USING ROBOTS TO BUILD ENGINEERS

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Why Robots?

"I Didn't Know You Could Do Something Fun Like This When You Grow Up"

This surprised comment came from a fourth-grader in an inner city DC classroom who was seeing a real robot for the first time during a presentation I was giving for his school. He then asked, "How can I do what you're doing when I grow up?" What an irresistible opening for the old "stay in school, study science and math" message we've all grown so used to giving. But with this cool-looking robot rolling around the classroom, the message was believable, once we explained the connection between the math he was currently learning and his potential career as a robot designer.

Robots appeal to a wide variety of students, including kids who have been labeled gifted, underachiever, learning disabled, "troubled", and honors student. Even very young students can be creative about what they would like robots to do, and the specialized equipment a robot would need in order to perform such tasks. Older students are often intrigued by the excitement of personally creating something that actually moves by itself.

Multimodal Learning

Robots can be used to support existing curriculum, or explore new avenues in several different types of classes in addition to the obvious STEM[1] core (science, technology, engineering and math). Social science, ethics, economy, art, design, and language arts are just some of the areas that can easily focus on robots as subject matter. And in science, it doesn't take much to imagine how robots can be part of the study of geology, space sciences, physics, and for younger students, the scientific method.

Students who may not do well in the everyday classroom experience of reading, writing, and listening may find themselves becoming quite involved in the hands-on creation, programming, teamwork and experimental aspects of robotics. Our work with primary grades indicates that even children who normally don't participate in class discussions tend to become enthusiastic and engaged in the process of experimenting with robots.

For students with alternate learning styles and strengths, robotics can provide a welcome

[1] Although "SMET" is the usual acronym for these subjects, I find it aesthetically objectionable, especially when the obvious "STEM" sounds better and bears more promising implications. "SMET" is something one wipes off the car's windshield.

opportunity to shine. A science teacher from a high school in Tulsa, Oklahoma told us how she experienced this sudden discovery of talent when she recruited a Botball (robotics) team, despite the technophobic environment at the school. She felt pressure to drop the project, however one girl[2] had surprised both the teacher and herself by discovering a mechanical aptitude that no one knew she had, and a boy from a non-technical family who had never programmed before became the star programmer for the team. This teacher said that although there was pressure to withdraw, these students insisted that the school continue with the program.

One of the most beautiful examples of a multimodal experience supporting existing curriculum, and the application of previously learned knowledge, came about during an extracurricular robotics class for sixth graders. Several students were attempting to use timed moves to figure out when the robot should turn away from a circular pattern. Timing when to turn doesn't actually work very well because factors such as friction and battery charge tend to change the time it takes for each run. It was suggested that the students try dead reckoning to determine the robot's position, which involves several calculations, including the circumference of the wheels, the distance traveled, and the circles each wheel would make if it traveled in a circle. Suddenly one student jumped up and exclaimed, "So THAT'S what Pi is for!" Every adult in the room had a huge grin as we enjoyed this happy display of authentic mathematical understanding.

Timing is Everything

The first class we offered at an elementary school was a before-school course for fifth and sixth graders. We distributed information and registration flyers one day, and the following day we received 30 completed registrations. Pretty good, we thought, until we noticed that out of 30 registrations, only one came from a girl. No other girls signed up for the course, and when this individual found that she was going to be the only girl, she got very nervous and almost withdrew, but finally chose to stay in the class. To make matters worse, we overheard comments such as "That's the robot class – it's for boys" from her classmates as we walked down the corridor.

This all was sufficiently disturbing that some kind of response was needed. I got permission from the principal to do a series of robot demos for the second graders. I brought a small robot in to each second grade class, showed its interesting abilities, let the children interact with it, and, later, let the teacher distribute registration flyers for a second grade after-school class. We were not surprised to find half our registrations were from girls this time. What was most significant, however, was that when this group of students became fifth graders we again offered a fifth/sixth grade class. This time we had quite a large response, and slightly more than half the registrations were from girls.

Now obviously we don't have anything remotely like a controlled experiment going on here, and quite a number of factors changed over those three years. But it is very possible

[2] In this era of increased linguistic awareness, please note that although I will be speaking about high school students, many of whom may be considered young women and men, I will call them girls and boys, because that is how they referred to themselves.

that those early, fun experiences in robot class (and word of mouth) accounted for the increase in fifth grade registrations.

KIPR's Educational Programs

KISS Institute for Practical Robotics (KIPR) is a non-profit robotics research and education organization (and yes, KISS does stand for Keep It Simple, Stupid.) The organization was founded in Fairfax, VA in 1993, but was recently moved halfway across the country to join the College of Engineering at the University of Oklahoma. Our mission is twofold: to use robotics to communicate the excitement of being on the creative side of technology while at the same time inspiring students in STEM-related fields; and additionally, to promote and carry out research and development in the practical use of robotics.

