Project Oriented K-12 Programs in Rural South

Dr. Atin K Sinha, Albany State University

Dr. Atin Sinha is the professor and coordinator of the Engineering Program at Albany State University. He received his Ph.D. in Aerospace Engineering from the University of Tennessee Space Institute in 1984. He had worked in Learjet and Honeywell before moving to academia in1990. He is a Registered Professional Engineer. Currently, he is engaged in motivating undergraduate engineering students in inquiry based learning through hands-on, realistic projects. He is also involved in various outreach activities with K-12 students.

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Abstract

Albany State University (ASU), located in the rural south, conducts a transfer engineering program since 1985. With the help of external funding, an engineering laboratory consisting of a number of manufacturing and testing equipment was established in 2002. The existence of the laboratory and the industry advisory committee established as a direct result of external funding helped launch a number of project oriented outreach programs targeting middle and high school students to motivate them towards an engineering career. This paper describes the programs and feedback from the students and parents.

Introduction

It has been widely accepted that hands-on project oriented activity is more successful for understanding the concept and retaining knowledge in any of the Science Technology Engineering and Mathematics (STEM) disciplines for K-12[1,2] as well as university students[3,4]. As such private organizations and universities have collaborated in marketing new equipment / software and sponsored various contests and workshops routinely for K-12 as well as undergraduate students. Notable amongst these are the Lego-Mindstorms / Nxt robots that have widely been used from elementary to college level students in basic understanding of mechanisms to fairly advanced electronic communications and programming[5]. First Lego Robotics[6,7] has drawn wide attention and is continuously gaining in popularity among K-12 students. Albany State University, located in the deep south is a liberal arts university with a 24-county service area covering largely the agricultural communities of the rural south. It offers over 50 degrees through its four colleges. Since 1985, it is also conducting a transfer engineering program through an articulation agreement with Georgia Institute of Technology (Georgia Tech), state's flagship engineering research university located 180 miles north. The Regents Engineering Transfer Program (RETP) was created by State Board of Regents to facilitate students in the outlying communities complete the first two years in a familiar home town setting before transferring to the engineering program of their choice in Georgia Tech. Though the engineering program at ASU is quite well known throughout the state, it is only in the last decade that a number of project oriented activities have been organized on a regular basis targeting K-12 students primarily with the intention of motivating them towards an engineering career and specifically increasing the engineering program enrollment.

Early Years

From the beginning the engineering program was funded by a special grant from the State Board of Regents. As there was no additional funding available to conduct K-12 outreach program, till about the year 2000 no outreach activity was undertaken nor was there any attempt to include any laboratory classes for the engineering courses. However, in 2001 with a modest funding from Georgia Space Grant Consortium (GSGC) sponsored by NASA, a set of Lego-Mindstorms was purchased. This provided the basis of holding the first outreach projects with high school students in the form of Saturday Engineering Workshops. In the next year, a substantially more multiyear grant was obtained from the U.S. Department of Education. The following four computer-controlled testing and manufacturing equipment were acquired in the next two years:

1. Flotek 1440 Wind Tunnel
2. PC Turn 55 Computer Numerically Controlled (CNC) Lathe
3. Tinius Olsen Universal Testing Machine
4. Rapid Prototyping Machine – Stratasys 3D Printer

Subsequently, a metallurgical microscope, heat treatment oven, grinding/polishing machine, a couple of 3D Scanners and reverse engineering software were added with funding obtained from different sources. With such a sizable variety of equipment, an Engineering Laboratory was established in a converted Earth Science laboratory. The newly established laboratory was first used in support of a lab class for an introductory engineering course in the year 2002 apart from conducting the first Saturday Engineering Workshop in the very same year.

