Botball Robotics and Gender Differences in Middle School Teams

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Abstract
The Botball Educational Robotics Program is useful in sparking and maintaining an early interest in engineering and technology. Thousands of middle and high school students across the country have participated in Botball, many of them in all-girl or all-boy teams.

Botball gives students experience in working as a team to strategize, design, build, and program a pair of autonomous mobile robots from a kit. They learn to trouble-shoot, to document their procedures, and to stay focused on a long-term goal. This paper describes Botball, an engineering outreach program for middle and high school students and their teachers (now available at the collegiate level as well). This paper will also discuss the National Conference on Educational Robotics, which includes the National Botball Tournament and also provides early opportunities for middle school through college students to present and publish research papers.

The first year in which an all-girl Botball team participated in the program, they won the national championship in the robotics head to head division. Are there differences in how girls and boys approach being on a robotics team? Does it matter whether they're on an all-girl, all-boy, or mixed team? The authors ran focus groups with middle school Botball participants. Our purpose was to gain some insight into whether there might be gender-related differences in approach to participating in Botball at this age.

Introduction

Years ago, a seventeen year old girl graduated first in her high school class and headed out to the University of Oklahoma to study aeronautical engineering. Her university advisor told her flatly "Girls can't be engineers!" She stood her ground and eventually earned a degree in aerospace mechanical engineering, but throughout her studies she was the only girl in her engineering classes .[1]

As unthinkable as her advisor's comment is today, there was nothing unusual about it at that time. More extraordinary was the passionate seventeen year old who was so driven by her dream that she then went on to NASA's Jet Propulsion Lab (JPL), where as an aerodynamicist, she was the only degreed female out of 2000 engineers. Donna Shirley is known today as the former

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manager of the Mars Exploration Program at JPL, and the leader of the team that created Sojourner, the Mars Rover for the Pathfinder mission in 1997.

It takes a certain kind of person to flout the general attitude of the day, heading full speed towards a virtuous, yet socially disapproved goal. Fortunately times have changed a bit. WEPAN (Women in Engineering Programs and Advocates Network), WIT (Women in Technology), this ASEE division of Women in Engineering, and other organizations and programs have been created to try to address the challenge of recruiting more women into engineering.

Even though there are organizations and individuals working towards helping more women choose engineering as a profession, there are still obstacles. Although girls may express confidence in their ability to do any kind of career, Silverman and Pritchard [2] found that if girls are not informed about the aspects of a variety of careers by eighth grade, they may not make the connection between classroom learning, world-of-work, and classes available to them in high school. Silverman and Pritchard contend that this could limit options for girls to select high wage careers, such as engineering. Therefore, it is important to look at ways in which middle schools and outreach programs, such as Botball, can be useful in expanding women's horizons, especially when it comes to engineering.

According to Sheila Widnall, the main reasons women don't go into engineering are a "Lack of connection between engineering and the problems of our society. Lack of understanding what engineers do."[3] More must be done to help girls understand the usefulness and variety of activities inherent in engineering. Clearly more outreach is needed.

Adolescence is the time when individuals make crucial decisions regarding their adult identity, according to Whitehead.[4] Welty and Puck [5] state that adolescent girls tend to prefer activities that involve cooperation and allow them to work together, allowing for strong bonds among female peers. Welty and Puck suggest that projects be selected that provide opportunities for group work and interaction, and that incorporate aesthetics and human needs.

During this time young women need to be exposed to programs and experiences that bring out the fun and the positive, female-friendly aspects of engineering. One such program is the Botball Educational Robotics Program. Botball is an effective engineering outreach program, designed for middle and high school-aged students, that does have success with young women.

Background: The Botball Educational Robotics Program

Botball is a national program produced in regions across the country by KISS[1] Institute for Practical Robotics, a 501(c)(3) nonprofit educational organization. The Botball program has been in existence for six years, starting in 1998 with twenty-eight teams (about 560 students) in three regions. In 2003, two hundred fifty teams (about 5,000 students) participated in twelve regions across the country.

