engineering discipline through fun design challenges while offering mentoring and engineering instructor jobs to engineering freshmen.

The grant funded these activities for two years and enabled us to acquire materials and supplies required to start new engineering outreach programs as well as paying salaries to participating college student mentors and K-12 teachers.

In the remainder of this paper we will first describe the engineering outreach activities we offered during the grant period and how the funds provided by the grant were instrumental in setting up these programs. We will then describe partnerships that we formed during the grant period and how these partnerships were not only of ultimate importance to turn our engineering outreach activities into a series of success stories but also enabled us to continue our activities beyond the grant period.

ENGINEERING OUTREACH GRANT FUNDED ACTIVITIES

One core strategy of our TETC grant was to provide a pipeline of engineering outreach activities for K-12 students while at the same time being able to offer hourly paid mentoring opportunities for engineering undergraduate students. We here describe the different outreach activities we offered, how the grant helped us implementing them, and how undergraduate engineering students were involved in all activities.

1. Robotics Challenges for K-12 Students

To involve primary and secondary schools in our outreach activities, we offered a series of engineering design challenges during the school year to local elementary, middle, and high school students. Through these challenges participating students playfully learnt engineering concepts. Participation was open to any interested school and was free of entry fees. The challenges we offered were designed by volunteer organizations whose aim it is to foster interest, education, and participation in STEM disciplines. We

served as the local organizer and contact persons. The activities we offered for the different age groups were:

Get Excited About Robotics (GEAR) [2] for elementary and middle school students: GEAR is a 6 week long competition in spring. During this time period, teams build LEGO robots based on the Mindstorms NXT kits [3]. The robot has to perform specified tasks autonomously. During the 2008 competition these were: maneuvering in Antarctica to retrieve meteorites from the ice surface, assist archeologists with retrieving a fossil bone and load it into a cargo container, retrieve film canisters from the IMAX film crew, load the station's waste container into a cargo container, retrieve ice core samples from a drilling site and deliver them to the station for analysis, and deliver a science package to the volcano [4]. The game field is an 8' x 8' table on which four teams compete in 2 minute matches to perform as many of these challenges as possible and score the most points. Prizes are awarded not only to the teams with the highest scores but also for the most creative robot, the most elegant robot, the best engineering essay, etc..

During the first year of our grant we ran the GEAR competition in Lubbock for the first time and had 14 elementary schools participate. As reported earlier [5], [6], [7], we observed several key elements contributing to the success of this program. Motivating teachers with a modest (\$200) stipend and holding workshops to provide the necessary skills generated commitment and confidence. Providing LEGO NXT kits and game boards/pieces eliminated the need for fundraising by the schools. Perhaps most importantly the undergraduate mentors provided a technical backstop for the teachers and served as positive role models for the participants. In addition to mentoring school teams, we also paid the engineering students to build the game pieces and organize the competition. All of the above actions were funded by the grant and would not have been possible otherwise.

Boosting Engineering, Science, and Technology (BEST) [8] for middle school and high school students: BEST was first organized by engineers from Texas Instruments in Dallas, Texas in 1993. From the first year with 14 schools and 200 participants it has grown to a national presence with 700 schools and reaching more than 10,000 middle and high school students. Our local hub, West Texas BEST, has 23 schools registered, of which 18 fielded teams in the 2008 competition. It typically reaches more than 500 participants from a region stretching from Midland to Amarillo, Levelland to Rawls. BEST also involves a theme which changes from year to year. Last year's challenge, which was created by the Wichita, KS, hub was entitled 'Just Plane Crazy' and involved the robot assisted assembly of airplanes. The website [9] describes the competition and has more general information about BEST as well. The equipment for the competition is free to the participating schools and consists of a returnable kit including programming and control electronics, motors and servos, batteries, and radio control transmitter/receiver pairs. There is also a nonreturnable portion which varies from year