An advisory committee was required as a condition of the Department of Education grant. Hence, a committee was formed with 3 members representing local industry and a national research laboratory. Though primarily their responsibility was to monitor how the funding was used to improve the engineering program, it became natural for them to recommend starting an active outreach program to increase the enrollment. After some brainstorming sessions, the idea of a contest among the high school students who are about to decide on their career choice was promoted. Upon further discussions, the balsa wood bridge building contest was chosen primarily because of the modest cost of the materials and secondarily a sizable amount of literature on methods of bridge building is readily available. Some prototypes of the balsa wood bridges were built and a set of specifications were drawn based on the physical measurements of the prototypes. Though the first contest in the year 2003 was held with only one category of bridge, subsequently another category was added and the contest itself was extended for the middle school students. The contest is held annually on the last Saturday of the month of February celebrating National Engineers Week. In 2012 on the tenth anniversary of the bridge contest, an open category was added to promote the event to the local bridge enthusiasts and general public. The bridge building contest has become one of the most widely known events of its class throughout the state and attracts over 100 students every year some travelling over 75 miles. In 2013, the number of teams and the participating students registered have increased by 40% and 74% respectively from the previous record high making this year's contest the most widely attended event in its 11 year history.

The last of the outreach projects, a computing Summer Camp, was first organized in 2008 with funding from National Science Foundation (NSF) through Georgia Tech's College of Computing. A set of Lego Nxt was acquired from the seed money provided from the NSF grant. Besides the programmable robots, the weeklong camp taught high and middle school students, computer animation software such as Alice and gaming software Scratch. Apart from computing, the camp activities have been expanded to include engineering projects in Computer Aided Design (CAD) and CNC machining since the next time camp was held.

A website (www.asu-engineering.org) was developed to publicize these annual events and has been constantly updated with the latest information such as results and photos of the bridge contest. The website also contains relevant information about the engineering program such as required courses and laboratory facilities that is useful to the prospective students. The site has been a resource for the K-12 students around the region, particularly those interested in participating in the next bridge contest.

Apart from holding the Bridge Contest, the Advisory Committee members from industry had from time to time helped organized seminars on relevant engineering topics during the weekly seminar scheduled by the Natural Sciences department and attended by all science students including engineering. Many field trips had also been arranged with the help of the Advisory Committee members to the local engineering industry which allowed the engineering students a firsthand look at the working of manufacturing and assembly operations.

Saturday Engineering Workshop

Targeting students of four high schools located within Albany metropolitan area, this event started in the fall semester of 2002. The primary motivation was to introduce high school students to the recently acquired manufacturing and testing equipment in the Engineering Laboratory and in the process motivate them to choose engineering majors at college. The format chosen for this activity is to allow the science or math teachers to select about 18 students from their respective classes (the maximum occupancy of the lab) bring to the university for an entire day of hands-on projects in Lego Mindstorms or Nxt programmable robots, CNC lathe, Wind-tunnel demonstration, SolidWorks CAD and 3D printer. The teachers were compensated with a stipend for their effort. Students meet at 9 in the morning and continue to work till 5 pm with an hour's lunch break. Though the work is quite demanding, most students enjoy their first opportunity of working with such high precision computer controlled equipment. Besides the local schools, students from the surrounding communities as well as home-schooled students have participated in the daylong workshop. In general, one or two such workshops are held each year. In the beginning Lego Mindstorms were the only equipment available for the workshop and a set of projects was developed for the first workshop held in 2002. Later with the purchase of Nxt robots another set of projects were developed (Fig 1). All the projects utilized the robots' sensors (touch, light, sound and ultrasonic) and output devices (normally motors for motion and a lamp). The robotics projects also use the structural construct such as loops and switches.