In Botball, student teams have about seven weeks to design, build, and program a pair of small autonomous robots to play in a non-destructive tournament. At Botball's core is the team project involving hands-on robotics original design, computer programming in C, foresight, strategy, and creation of a Documentation Website, describing the team's project management and other

[1] KISS stands for Keep It Simple Stupid, an old engineering acronym.

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team issues. Botball also offers an optional Research and Design Website Competition on a robotics topic relating to human needs, such as this year's topic: assistive robotics for the disabled. (The topic chosen for the Research and Design Website Competition is not related to the physical tournament game). The program starts with a workshop for educators, where they receive reusable equipment that will serve their schools for years to come. The program also features a regional public tournament, and a National Conference on Educational Robotics (including a National Botball Tournament).

The program was developed to serve the following goals:

For Students: Botball's goals are twofold:

1. To reach out to all, from at-risk through honors students, to help them develop valuable work-related and academic skills, challenge students' creativity, and promote positive attitudes, understanding and a spirit of inventiveness in the fields of science, technology, engineering and math.
2. To function as a pipeline for getting middle and high school students to college in technical fields by embedding the values of higher education in everything we do and by offering students a means to get reviewed work published early to strengthen their college applications.

For Educators and School Districts: Botball exists to provide educators with knowledge, resources, training, and equipment with which to foster an engaging and continuous hands-on learning environment for several subjects. Botball is part of a long-term approach towards improvement in the way science is taught, by exposing students to inquiry-based activity that appeals to their hearts and hands as well as their minds.

For the General Public: Botball Tournaments and Exhibitions serve as public outreach opportunities during which the field of robotics can be made more accessible to the public. An additional goal is to use these public events to help increase the societal value placed on intellectual achievement and inventiveness.

For the Corporate and Government Marketplace: Botball addresses our nation's need for well-prepared, creative, yet disciplined, diverse technology workers with experience working in a team on a complex project. Botball also provides an opportunity to sponsor (on a regional or national level) an effective, educational enterprise that yields both individual and public relations benefits.

How the Botball program works

Botball teams are organized in schools or through community groups. Any middle or high school-aged student may participate as part of a team. Teams sign up in fall and winter to participate in the program. In late fall a research topic, such as assistive technology, is announced, and teams do Internet research and create a website detailing their work, which includes original designs.

In early spring, a Botball Educator Workshop is held in each region where a regional tournament will be held. The Educator Workshop is for leaders of Botball teams, and it gives teachers or mentors necessary hands-on experience in working with the Botball robot kit, as well as ideas about how to use Botball to support their current curriculum in a variety of subjects.

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At the Educator Workshop teachers receive their new Botball robot kits. These kits are self-contained – everything needed to make a pair of robots is provided, including microprocessors, beams, motors, gears, sonar, customized sensors, wires, software and documentation, Legos, and other goodies. At the workshop, educators learn how to make small autonomous robots, how to program the robots to do a task, and how to reuse the reprogrammable equipment in classes for years to come. The new tournament game is revealed at this time.

The team leaders then take the robot kits back to their teams, who have about seven weeks to design, program, and build a team of mobile robots to play the tournament game (this is always a non-destructive, open-ended challenge). The robots will all be autonomous – no remote control is involved in Botball robots. Instead, students program the robot in the C programming language. The teams must use foresight, logic, and imagination to determine how they want their robots to behave and respond to information from sensors. Although the materials and software come with written resource materials, there are no directions for assembling a robot, so participants must come up with original designs.

During this time the teams document their process and their project management at a special Documentation Website for that purpose. Documentation websites are required and are worked on throughout the seven weeks. They are judged based on meeting the following criteria:

- Team Strategy
- Team Assignments
- Schedule
- Game Strategy
- Testing Procedures
- Code
- Mechanical Design
- Weekly Status Reports
- Lessons Learned - Advice to future teams

At the end of the seven weeks, all participants gather for a public regional Botball Tournament. The student pit area where they can work on their robots is roped off from teachers and other adults, and it's filled with students doing last minute programming or redesign. The robots compete in a double elimination tournament, and afterwards framed certificates and tall trophies are given out. For more information about the Botball Program see Miller and Stein [6].