to year with the game. Robots typically are limited to 20-25 pounds. The control electronics underwent a major upgrade in the 2007 season, offering for the first time an autonomous capability as well as teleoperation. Our involvement in BEST extends to maintenance and repair of the returnable kit, stocking the consumables, training of the teachers, construction of the playing field and exemplars of competing robots, and undergraduate mentors to help coach the schools. While West Texas BEST was a well established program already at the beginning of the grant period, the grant provided support for six undergraduate students through the summer to catalog the returnable kits and restore them to a full working complement. We also hired approx. 5-10 undergraduate students as mentors for the schools. The mentors met with their school team once or twice per week and helped in particular middle school teams to operate machines for metal and wood shop work that they were not allowed to use themselves. Two mentors even recruited their former high school to participate in BEST for the first time. Mentors from local schools enjoyed returning to their middle schools. We noticed, however, that engineering freshmen who returned to their former high school were not as effective as other mentors. We contribute this to the fact that they were still considered as friends by those team members who they knew from previous participation in the program whereas mentors who did not know any participants at the school they mentored were considered as "engineering experts" and students eagerly listened to their suggestions. BEST robotics teams document the design process, learn to use CAD tools in design and simulation, and learn basic shop skills along with an introduction to programming.

For Inspiration and Recognition of Science and Technology (FIRST) [10] for high school students: FIRST is an international program developed by Woody Flowers and Dean Kamen at MIT. FIRST represents a higher level of sophistication and requires a significant commitment of funds, typically \$20,000 - \$30,000 per season for each team. The robots built are in the 120-125 pound range and often quite sophisticated. Our involvement in FIRST robotics was to sponsor a team made up of several area high schools, make design and fabrication facilities available at Texas Tech, mentor the high school students in design, CAD specifications, and shop skills. The program reaches approximately 20-30 students per season from 4-5 area schools. Grant funds were used to seed the fund raising necessary for the team, and to support undergraduate coaches/mentors. In our initial season we enjoyed great enthusiasm at the beginning of the program but our final team consisted of only six students. Our second season built on this base and our team at the end of the season consisted of twelve students.

II. Summer Camps

Given the success of our first GEAR competition, we expanded our LEGO robotics engineering outreach activities to residential summer camps for which students could sign

up individually. We contacted Texas Tech University's Institute for the Development and Enrichment of Advanced Learners (IDEAL) which has over 20 years of experience in offering summer residential camps with exciting, hands-on, application-oriented opportunities to learn about science and the related professions. These camps are geared toward middle and high school students and aim at encouraging the participants to attend college after graduation from high school. Two summer programs offered annually are "Science: It's a Girl Thing" (SIGT) and "Shake Hands with your Future" (SHWYF) [11]. Participants of SHWYF spend 6 days on campus and pick two different classes (one morning class and one afternoon class) with 15 contact hours each. Classes are out of the areas of architecture, biology, chemistry, media technology, law, and engineering. SIGT basically offers a similar set of science and engineering classes to female participants only with the goal to provide girls with strong role models and dispel myths and misconceptions about science and careers in science and engineering. Participants get assigned to one of the classes by the organizers based upon their areas of interest stated on the application form. Both camps have a high percentage of participants from under-represented groups and draw students from a larger area than our local robotics competitions. Since summer 2006 we offer sessions on LEGO robotics for both camps. Particularly in SHWYF, where participants choose their classes, interest has been so high that we had to offer two parallel sessions in some of the camps. Since there is no overlap between the camp participants and students who were involved in the GEAR challenge, given the different age groups, we mainly reused the GEAR challenge for these classes. Through our grant, we contributed to the summer camps by providing the necessary equipment (LEGO NXT kits and laptops) as well as salaries for instructors and undergraduate student mentors. We also recruited new graduate students, K-12 teachers, and engineering faculty to teach the camp section.

III. Enrichment Classes

IDEAL also offers enrichment classes to elementary school students in form of "Super Saturdays" [11]. Participants sign up to take a two hour class on the Texas Tech campus on four consecutive Saturdays. Super Saturdays is offered every spring and fall semester. As part of our grant initiative, we added LEGO robotics as a new course, which we started offering in fall 2006 and which has quickly developed into a very popular class. From our contact list of teachers who coached a GEAR team, we were able to recruit K-12 teachers to teach these classes.

