**Session 2586**

# The Role of a Middle/High School Engineering Design Contest in Student Preparation for Higher Education and Careers

**Ken Vickers, Peggy Samson**
**University of Arkansas/Texas A&M University**

Abstract

BEST (Boosting Engineering, Science, and Technology) is a non-profit, community-based volunteer organization started in 1993 by a group of technologists in Sherman, Texas to systematically address the lack of public peer acclaim for academically successful K-12 students. BEST provides public recognition of these students' academic, technological, and problem solving skills by offering students a chance to compete in a sports-like engineering design contest, one that deliberately mimics a product design-to-market cycle. This paper will document the growth of the BEST local hub network from its inception in 1993 to its 1999 status of 14 local hubs in five states. Variations in local hub organizations will be discussed to illustrate the many ways that communities can implement a BEST contest. A detailed roadmap by which a new local hub can implement a BEST contest in its community will be presented, along with a description of the evolving nature of the BEST Robotics Inc. parent organization. The BEST program's positive effect on individual students, schools, and communities will be discussed, with examples of some significant changes directly attributed to BEST implementation in their locales.

## I. Introduction

The performance of American school children in science and mathematics is low compared to that of many other industrialized nations. Several theories have been proposed to account for this low performance, from ineffective schooling to lack of parental encouragement to over-selling of non-academic careers such as professional sports. But regardless of cause, it can be observed in almost all school systems that academically successful students in our schools receive much less peer recognition and acclaim than do athletically successful students.

In 1993 a group of concerned industrial technologists in the Texas Instruments facility in Sherman, Texas decided to combat this problem by creating an opportunity for academically successful students to receive the same type of public acclaim as the school's athletic teams. Modeling their new effort after a Massachusetts Institute of Technology freshman design class,

they created an academic competition named BEST (Boosting Engineering, Science, and Technology).

BEST is an event that motivates students by challenging them to build a remotely controlled robot that accomplishes a defined task within a newly designed competitive setting each year. School teams are coached through the engineering process by business and industrial mentors from their communities in partnership with teachers from their schools. This competitive situation is designed to deliberately mimic a new product "definition to market" process model by keeping the nature of each year's game secret until all the schools are brought together at a kickoff event and are given:

a) the specifications for the contest (a detailed game task description and machine size limit to simulate customer defined product requirements and specifications),
b) the time period of the contest (a delivery date for the machine six weeks from kickoff to simulate a product time-to-market constraint), and
c) the resources for the contest (an identical box of odd parts, fasteners, materials, motors, and a radio controller to simulate product cost and resource constraints).

Using this fixed set of materials provided by the local BEST organization, students have only six weeks to design, develop, build, and evaluate their robots in their drive to outperform their competition in a game they have never seen before.

During the course of this six-week process, the students experience the same problems and challenges that an engineering team encounters when it takes a product from need identification to product launch into the marketplace. In both cases, there are team dynamics, time constraints, material constraints, and pressure from other teams that are trying to solve the same problem. In this real situation, with real problems, the students apply their theoretical knowledge learned in the classroom to achieve real (and surprisingly ingenious) results.

The six weeks of hard work culminate in a thrilling day-long competition resulting in the identification of both the top-performing teams on the competition field and the winners of the BEST Award. This inspiring competition day merges the excitement of a high school basketball game with the strategy of a chess match and the intellectual challenge of a science fair.

The competition award winners are determined by the machine performance on the field, but the BEST Award requires elaborate judging of each team's activities in its community and school, and the level of support the team receives in return. The BEST Award recognizes the teams that best accomplish the core goal of the BEST organization: spreading the excitement of engineering, science, and technology in their schools and communities.

It is the intent of each local BEST hub to provide an uplifting experience to students touched by a BEST team in their schools, and to develop confidence in students that they are capable of doing more academically than they previously thought possible. The heart of BEST is the experience of solving a seemingly overwhelming task using simple scientific methods, project management skills, and old-fashioned teamwork. Thanks to this experience, students who

participate in BEST are better prepared to meet the challenges of the technology they must one day manage.