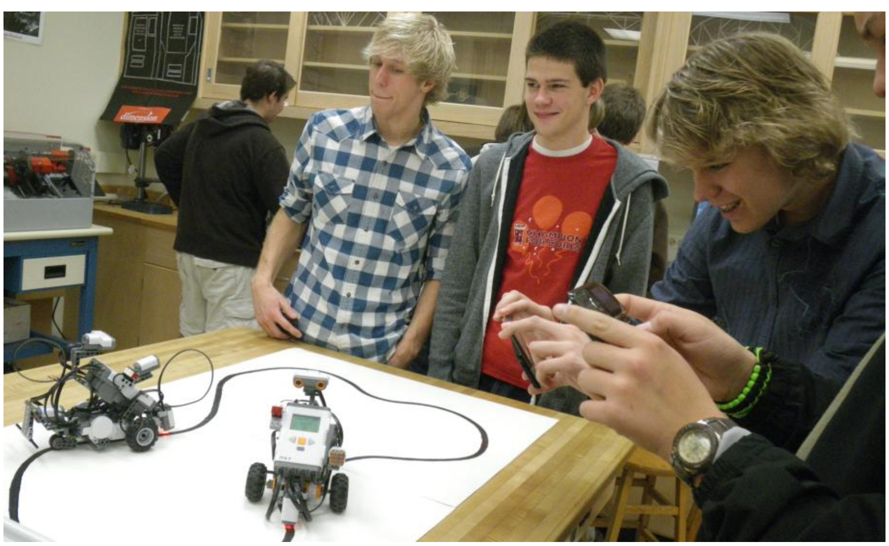

Fig 1. Students watching their robots going along a line.

Other engineering projects used in the workshops such as, chess pieces in the CNC lathe and candle stick in the SolidWorks CAD software are shown below (Fig 2).

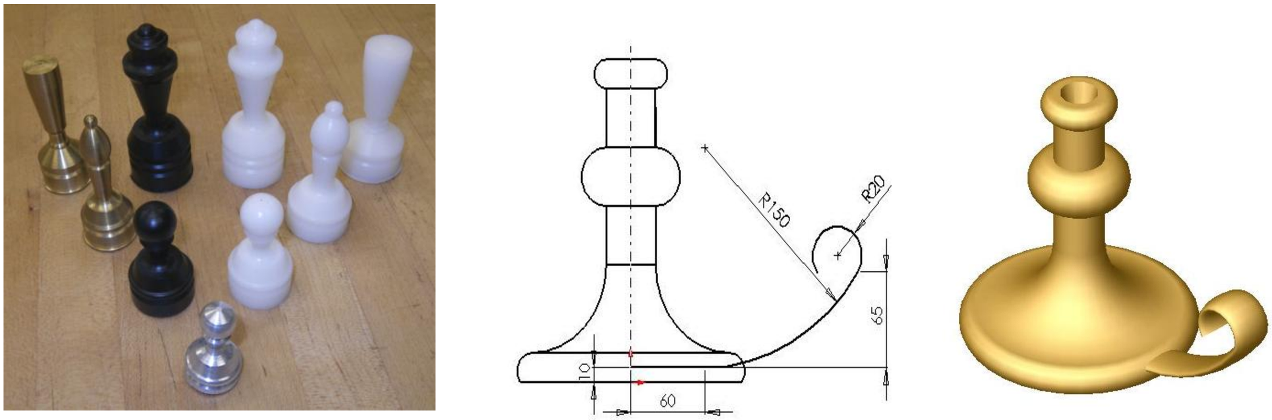

Fig 2. Examples of engineering projects in CNC machine and SolidWorks CAD

Bridge Building Competition

As mentioned earlier, the bridge building competition[8] started as a result of initial meetings of the Advisory Committee formed as a condition of the Department of Education grant in 2001. From the beginning it was intended to be different from a Science Fair but more of a contest with clearly defined rules that must be followed. Teams of two to three high school students designed and built their bridges under the stewardship of the teachers/mentors, working after school hours according to the following specifications (Table 1) that emerged from researching other bridge contests as well as what was realized during the construction of the prototypes.

Span	22 in. (55.9 cm)
Maximum Allowable Weight	1 oz (28.3 g)
Maximum Allowable Height (Overall)	10 in (25.4 cm)
Max Superstructure Height	6 in (15.2 cm)
Max Substructure Height	4 in (10.2 cm)
Minimum vertical clearance through the bridge	2 in (5.1 cm)
Minimum horizontal clearance through the bridge	2 in (5.1 cm)

Table 1. Design Specifications for the Model Bridge

Some of the important rules are described below:

1. The bridge must be a free standing structure that may be able to rest on the top of the test frame. No glue or attachments can be used to the top or sides of the frame. No braces can be placed against the sides of the frame or extended to the floor.
2. The bridge will be loaded on the roadbed of the bridge at the middle of the span (Fig. 3).
3. The load includes a wood block, a threaded hook and nut, a bucket, and glass beads. Glass beads will be slowly added to the bucket until structural failure occurs.
4. Failure of the bridge occurs when the structure collapses or any part of the structure deflects 2" or more in the vertical direction from the original unloaded position.