To accomplish our missions, KISS Institute has established several programs, each designed to bring robotics technology to a particular audience. For our purposes here, I'll briefly summarize the Robots in Residence program, and will focus primarily on Botball, our national program aimed at getting middle and high school students excited about creating new technology, and learning about engineering and computer science.

KISS Institute's Robots in Residence program addresses the need to give students early enjoyable experiences with technology. The program is generally used in elementary and middle schools and involves a KISS Institute certified robotics instructor visiting a particular school for a pre-arranged amount of time. The instructor consults with school personnel in advance to work out a plan that accomplishes the needs of that school. For example, teachers may wish to have the sixth graders work on a large robot building project, while the younger grades get robot demos or small, general robotics classes.

In contrast, all the middle and high schools that wish to participate in Botball do so at the same time, as part of a regional Botball program. Later they may choose whether they wish to participate in the national tournament.

The Botball program contains two major challenges. First, students have about six weeks to design, build and program (in C) a small, mobile robot to compete in a highly charged double elimination tournament that pits robot against robot in a game of skill, speed and strategy. Students work in a team, and each team is given a specialized kit that contains a micro-controller, motors, sensors, lots of Lego and plenty of other goodies.

It is important to point out that these are autonomous mobile robots, and no remote or radio control is involved – all robots perform based on their programming. Although two robots play at the same time, and there is frequently some fairly entertaining interaction, the Botball game played by the robots is intended to be non-destructive and is based on real functions one might normally have a robot perform. The robots are all student designed, built, and programmed.

In addition to the Robotics Tournament itself, as part of the Botball Program students participate in an Internet Research/Website Development competition. Students are given a specific robotics challenge. They must then use the Internet to do research, design a solution, and create a website – using whatever tools they wish – detailing their solution to the assignment.

Botball provides new, reusable robotics equipment to schools, and trains teachers in its use. Each Regional Botball program kicks off with a three-day tutorial for the lead teachers, where they learn some of the basics of robotics and how to work with the robotkit. Instructors also discuss ways to use this equipment to support the current curriculum in several fields.

A Botball Tournament can be a thrilling experience! Six weeks after the tutorial, students bring their robots, families, and friends to the regional double elimination tournament. Students are highly focused and motivated at this point, yet we have also seen tremendous acts of sportsmanship and mutual assistance. At the end of the tournament we have an informal awards party where trophies are awarded for robots and websites.

We encourage the students to put these trophies in their school trophy case, right beside the basketball and football trophies. It can be very moving to hear about Botball students becoming heroes in schools that previously recognized only excellence in sports. In addition to trophies and special awards, top teams from each regional tournament win travel scholarships to the National Botball Tournament, hosted by the American Association for Artificial Intelligence (AAAI) at its annual summer conference. The travel scholarships are contributed by AAAI as well. All teams that have participated in a regional tournament are welcome to participate in the National Botball Tournament, regardless of whether or not they win a travel grant to attend.

Both the corporate and educational communities support the regional Botball experience. Since our cost is $2000 per team (including all teacher training, equipment, etc.) there is usually a local committee or individual helping to raise scholarships for schools that cannot afford that amount. Local organizers seek scholarship funding from local businesses, especially high-tech corporations who stand to gain a great advantage from having Botball in their community. (Even a quick glance at the help-wanted section of the newspaper suggests that students who learn the skills of computer programming in C, website development, and working as a team to accomplish a major project will be well on their way to becoming highly employable.)

Businesses frequently do more than just write a check. Although the robots must be student designed and built, mentoring is encouraged, and Botball provides an opportunity for corporations to have a direct impact on their future workforce.

Gender Differences

The prelude to the final match of the 1999 National Botball Tournament was incredibly tense. The crowd was excited and people were cheering for their favorite teams as the two superbly crafted and programmed robots were being calibrated. One robot had a clever

design that was sensitive to the personality of the opposing team's robot, and could be switched during calibration to play either an aggressive or a nice game, depending on the opponent's track record. This robot was equipped with a sorting mechanism that allowed it to sort black and white balls. The opposing robot had been effectively designed to be extremely fast and powerful, with wide wings that expanded to trap its opponent's robot.

In this "clash of the titans" the winner was the mighty "Fembot", built for speed and brute strength by the all-girl team from Oak Ridge High School. The crowd went wild as the all-male Menlo-Atherton team congratulated the winners. Many surprised comments were overheard about the toughness and power of the girls' robot and the sensitivity and the "thoughtfulness" of the boys' robot.

Although it is not unusual to have all-male teams in this program, in every tournament in which there has been at least one all-female team, an all-female team has won. We asked a few of the participants about that, and were told by one girl, "When we were in the pit working on the robots before the tournament all the guys were kind of yelling at each other, but we worked really well together as a team, and we each had our job, and I think that helped us a lot."