## II. History of BEST Robotics Inc. (BRI) Growth

The first BEST contest was held in Sherman, Texas in the fall of 1993 using the name North Texas (NT) BEST. Contest participants included one team from each of 14 local schools as well as a team sponsored by a group of volunteers from San Antonio, Texas. In the fall of 1994, San Antonio (SA) BEST was formed and hosted 13 teams in a local hub contest, while NT BEST grew to a radio technology-limited 26 teams. The two hubs brought their top-performing teams together two weeks after their local contests for a first regional contest hosted by Howard Payne University.

The growth of the BEST organization to date has been primarily through word-of-mouth recommendations, as individuals with BEST experience introduce the game to new communities. Early demand for new hub operations instructions to assure adherence to BEST standards has been provided through direct mentoring of a new hub's volunteers by those of an established hub in corresponding roles.

While this method was somewhat effective for the first three years, the four hubs existing in the spring of 1996 joined together to consolidate hub start-up information and local hub management information into a standard format in a central location. The formalization of this effort was their incorporation into the non-profit corporation, BEST Robotics Inc. (http://www.bestinc.org).

BEST Robotics Inc. (BRI) was self-funded through nominal dues from the local hubs to support a part-time executive director. The person contracted for this effort was Ed Wheeler, a retired Texas Instruments employee who was instrumental in the start-up and early management of the Collin County (CoCo) BEST hub. Through Wheeler's action and the efforts of other BEST volunteers, a web site was created containing hub start-up and operational manuals, making these materials available to any interested person.

With little except word-of-mouth advertising, local BEST hubs have now formed in 14 communities, with each hub receiving its primary financial sponsorship from a variety of sources:

| Location | Name | Primary Financial Sponsor |
|---|---|---|
| Sherman, TX | North Texas (NT) BEST | TI, MEMC SW |
| San Antonio, TX | San Antonio (SA) BEST | SWRI, UTSA, other business |
| Lubbock, TX | West Texas (WT) BEST | TI, Texas Tech U |
| McKinney, TX | Collin County (CoCo) BEST | Raytheon, other businesses |
| Dallas, TX | Dallas Area (DA) BEST | TI, Raytheon |
| Chicago, IL | Chicago BEST | Chicago School District |
| College Station, TX | Brazos BEST | Many small businesses |
| Denton, TX | Denton County (DC) BEST | Boeing |
| Fort Collins, CO | Northern Colorado (NC) BEST | LSI Logic |

| | | |
|---|---|---|
| Fayetteville, AR | Northwest Arkansas (NWA) BEST | UA, other businesses |
| Oklahoma City, OK | Oklahoma (OK) BEST | OCU, other businesses |
| Houston, TX | Four Star (4 Star) BEST | Montgomery College |
| Kansas City, KS | Kansas (Kans) BEST | WSU |
| Houston, TX | Space City (SC) BEST | TI, ASME |

By the fall 1999 BEST contest, BRI had grown to over 250 teams competing in these 14 local hub contests, with over 3,800 students directly involved on the teams and many other students, parents, and teachers involved in support of their schools' teams.

As the number of local hubs was increasing, the interest in a playoff of the "best of the BEST" teams remained strong. For the past five years, Texas A&M University and Texas Instruments have sponsored the BRI-sanctioned Texas BEST regional championship on the Texas A&M University campus in College Station, Texas. The contest this year hosted teams from 13 of the 14 local hubs, with a total of 50 teams competing on the game field and for the coveted Texas BEST Awards (http://www.texasbest.org).

III. Core Values and Objectives of BEST Robotics Inc.

In order for a community to be sanctioned by BRI as a local BEST hub, its organizing committee must adopt the core values of the BEST organization:

a) All design, construction, and operation of the robotic vehicle will be under the direct control of the student members of the team. School and industrial team mentors can interact with the students to help guide the process, but all decisions must remain in the domain of the students.
b) The contest will be open to all students in a participating school, regardless of race, cultural background, gender, or religion.
c) The contest will be financially independent of the participating schools, requiring resources from each participating school to support at least one teacher-mentor, machine building facilities, team shirts, and transportation to the BEST events.
d) The contest will be fun for the participants.