5. The structural efficiency will be calculated by dividing the load that caused failure by the weight of the bridge.
6. The bridges will be ranked according to their structural efficiencies. The top three teams will be awarded prizes. Winner's trophy will go to the team with highest structural efficiency.

Fig 3. Model bridge being tested using a block of wood, threaded hook, and glass beads being slowly poured into the bucket.

The actual bridge contest itself is organized by the members of the Advisory Committee every year who are intimately involved in every phase of the event from finalizing the rules to testing the model bridges, selecting the winners and awarding the prizes on the day of the event. Table 2 shows the breakdown of participants by year in the bridge contest since its inception.

Year	No. of Schools	No. of Teams	No. of Students
2003	7	16	42
2004	5	12	25
2005	4	21	43
2006	5	43	86
2007	3	15	34
2008	10	45	109
2009	9	43	105
2010	8	40	81
2011	8	40	91
2012	9	47	97
2013	8	66	169

Table 2. Number of participants in the Bridge Contest. (Middle School category started in 2008)

Fig 4. Student participants along with the parents and teachers on the day of the contest

For the first few years, additional credits were given for the teams that documented their design calculations with the hope that they are getting an early exposure to the laws of Statics. However, that approach was abandoned as most teams did not care about it. The teams were ranked by the structural efficiency of their bridges. The top three bridges were given cash prizes with the best bridge winning a trophy and a plaque for the winning school. Some years later, at the suggestion of the teachers/mentors, the cash prizes were substituted for mementoes with the hope that the memories of the event will last a long time. All participants, including the teachers and judges, are given commemorative T-shirts. Since 2008, the contest was extended to include middle school students to compete in their own category. The rules for the middle school category remained same with the exception that there was no height restriction. Fig 4 shows the students along with their parents and teachers eagerly watching the testing in progress. Details of the best bridge design in both high and middle school categories are shown in Table 3 and 4 respectively.

Year	Bridge Weight (g)	Breaking Load (g)	Structural Efficiency
2003	28.1	10276	366
2004	25.6	5789	226
2005	22.8	10198	447
2006	17.5	9489	542
2007	23.7	13253	559
2008	28.1	11114	396
2009	22.7	5930	261
2010	25.8	11542	447
2011	22.6	6671	295
2012	26.9	8835	328
2013	22	5605	255

Table 3. Best Bridge Design in the High School Category

Year	Bridge Weight (g)	Breaking Load (g)	Structural Efficiency
2008	27.8	8140	293
2009	28.3	8497	300
2010	25.3	4832	191
2011	22.6	9332	413
2012	27.5	11932	434
2013	27.1	6749	249

Table 4. Best Bridge Design in the Middle School Category

It is interesting to note that during three of the six years (2009, 2011, 2012) that the middle school bridge contest was held, the best design in that category came out better than the best design in the high school category as judged by the structural efficiency.

Though it is almost impossible to track the advancement of individual students through their careers, more than one student had joined the RETP program of the university and at least one had successfully transferred to Georgia Tech to complete his engineering education. Also, the past record indicates that many students have come back again and again to take part in the contest for as long as they qualified in their respective category. In one case, a student who won the first-place prize in the middle school category in his 8th grade also won one first and one second-place prizes in the high school category in next two years. Hence, the bridge contest has unquestionably made an impact on the K-12 students in this region of the state. It also has established a forum for the teachers to meet and exchange notes on the activities in their respective schools.