The National Conference on Educational Robotics

After the regional Botball Tournament, teams can still work on their robots, or in some cases, build new robots. In summer, students, educators and the general public are invited to the National Conference on Educational Robotics[2], which features the National Botball Tournament. All Botball participants may compete in the National Tournament, regardless of how well they did in their regional tournament.

The National Conference on Educational Robotics includes many opportunities for students and educators to give presentations and demonstrations, and of course this means a publication in the proceedings, especially useful for students preparing a resume for college. The National Conference also features a Collegiate Botball Challenge, invited speakers, technical sessions by

[2] The National Conference on Educational Robotics is also a program of the KISS Institute for Practical Robotics.

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and for students and teachers at all levels, pre-conference workshops, and many opportunities to network.

Botball as outreach in engineering

Botball is similar to engineering projects in the world-of-work. There are task constraints, milestones, leadership, teamwork, research and design, information dissemination, and project management issues. Robotics includes both hardware and software. Since Legos are involved as well, there is high tech and physical modularity – what Eisenberg and Eisenberg call "Middle tech": "the unexplored terrain in which programs and materials, complexity and concreteness, blend into new media." [7].

The "new media" gives students a chance to work with materials in a way that blends physical and cognitive elements. Students have opportunities to specialize, and students who may not traditionally do well at school may find themselves completely engaged in this program.

Because it provides teacher training and equipment, the Botball program provides a long-term strategic approach to improving instruction and engaging students, keeping them involved, enthusiastic, and potentially more interested in engineering and technical professions. The Statistical Consulting Center at Virginia Tech, in its analysis of surveys from Botball students [8,9], found that:

- 85% of the respondents have a more positive attitude about the usefulness of math and science than they had before participating in Botball;
- 51% of students surveyed reported a definite increase in confidence in being creative with technology, with 24% reporting somewhat of an increase (nobody felt less confident);
- 72% of students surveyed said they were interested in pursuing a career in engineering, science, or technology;
- 35% felt Botball influenced their decision about career choice;
- 37% felt Botball influenced their decision on what to study in college;
- 83% reported that Botball was one of the best experiences they've had in school.

Of possible significance in the workforce issue is that Botball may also prove to be helpful in retention of college engineering students. Years ago high school students bemoaned the fact that once they graduated they could no longer do Botball, which at that time was limited to middle and high school students. In 2002 students were surveyed and it was found that 86% were interested in participating in a college level Botball program [8,9]. More research may show that students enjoy working on familiar projects over the transition from high school to college and therefore, may continue to stay with engineering. In 2003 the Collegiate Botball Challenge was inaugurated, and it is now featured as an important part of the National Conference on Educational Robotics.

Middle school focus groups

Middle School Botball teams that we studied took three forms—all-girl, all-boy, and mixed. Twelve students from two suburban middle schools were selected to participate in focus group discussions, six girls and six boys, ages 11-15. Their participation on a Botball team had been

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completely voluntary, and the makeup of the teams varied by school and interest. Our focus groups were separated into female and male groups. As investigators approached this topic of whether girls and boys differ in approach, certain assumptions were made. These assumptions, listed below, were based on our reading and personal observations.

- Parents would have an influence on the child's participation in Botball, but more so for girls.
- Girls joined Botball for the social aspects.
- Girls would not like the competitive aspect of Botball.
- Girls would prefer to be on all-girl teams and boys would prefer to be on all-boy teams at this age.

Our first topic with each group centered on what attracted the students to Botball and, once a member of the team, what aspects kept them interested. Our research corroborated Silverman and Pritchard, [2] who found that girls were attracted to hands-on activities and those that had an element of design involved. Once asked what attracted them to Botball, the first girl's reply was an emphatic "Building things!" Other answers included the computer programming, designing, and "seeing how things were connected".