At the same time, BRI has specific goals to be supported by each local hub:

a) Continuing relationships between local businesses and industry will be established with the schools in their communities they support in the BEST process.
b) The student population in participating schools will demonstrate an increased interest in science, mathematics, and technology courses offered in the schools.
c) Individual students in participating schools will demonstrate improved academic performance in the classroom.
d) Communities with participating schools will give increased public recognition of all students who have achieve academic success in or outside of the schools.

The BEST core values are somewhat easy to monitor and protect, but quantitative measurement of goal attainment has been, and continues to be, one of the unsolved challenges of BRI.

BRI encourages schools to form teams from the full student population in order to support both its core values and key goals attainment. BRI data show that consistently successful teams are those that attract both physics and vocational technology students, technology and literature students, and students from the full diversity of their student populations.

IV. Formation of New Local Hubs

The BEST process is built on the premise that the community as a whole will benefit from linkages formed between formal educational institutions, local business and industry, and individual community members such as parents. The most robust and successful hubs attract central committee members from all of these community populations.

Many institutions of higher education have been involved in a variety of ways in the BEST process. Murray State College (two-year technical college) in Tishimingo, Oklahoma sponsored its community's high school team. North Texas State University, Texas Tech University, the University of Arkansas, Oklahoma Christian University, Wichita State University, Montgomery College, and the University of Texas at San Antonio are all active members of their communities' local hub management teams. Texas A&M University has been the host venue and a sponsor of the Texas BEST regional contest for the past five years. By participating in the BEST process, these institutions have forged new links with their feeder school systems and with industrial partners interested in the improvement of students at all levels of the education system.

Local business and industry can also be critical to a new hub's success, particularly in supplying organizational or operations expertise. Local industry can also provide logistical support in parts acquisition, facilities for hub committee meetings, and even access to promotional methods such as internet web page formation. Examples of local industry can range from local engineering companies (such as Hale Engineering, Inc. of Pea Ridge, Arkansas) to local plant locations of major international companies (such as Texas Instruments, Raytheon, and Boeing). These companies benefit from their local school graduates having increased technical education as they enter the hiring pool.

While BRI has not targeted any community for hub formation in the past, the majority of the local hubs have been formed in large towns as opposed to cities. At the same time, the performance data from the Texas BEST regional competition indicate that smaller rural schools are more successful than larger urban schools (probably due to an integration of a wider diversity of skill sets into the smaller schools' teams). School participation is open to both private and public schools, and in some smaller school districts the teams have included members from grades 6 through 12. In larger school districts, teams have been formed at every high school and junior high school campus. The only restriction placed by BRI is that each campus may field only one team.

A community considering the formation of a local BEST hub should begin the process in the summer a year before its first planned BEST contest. An organizing committee should be formed that has assigned persons to the key functional tasks defined in the BRI hub start-up documentation found at the BRI web site. This committee should begin communicating with the

BRI office to identify the closest mature hub that will accept the mentoring responsibility for the new hub in their start-up year.

During the fall following their formation, the new hub's personnel will be in communication with their counterparts in the mentoring hub to understand the details of the tasks they have accepted. The new hub personnel will travel to the mentor hub's key events to gain operational experience for their own hub start-up the next fall.

The new hub will also be using its mentor hub's events to show the benefits generated by the BEST process to potential financial sponsors. Videotapes are available from different BEST operations for use in fund-raising and school recruitment by a start-up hub. However, the full impact of a BEST contest with 20 or more local school teams in a gymnasium cheering on team-built robotic vehicles is difficult to capture except in person.

A new hub will often sponsor one local high school team to participate in its mentor hub's contest as a visiting team. This school can then become part of the school recruitment effort for the new hub the following spring. It is imperative that schools planning to participate in the BEST process commit to participation before the summer vacation break.

The new hub must decide in late fall how many teams it is willing to host in its start-up year as a BEST local hub. New hubs often begin with approximately 12 teams but have started with as few as 8 teams and as many as 24 teams. An early decision is necessary because lead time for ordering reusable robotic kit parts, such as motors and radio control systems, requires that these parts be ordered early in the year of the hub's first contest cycle.