In addition, we offered LEGO robotics courses also at the Maxey Center, a local community center, offering leisure classes to participants aged 6-13 at a low cost. Many of the course participants are from low income families. Given the cost of course (\$30 for a one hour class over an eight week time period) the Maxey Center would not be able to acquire their own LEGO NXT kits (about \$280 per kit) nor have they established the network connections to recruit

instructors. These courses were made possible by bringing our LEGO NXT kits and laptops to teach the course. Since spring 2007 we have offered 1-2 LEGO robotics classes every semester and as part of summer camps. Traditionally these courses are taught self-responsibly by engineering undergraduate students. We have even encountered engineering graduate students showing interest in teaching this course and have given them the opportunity. Typically, the instructors of the class have prior experience with LEGO robotics and teaching experience from being a mentor of a GEAR team or having assisted in the instruction of Super Saturdays or IDEAL summer camps. Engineering students also developed the curriculum for these classes [12]. While GEAR is more challenge oriented, these classes aim at introducing the participants to the programming of the robots as well as the functionality of the different sensors.

IV. Traveling LEGO NXT Laboratory

Many of the teachers who participated in GEAR showed interest in continuing their robotics activities. Three school districts decided to offer LEGO robotics summer classes. One school offered a LEGO robotics summer class for underperforming students in order to motivate them by exposing them to applications of the math curriculum. Having bought over 40 LEGO NXT kits to perform the activities described above, we were able to support these activities by lending NXT kits to schools in between IDEAL summer camps.

PARTNERSHIPS

Our TETC Texas Youth in Technology Demonstration Project Grant enabled us to form a variety of important partnerships that were crucial to the success of our engineering outreach activities. The equipment and salaries we were able to bring in and our engineering expertise were key factors in building these partnerships.

First, we invited a social worker on board of the team of investigators to perform the assessment of K-12 robotics our outreach activities. The performed assessment [5], [6], [7] demonstrated an increase in positive attitude toward science and engineering as a consequence of participating in our GEAR and BEST robotics challenges.

Our collaboration with Texas Tech University's Institute for the Development and Enrichment of Advanced Learners (IDEAL) turned out to be invaluable. Given the over 20 years of experience of the IDEAL staff in running residential summer camps, they organized everything from registration, on campus housing, chaperones, leisure time activities to transportation of out of town participants to and from the airport. They also designed the camp brochures, sent them out to schools and previous participants and organized other avenues of advertisement such as radio spots and newspaper ads. The excellent reputation of the camps ensured an immediate high enrollment in our LEGO robotics courses. Also, IDEAL has an ongoing collaboration with a faculty member in the College of Education who evaluates the effectiveness of the camp in encouraging participants to

attend college [13], [14]. This gave us as engineering faculty the opportunity to concentrate on our contribution to the camp: new course contents, acquisition of required equipment, and recruitment of faculty and undergraduate engineering students to teach the courses.

Our collaboration with the Maxey Community Center has been a similar success story. Again, the design of brochures, advertisement, class scheduling, and classrooms were organized by the Maxey Center staff. Their brochures are distributed at local elementary schools and are published on their website such that our new LEGO robotics courses immediately drew enormous interest. On our side, we concentrated on recruitment and training of instructors from our pool of engineering students and the development of lesson plans that keep the course exciting even for students who reenroll in it.

SUSTAINABILITY

The partnerships we built during the grant period, the excitement we created among participants of our engineering outreach activities, and their positive evaluation allows us to continue all engineering outreach activities beyond the grant period and to attract future funding. Given the current lack of funding for undergraduate mentors, we explore other avenues to involve engineering students.