Several girls have said that they were initially attracted to working on the Botball team because it seemed like a fun social activity, and they liked working on design. We are interested in looking more closely at factors influencing girls' interest in robotics, and how Botball can contribute to producing more female engineers.

Systemic Changes

One of our straightforward goals in producing the Botball program is to spark some students who may not have considered participating in an engineering-like project before, and who might not have known how fun it can be to be on the creative side of technology. Our less obvious goal is to inspire schools to provide more of this type of activity and provide them with the means and training to do so. Countless schools have money, organization, and public recognition for extracurricular sports activities. Many do not have anything available for individuals who might be talented in technology-related fields.

Some striking things have happened as a result of the Botball Program. In Oklahoma this year we fielded 26 teams for the first Oklahoma Regional tournament. One of the teams' registrations stated that they were looking for a scholarship, as that they were the poorest school in the county, and in the bottom 10% in the state. Naturally we wanted to support this school and we were able to provide a scholarship. Two weeks before the tournament I happened to show the list of teams to the Oklahoma State Superintendent of Schools. As she skimmed down the list, the only school she pointed out was this particular school. "Dibble High School is sending a team!?" she seemed very surprised, explaining that this was a tiny, rural community that rarely participated in outside activities.

In a field of 26 teams from across the state, including private schools and magnet schools, Dibble High School won First Place Robot. Interestingly, the second place team was also from a small, rural school.

In an email thanking us for this experience (written after the tutorial, but before the tournament), Mr. Hayhurst, Dibble's lead teacher, described his plans for using the robotics equipment after the tournament, including the following: "High school physical science and physics classes will have opportunities for using the equipment in construction and programming activities designed to introduce students to the use of technology and encourage further study. Demonstrations will use the robot components to illustrate physics concepts in mechanics, force, and electricity"

One of the most dramatic turn-arounds took place at Foothill High School, a "continuation school" in California. (This is a high school for students with legal, drug, or behavioral issues who cannot be mainstreamed.) This school contains a large number of students from populations that are under-represented in engineering. Foothill registered a team of three students during our first year of Botball. One of the participants was a single mother who was doing this to get some credit to graduate. She had no experience doing anything like this before, and she got so excited about this project that she applied for, and got, an internship at NASA.

Another Botball student at Foothill, who would not have graduated otherwise, improved his attendance and attitude and was able to graduate that year. He then stayed at the school, worked with the teacher to develop the curriculum for next year, and became a paraprofessional, motivating and mentoring students, while he prepared to attend a local college. Jeneva Westendorf, the lead teacher at Foothill High School, informed us that attendance went to 100% for the students who were working on the robot project. This year Foothill is sending five Botball teams to the regional tournament, and has so integrated robotics into its core curriculum that teachers use the robotics equipment in almost every science and math class.

I'd like to close with an excerpt from an essay by Jeneva Westendorf on the value that robotics has brought to her school and students:

Several students have jobs with NASA, students have goals and dreams that they never dreamt of having. Our school and district of 11, soon to be 12, high schools in the East Side Union High School District now have an exciting future in science and technology. Robotics motivates students to make plans, to accomplish, to look forward, to achieve and to feel good about themselves, in some cases for the first time in their lives.

The robotics class itself is set up to allow students to feel comfortable with the *new and sometimes very complicated concepts that robotics brings with it. To build an autonomous robot, students must learn the basic concepts of mechanics, engineering and computer programming. They must also learn the skills of effective communication, teamwork and problem solving. They get to learn by making mistakes, in fact mistakes are essential to their learning. The programming piece allows the students to tap talents in logic and math that they once were unable to recognize in any other way. Robotics is also a great introduction to the uses of Algebra, Geometry, Trigonometry and the science of Physics. It gives practical application to these disciplines so that they have more meaning and use for the students, therefore motivating them to want to learn these subjects, rather than learning* them in *isolation.*

This is why I love robotics! Robotics is a tool for learning through experience and discovery. Students get to "own" their learning and the teacher becomes the facilitator of their learning. It's not the teacher's "stuff" that is being shoved down their throats, but it's theirs!!!!!!!

We encourage members of WEPAN to contact us to explore the possibility of bringing Botball to their institute or region. If you are interested in using the Botball program, or its demographic data, for your own research, please let us know and we would be happy to make this available.

REFERENCE

Miller, D.P. and Stein, C., "So That's What Pi is For" and Other Educational Epiphanies from Hands-on Robotics, in Robots for kids: Exploring new technologies for learning experiences. Druin, A. & Hendler, J. (Eds.) 2000. San Francisco, CA: Morgan Kaufmann.

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