Summer Computing Camp

The first camp was held in the summer of 2008 with only 7 students from both high and middle schools. The camp activities included Lego Nxt robotics, computer theories through games, Alice animation and Scratch gaming software. The robotics projects used are variations of the same projects developed for the Saturday Engineering Workshop. As for the computer theories, students were exposed to some basic searching and sorting algorithms during the camp. For instance, students were told to arrange ten pen or pencils as per some order, such as shortest to longest. After that, they were asked questions: (1) can you do it in some other way? and (2) what would you do if you have ten thousand pencils to line up? This discussion naturally would lead to different algorithms such as Insertion Sort, Bubble Sort. The concepts of Sequential Search and Binary Search were also introduced in a similar manner.

Alice animation software

Alice[9] is a 3D programming language that is based on Computer Graphics. It is event-driven and object-oriented. That design can easily attract students into programming, which makes instructions much easier. When coding, students started with selecting some objects from the existing galleries, and placeing them inside a so-called “world”. Each object is equipped with some abilities (methods) that a programmer can use so that the object can do certain things.

Programming in such an environment, students assume the role of the commander (or director) of a team.

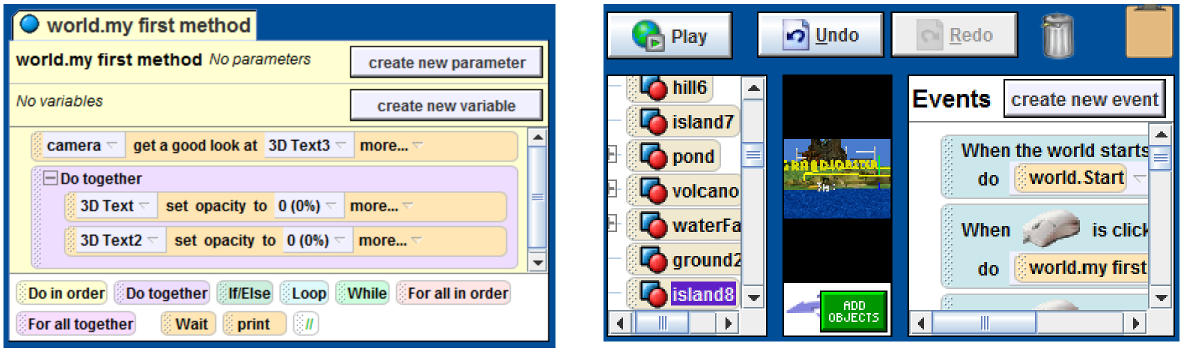

Fig 5. Screenshot of a student's Alice program

A commander will issue orders by adding pre-defined events into the coding. Control structures (Fig 5) are introduced naturally when students wanted several objects to act in certain ways. Variables and grammars are not a concern at all in Alice, which is a major factor that keeps students interested and increase their confidence in computer programming.

Scratch gaming software

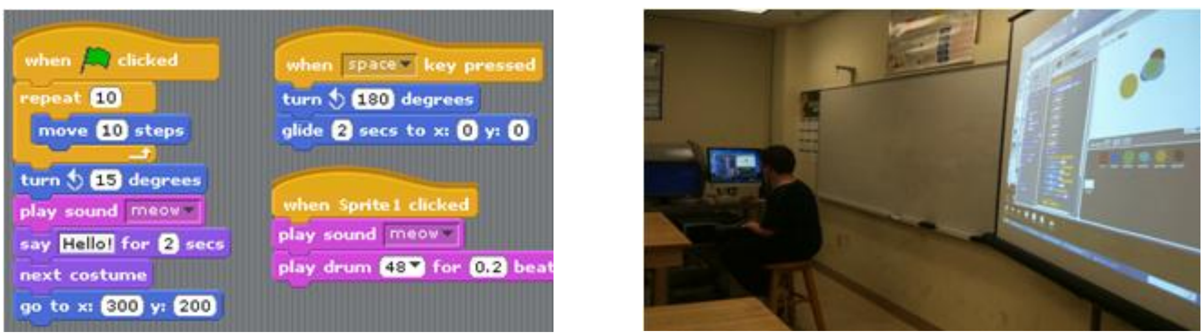

Fig 6. A student demonstrates his Scratch project

Scratch[10] is a similar interactive programming environment. Each (2D) object has a place for scripts, a place for loading or creating new costumes, and a place for loading or creating sounds. Scripts are built by control blocks such as loops, operators, if-then-self, etc. This environment is a very good tool to create a cartoon for telling a story. However, students must get used to variables and logical thinking, which have been major obstacles for students writing a computer program. During the camp, students were asked to use either one or two objects (sprits) and include at least three stages for a short story. In general, students were able to use the building blocks for creating a game. Some students showed strong interests in control structures. The picture (Fig 6) showed a student demonstrating his game, which contains six balloons moving at randomized path at a very fast speed. The player will score if (s)he can click on a balloon.