The 2009 GEAR competition was funded by the Texas Tech T-Stem Center [15] and an industrial sponsor. The T-STEM Center paid for game tables for schools that participated for the first time and lent out additional LEGO NXT kits to participating schools that would involve more students in the competition if they had more LEGO NXT kits. Since providing teachers with engineering students as mentors was evaluated as a major success factor, we involved electrical and computer engineering undergraduate students enrolled in their second engineering design lab, which counts toward the service learning project in their degree plan. The students were responsible for the construction of the game pieces and serve as mentors for the 14 participating schools. We also were approached by the electrical engineering honors society Eta Kappa Nu (HKN), which was looking for service projects for their new initiates. They organized the kickoff event, during which over 150 students built bridges from straw and competed in the categories of longest, highest, strongest bridge as well as best use of material and best team work. They will also serve as judges during trial run and game day. We are in the process of recruiting new industrial sponsors. First impressions from discussions with companies present at the TTU Engineering Job Fair were positive and we expect future support from them. Given the large interest in GEAR we opened up the competition to middle schools for the first time.

2008 BEST Robotics was funded by a group of industrial partners and professional societies and currently enjoys a positive balance. On the order of 500 participants can be supported on a hub budget of approximately \$18,000. The playing field was created by and Engineering

Technology undergraduate lab project. An Electrical Engineering lab section took on the kickoff, demonstration day, and competition as a service learning project. The undergraduate mentors came from another Electrical Engineering lab service learning project.

2009 FIRST robotics has been successful in securing funding in excess of \$20,000 to date through donations, in-kind support, and team fund raising activities. This season we were able to attract more mentors to the program and a solid base of approximately twenty-five high school students, doubling the size of the team for the second year in a row. We have been successful in motivating undergraduates to mentor the team by offering laboratory credit for participation. This credit also includes weekly status reports and written interim and final reports. Students involved in the mentoring program seem to understand that we have limited funds but continue to work with the team because they are personally invested in the team. We provide a reasonable lab space and access to tools that they would not ordinarily have. We also encourage them to bring projects other than FIRST into the lab.

The success of FIRST Robotics, and of our team in particular have been recognized by TETC. TETC has funded the Texas TSTEM academies to participate in FIRST Robotics and last fall asked us to host a training/orientation session for these new teams. We had a very successful one day class that included teams from as far away as Presidio and El Paso. There were two tracks for the program: one for the students in which they learned strategy and design/construction skills; and a second for the coaches in which we shared our experience in managing the team and the (short) design/build season. The Whitacre College of Engineering funded lunch for this group of approximately seventy-five students and coaches. We took it upon ourselves to follow up on this session by arranging for a kickoff at Texas Tech at the beginning of the season. We worked with FIRST to have pick up all the parts kits for six teams and hosted another one day workshop in which the teams built a driving base for their robots from the kit parts.

Even after the end of the grant period, our non-GEAR related LEGO robotics outreach activities continue and with the help of our partners we can continue to provide job opportunities as LEGO robotics course instructors to our engineering undergraduate students.

The LEGO robotics sessions which we introduced to SIGT and SHWYF summer camps continue to enjoy great popularity. IDEAL now pays for the instructors of the courses from the camp fees. We still provide the LEGO NXT kits, laptops, and GEAR rules and game pieces required to teach the classes and recruit engineering undergraduate students who assist in teaching the class. Based on our experience gathered during the grant funding period, we were able to secure over \$10,000 in scholarships for the 2008 summer camps [16].

We continue to offer LEGO robotics enrichment classes as part of IDEAL's Super Saturdays program and at the Maxey Community Center. We have recently been

approached by the Maxey Center staff with the request to add electronics classes to their program which we will start offering with the beginning of the spring 2009 classes.

Future plans include the expansion of activities offered for elementary and middle school students. For K-3 students, we want to implement an early machines course in the Super Saturdays program. We also investigate the animation program “scratch” [17] developed at MIT to be part of the IDEAL camps. Scratch playfully introduces students who are more interested in arts to basic elements of programming languages and allows them to publish their movie designs online.

CONCLUSIONS

In this paper we have described the successful implementation of a wide variety of engineering outreach activities that were core strategies of a workforce development grant. Key success factors in their implementation were engineering undergraduate mentors who worked together with school teachers and the partnerships we were able to build with other institutions. These partnerships, the investment in LEGO NXT kits, and assessment of the effectiveness of the programs installed were important factors for sustainability of the programs and enable us to attract additional funds to continue and grow our activities.

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