How to Embed Basic Science Concepts in a High School Robotics Design Contest

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Introduction

When observing a BEST (Boosting Engineering, Science and Technology) robotics competition, it is obvious that to develop a robot that is competitive, the participating high school students have had to learn how to work as a team, be creative and problem solve. Knowing that the teams are only given a box of materials, a list of game rules and six weeks to design and build the robot, it is also obvious that they have gained time and resource management skills. Amid the fun and excitement of the competition, students barely know they are learning these important skills; skills which are invaluable for the continuation of their education and for their careers. In the heat of this competition, ripe for learning, is there a lost opportunity to more deeply teach basic science concepts as well?

With funding from a National Science Foundation Materials Research Science and Engineering Center (MRSEC) grant, and in collaboration with Texas Instruments (TI), the Center for Semiconductor Physics in Nanostructures (C-SPIN) is developing a reference tool The BEST Book of Science Basics to be distributed to the coaches and teachers of BEST robotics teams across the U.S. The book is not developed as a “how to” manual, but instead serves as a reference and study guide for better understanding the science behind the engineering (force, torque, center of mass, friction etc.). Through their desire to be competitive, BEST Robotics students will use this tool to learn how basic science concepts apply to the design and building of their robots.

The Collaborators

BEST, now beginning the tenth year of involving students in science, is a sports-like robotics competition for junior high and high school students that simulates real-world conditions within industry. In designing, building and testing the robot, students experience the teamwork, creativity, time and materials management skills that are very much a part of the working environment in industry today. Rules require that students design and build the robots and that adult coaches and mentors provide only guidance through innovative questioning of the students (i.e. “Have you considered the energy lost in gearing up and down with your square wheels on both carpet and hard surfaces?”)
BEST was first conceived in 1993 by engineers from Texas Instruments of Sherman, Texas in an effort to develop these leadership skills and to interest students in careers in science and engineering. The concept has quickly grown to an organization of over 400 teams and representing more than 8000 students who participated in twenty local competitions, known as “hubs”, across the country in 2001. Local industry, educators and community members organize and fund the local hubs. The volunteer adults who serve as coaches and mentors for the teams are typically teachers and members of the local engineering community. BEST Robotics, Inc. (a non-profit organization), now serves as the organizing umbrella over the hubs, with financial and volunteer support from several major corporations.

The BEST games typically involve a radio-controlled robot picking up game pieces and placing them in a container to score points. Both offensive and defensive maneuvers can increase the total number of points a team wins in a round. The theme and game rules change each year and are announced at “Kick-Off” where each team is provided with an identical box of materials and the current year’s rules. After four weeks of brainstorming, planning, developing prototypes, and building, the teams are invited to an exhibition event, usually held at a local mall, to test their robots and get a sneak preview of the other teams’ designs. Two weeks later the local contest is held, involving twenty to twenty five teams. Winners of the contest advance to a regional competition held two to three weeks later.

Both C-SPIN and TI are strongly committed to providing support for science and math education. C-SPIN is collaboration between the University of Arkansas and University of Oklahoma faculty conducting research on nanostructure growth and measurement. As the flagship research universities of the states, both recognize their role in supporting K-12 education in science and math. To that end, C-SPIN sponsors a K-12 Education Outreach program which provides inquiry-based professional development and student oriented activities in math, science and technology. The K-12 Education Outreach Program promotes partnerships with teachers, school administrations and communities to improve the knowledge of materials science and engineering in all K-12 students in Arkansas and Oklahoma. The program integrates the body of knowledge that extends from the research efforts of C-SPIN into K-12 education programs to engage the public in science, develop intellectual capital and promote careers in materials science and engineering. The ultimate goal of these efforts is to enhance the future economic development of Arkansas and Oklahoma. Supporting BEST robotics competitions is an excellent way to accomplish the educational outreach goals of the C-SPIN program.

Texas Instruments has a long-standing reputation for supporting math and science education and through the community support of BEST as well as being one of the leading suppliers of educational technology equipment in the country. Since 1986, TI has worked with educators designing, developing and supplying handheld technology to be used in classroom instruction. In addition to the equipment, TI provides classroom activities, training resources and supplemental materials for classroom instruction. One example of technical equipment developed by TI for the classroom is the CBL 2, a data collection instrument. The CBL 2 is compatible with calculators being used in middle school and high school classrooms all over the country. Students can collect several types of data using the CBL 2, such as temperature, acceleration, etc., and analyze the data using calculations they have learned in class. These
experiences not only improve the student’s comprehension of the material, but also provide them with an understanding of the practical use of the lesson.

The Need

In the ever-changing world of technology, the need to develop both the number of students graduating with science and engineering degrees and the students’ skills in math and science is apparent. John Glenn, serving as the Chairman of the National Commission on Mathematics and Science Teaching for the 21st Century, says in the report from the Commission, “From mathematics and the sciences will come the products, services, standard of living, and economic and military security that will sustain us at home and around the world. From them will come the technological creativity American companies need to compete effectively in the global marketplace.” The sheer number of science, math and engineering graduates must increase to meet the demands the future brings. Predictions are that within the ten-year period from 1998 to 2008, more than 1.9 million new positions in the fields of science and engineering are expected to become available in the U.S., an increase of about 51 percent over the previous decade. But the number of students in the U.S. choosing to study engineering, physical science and math actually declined in the decade between 1988 and 1998 by 14%.