After the first year, the camp enrollment was restricted to the middle school students only, with the understanding that they are the most receptive group of students who can be guided to a career in STEM disciplines. Also, the camp activities were expanded to include some of the engineering projects in CNC machine and SolidWorks CAD software.

Summer Camp Evaluations

The following two figures (Fig 7 and 8) show students' evaluations of the 2011 and 2012 summer camps.

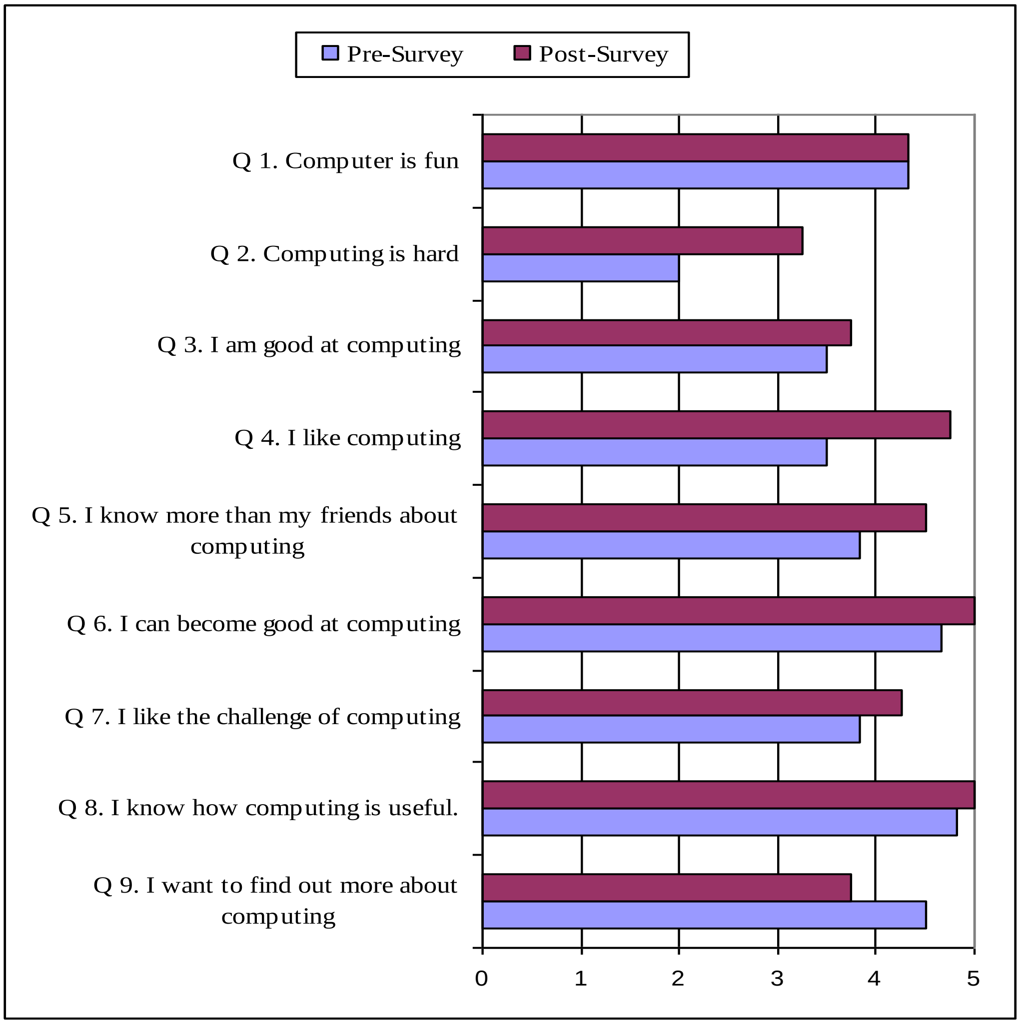

Fig 7. Pre and Post survey comparison for 2011 Summer Camp

Students' answers to every question showed the positive effect of the camp other than the second and the last one. The answer to second question can be explained as more students learned on the subject more they realized how complex it is which shows the depth of their understanding. The answer to the last question was probably due to fatigue of over exposure in a fairly short time (about two days).