Scheduling of the local contest must also occur early in the year to ensure that all venues are available and that conflicts with major local events are minimized. The new hub committee must find a suitable facility for (1) the kickoff activity, (2) the trial run for the teams at week five (known as Mall Day), and (3) the gymnasium that will be used for the contest day itself. The hub must also be cognizant of its obligation to begin the process in the BRI-sanctioned time window.

As BRI is maturing as an umbrella organization, it has been recognized that a start-up hub that avoids part of this training process is in significant danger of not becoming a long-term, sustained operation. As the number of hubs continues to grow, it is expected that BRI will no longer sanction a group to use its games or operate as a BEST hub unless it has first participated in a full BEST cycle as an observer.

BRI is also experiencing the difficulty of modifying itself from a pure volunteer organization with decision-making by committees with representatives from every hub, to an organization delegating decision authority to working committees of four to five people each. It is experiencing the uncertainty of how to reorganize its management structure to support championship contests in multiple regional locations to reduce travel costs of local hubs' winning teams. These would not be issues but for the fact that BEST is being adopted by more and more communities each year because of the value brought to their schools and communities.

The problems will be overcome, and organizational modifications will be implemented, to support the growth of BEST into every community that has an interest in the program.

## V. Performance Assessment

BRI does not yet have the centralized resources to create the tracking networks necessary to formulate statistically valid comparisons between schools with and without BEST programs, or to compare academic performance of students who have participated in BEST with those exposed only to traditional academic educational methods.

BRI does receive anecdotal stories of points of significant change. One small rural town that has participated in the NT BEST hub for seven years now has a BEST booster club that is more active than the athletic or band booster club. This community is a perennial contender for the BEST Award at both the local and regional contest, with many more of its graduates now considering technical fields.

One teacher has reported significant changes in the willingness to experiment and create new solutions in the portion of her all-girl algebra class that participated in their BEST team that advanced to the regional contest. She attributes this behavioral change to both the local team activities and to the inventiveness training given to participants at the Texas BEST championship.

A physics teacher at a second year participating school in the NWA BEST hub reported that enrollment in his physics class increased dramatically from the historical 8-10 students to 30 students after their first year of participation in BEST. This necessitated that the class be split into a regular physics class and an advanced placement physics class.

The reported anecdotal stories of individual student performance changes are too many to list, but as a whole offer evidence that the BEST process is having a significant impact on the quality of high school student graduates.

## VI. Conclusions

BEST Robotics Inc. provides an organized process for local communities to adopt in order to increase the public recognition given to their K-12 students interested in academic rather than athletic excellence. It also provides a proven method to increase the awareness of, and participation in, more advanced mathematics and science classes in the school system.

New BEST hubs can be formed around the organizational skills of an industry or business, through the leadership of academic institutions, or even through the dedicated effort of a small group of dedicated community volunteers. BRI can provide any such group with the model for a successful local hub start-up and is ready to promote the BEST process in any interested community.

KEN VICKERS

Ken Vickers received BS and MS degrees in Physics from the University of Arkansas in 1976 and 1978 respectively. He worked for Texas Instruments from 1977 through March 1998 in integrated circuit fabrication engineering, the last seven years as Engineering Manager of the TI Sherman IC Wafer Fab. During that time, he served for nine years on the Board of Trustees of the Callisburg ISD and for seven years as Chairman of the Industrial Advisory Board for Murray State College. Beginning in April 1998, he defined, implemented, and now acts as Director of a new interdisciplinary Microelectronics-Photonics Graduate Program at the University of Arkansas. Ken's technical accomplishments before leaving TI included chairmanship of the Sherman Site Technical Council for six years, election to Senior Member Technical Staff, chairmanship of two corporate level worldwide teams, and authorship of twenty-four issued patents.

PEGGY SAMSON

Peggy Samson received her BA and M.Ed. degrees from Texas A&M University and held positions in marketing and non-profit organization management before joining the University in her current position in 1990. As Coordinator for External Programs in the Office of the Associate Provost for Undergraduate Programs and Academic Services, she is responsible for projects in community relations and outreach. She has coordinated the Texas BEST regional event for Texas A&M University since its inception there in 1995. She has been extensively involved in community volunteerism and volunteer leadership roles.