Sadly, students in the U.S. are also not performing competitively in math and science in comparison to other nations. Results from the Third international Mathematics and Science Study which assessed student performance from 41 countries indicates that U.S. students are losing, rather than gaining ground as they advance in school. In the study, fourth grade U.S. students scored above the international average in math and science scores; eighth grade students scored only slightly above the average; and students in secondary level math and physics scored at the lowest levels. The report from the Commission identifies one of the reasons for the performance of U.S. students by saying “despite our good intentions, [the student’s] learning is too often superficial. Student’s grasp of science as a process of discovery, and of mathematics as the language of science reasoning, is often formulaic, fragile, or absent altogether”.

To address these concerns, the National Research Council has developed National Science Education Standards that set educational goals and benchmarks for the nation’s students. Recognizing that science is exploration, and therefore is best learned through investigation, the Standards emphasize inquiry-based experiential curricula. Educators are encouraged to provide students with learning experiences that incorporate scientific concepts into real world applications, making the concepts come to life for the students.

The BEST Book of Science Basics

While enthusiasm for BEST continues to grow among all those involved, concerns about the quality of education in our country loom overhead. The idea for a reference book of basic science concepts began with concern that while the game-like competition attracts students to participate and clearly fosters team-work and leadership skills, there was not enough strong evidence that students were learning science. The BEST Book of Science Basics will provide the basic science and math concepts so students can advance along the path of the scientific process, continually incorporating scientific principles into the design of their robots. As students operate
their own robots and observe others in action, they will see how the principles of science apply to efficient operation of the machine, thus more deeply understanding the basic concepts.

The development and production of the materials is being accomplished through the cooperation of C-SPIN and TI. C-SPIN faculty and staff are providing science content as well as coordination of the effort, and Texas Instruments is providing science and technology content. A panel of BEST coaches who are also teachers will provide consultation on the project.

To begin the process, a survey was sent to BEST coaches and mentors across the country to be sure a reference book of this sort would be considered valuable. The response was overwhelmingly positive, with only a few voicing concerns that the book should not be developed as a “how to manual”. Coaches also suggested several topics that they recalled students struggling with in the past. In addition to the coaches’ suggestions, national math, technology and science education standards will guide the topic selection.

In the process of developing their robots, shortly after the BEST kick-off event the students will begin to identify the tasks the robot must accomplish. For example, frequently the game calls for the robot to lift a game piece. The BEST Book of Science Basics will be organized by task, i.e. the “problem” in the process of scientific discovery, as an example, lift. Concepts that may have an effect on lift, such as force, torque, use of pulleys and others, will appear in the section in a one to two page format. The students could refer to the text to learn how to calculate mechanical advantage when using different combinations of pulleys, for example. There will be a short description of the concept, perhaps a diagram, and a short inquiry-based exercise to conceptually illustrate the idea. From studying these materials, students will come up with the solutions they think will best suit the need and move on to develop prototypes to test their ideas. Following the scientific process, students may then test the prototypes and gather data, perhaps using a data logging system such as TI’s CBL 2 to measure voltage. They may analyze the data using their TI calculators, build the robot, and evaluate the results by observation and more data collection.

The BEST Book of Science Basics will be distributed to all BEST coaches at no charge along with other kick-off materials. Coaches, who are often also science or math teachers, may use the materials in any way they see appropriate with their teams. They may choose to make the material available to the students for their own use, or they may take advantage of “teaching moments” and present the information as appropriate in the process of developing the robot. Reference to the national education standards as well as for some state standards in which BEST hubs are located, will be included, making this book an excellent source for high school robotics and engineering courses as well.

At the end of competition, coaches will be asked to evaluate The BEST Book of Science Basics for content, applicability and the frequency with which they used the book during the development of their team’s robot. As a part of an ongoing evaluation of student achievement based on BEST participation, student test scores and course selection will be correlated with the introduction and frequency with which the students were exposed to the material, to determine the effect.
In providing *The BEST Book of Science Basics* as a resource to BEST coaches and teachers, C-SPIN and TI can accomplish many of their education outreach goals. BEST hubs depend on partnerships between the schools and local community and industry for the organizational structure and mentoring needed to survive. *The BEST Book of Science Basics* can foster these partnerships by providing a resource for volunteer mentors from industry and community to feel more comfortable in working with students. The inquiry-based format and use of technical equipment provides teachers and students the opportunity for a deeper exploration of science and complements national and state education standards.

Most importantly, *The BEST Book of Science Basics* can both deepen the science knowledge of participating students and by doing so, potentially increase the number of students who choose to enter professional fields in science and engineering. Exploring basic science concepts in the context of real-world application brings a deeper understanding to the learner. When a student more deeply understands science and has experienced successes in exploration, that student is more likely to consider science as a field of study. Thus, though the production and distribution of *The BEST Book of Science Basics*, C-SPIN and TI accomplish their goals in outreach education.

2. National Science Foundation/Division of Science Resources Studies: data from Department of Education/National Center for Education Statistics: Integrated Postsecondary Education Data System Completions Survey

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