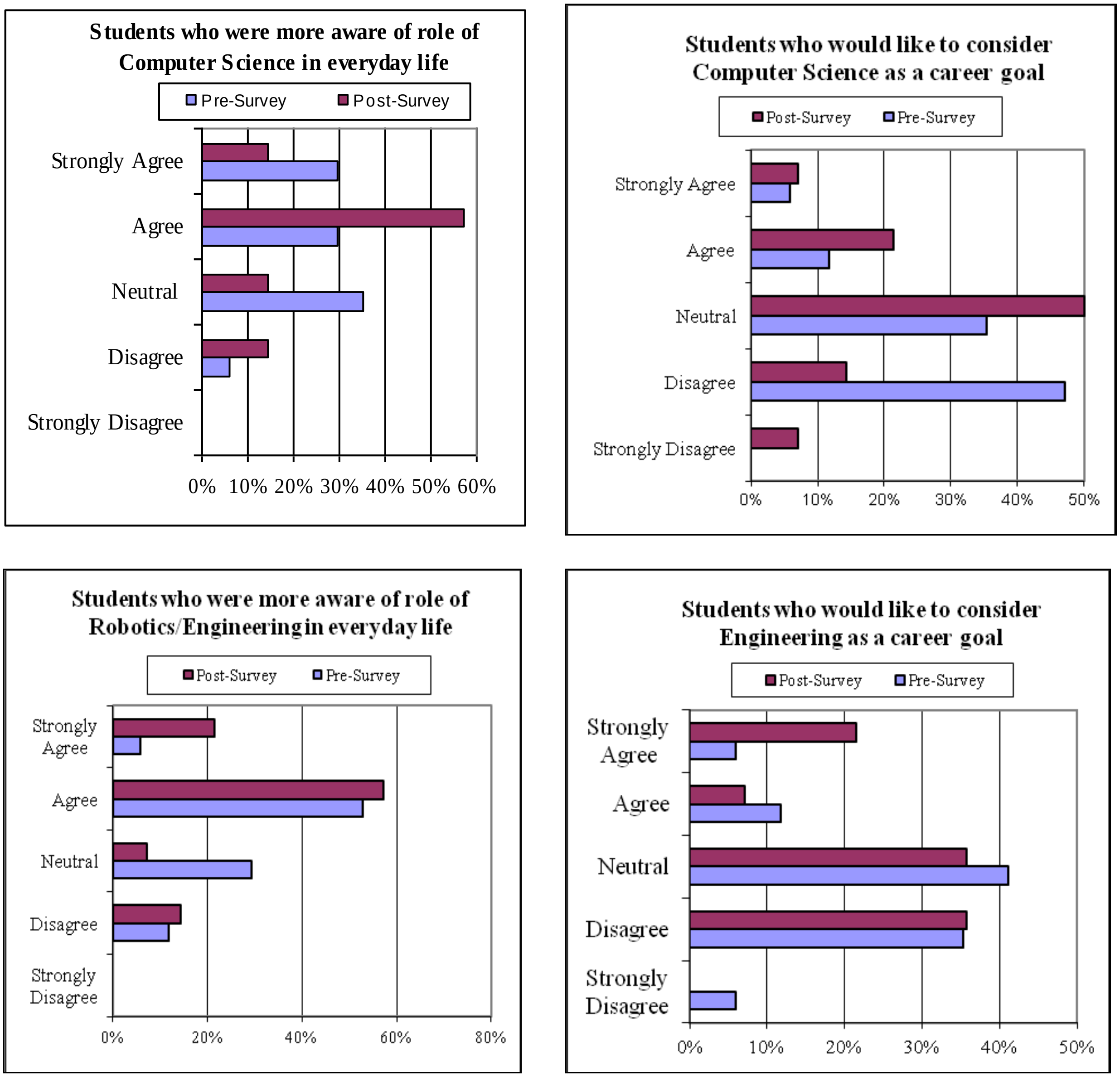

Fig 8. Pre and Post survey comparison for 2012 Summer Camp

Above charts show a clear shifting of students' attitude on both computing and engineering as a result of the camp. Students' awareness about the role of computer science jumped from 59% pre-camp (judged by the answers given as "agreed" or "strongly agreed") to 71% post-camp. For robotics/engineering, the same figures showed 59% pre-camp to 79% post-camp.

Though the comparable figures in answer to choosing either of the disciplines as career goals are much more modest, it also showed the positive effect of the camp. Both for computer science as well as robotics/engineering, the choice of career goals jumped from 18% pre-camp (judged by the answers given as "agreed" or "strongly agreed") to 29% post-camp.

Perhaps the most encouraging written testimonials came in the form of the following e-mails from parents after the conclusion of the very first camp:

(a) "Trey has not quit talking about the classes – he has been on the computer continuously since the finish of the camp. Thank you for offering this camp. It is a great tool to use for increasing the interest of those students who are engineering oriented. Trey truly enjoys your classes and looks forward to learning more about the options available to him in the field of engineering (especially with Robots)."

(b) "I would like to thank you for everything that you all did to make this camp a success! As I watched the kids, I noticed they really were enjoying themselves. They didn't mind sharing what they had done. Please consider more opportunities for learning with the middle school students (to urge them to consider this major and as a possible career path). If possible, I would like to see more of this during the school year and possibly culminate with a visit to Georgia Tech campus. Brenten enjoyed himself and learned an amazing amount of information in such a short time."

Conclusion

Based on the experience of the past decade, it has been clearly established that a small liberal arts university located primarily in an agricultural community, has been successful in getting the middle and high school students of the region involved in hands-on science and engineering projects. Though it is not possible to conclusively prove how much of the initial enthusiasm has translated to higher enrollment in engineering colleges, the fact remains that the students, teachers and parents today are more aware than before of the opportunity in engineering careers and the pathway to get there because of the various outreach projects described here.

Acknowledgement

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Bibliography

1. Rabb, R., and Rogers, J., "Enhancing Outreach Through A Summer Hands-on Engineering Workshop", Proceedings of the 2010 ASEE Annual Conference and Exposition.
2. Sundaram, R., "Engage K-12 Students in Electrical and Computer Engineering (ECE): Outreach with K-12 STEM Schools Through ECE Project Activities", Proceedings of the 2011 ASEE Annual Conference and Exposition.
3. Lobaugh, M., "Revving Up interest in Hands-On Engineering ", Proceedings of the 2004 ASEE Annual Conference.
4. Maletsky, L., Hale, R., Sorem, R., and Ramirez, G., "Integrating Modern Design and Manufacturing Equipment into Engineering Curricula", National Science Foundation CCLI Adaptation and Implementation Award No.0127081, December 2001.
5. Lau, P., McNamara, S., Rogers, C., and Portsmore, M., "LEGO Robotics in Engineering", Proceedings of the 2001 ASEE Conference and Exhibition.
6. FIRST LEGO League – www.firstlegoleague.org
7. FIRST Robotics Competition – http://www.usfirst.org/roboticsprograms/frc
8. Sinha, A., "Model Bridge Building Competition – An Outreach Project to get High School Students Involved in Engineering", presented in 2008 ASEE Southeast Section Conference held in Memphis, TN.
9. Alice-an Innovative 3D Programming Environment, http://www.alice.org .
10. Scratch – a programming language for interactive stories, animations, games, music and art http://scratch.mit.edu/