Further conversation confirmed that the girls were quite attracted to the design, construction, and teamwork associated with Botball. Many had played with Legos growing up and enjoyed "tinkering" with things. Another interesting factor mentioned by girls is that they enjoyed the competition itself—getting to talk with other players, seeing what other kids had built, and having this chance to do something different and interesting.

In contrast, boys mentioned specific terminology related to Botball (e.g., the word "bot", or, "the announcement said Legos, and computers!") was what initially attracted them to Botball. Once involved, their favorite things were building, mechanics, "figuring it out" and "getting it to FINALLY work at the end". One boy in particular took on the role of programmer and clearly took great pleasure in the perfection of his coding.

There was a difference between the way boys and girls perceived and communicated parental influence. Every girl mentioned first and foremost that she was strongly encouraged to participate by her parents, and one mentioned a sister who had done Botball before and encouraged her to follow suit. The girls said that their parents really wanted them to do Botball—that in addition to providing transportation to and from practices and competitions, parents also encouraged them in their efforts, whereas the boys repeatedly mentioned parents as transportation and seemed to focus on that one aspect. One boy, however, did mention that his father had urged him to persevere when he was feeling negative one time, "and I'm really glad he made me stick with it". The boys also mentioned one father who was helpful in teaching programming.

Our findings also showed that the perceived involvement or support of friends of Botball participants varied somewhat between the boys and girls. Some of the boys did mention that friends and former Botball participants had influenced their decision to participate. Girls said that

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their friends tended to be supportive and interested. One girl even joined the team because one of her friends was on the team. Girls said that if they "do something interesting, then friends want to know more about it." In contrast, the boys as a group agreed that not many friends even knew about their Botball activity. The exception was one boy who said that some friends viewed Botball as "nerdy" but some also thought it was cool. Yet, for the most part the boys said their friends did not ask much about Botball as the season progressed.

We found a difference when we asked about how roles were decided within the team. The all-girl team felt that "There wasn't any fighting. We got to do what we wanted to do". They described how each girl chose her own role, and who was the leader. By contrast, the all-boy team seemed to have no leader and, although they did have programmers, they could not describe any other roles. One boy said that this all-boy team was different than the previous year when he'd been on a mixed team. He said that on the mixed team they'd had a president and vice president and everyone else was assigned a role, but that things were very different on this boys team. (The girls who had observed the boys team commented, "The boys team fought and they all tried to do everything. They didn't have roles.").

In contrast to the all-girl team and the all-boy team, descriptions of what happened on the mixed team varied depending on whether you asked a boy or girl. The girls described being told to work on an extra exhibition robot because "that was the only role left". But the boys said that there was initially a written questionnaire and that each person was asked what they were interested in, for example "Most people got their first or at least second choice", and "Everyone said what they wanted or drifted to something else that they liked – the only set job was the programmer". (The girls from the mixed team never mentioned the questionnaire. They did mention missing a couple meetings due to basketball, and may therefore have missed the questionnaire.)

When asked how they felt about how the roles had worked out, the all-girl team and the all-boy team felt things had worked out just fine -- they were perfectly satisfied. Most of the boys from the mixed team felt things were fine except one boy who was dissatisfied because he had wanted to do others' jobs as well as his own. The girls from the mixed team felt things had worked out badly, "there was a lot of bickering", and that they had been prohibited from working on the main robot.

When asked how the teams developed strategy, not surprisingly the girls from the mixed team said that the boys decided what they wanted to do and went ahead and did it, ignoring the girls' ideas. The boys on that mixed team said that they all submitted ideas and voted. One boy then added, "We did reject a timing idea from a girl, she didn't want to use encoders".

The all-girl team described their process for developing strategy in detail: they talked, drew sketches, and made decisions together: "Everybody contributed ideas without hurting anyone's feelings". The all-boy team also seemed cooperative about developing strategy: "We discussed how each robot would be used and who would work on each—we compromised to make it less cool" (trading off appearance for mechanical effectiveness).

We asked the students how they felt about the competitive elements of Botball – did the fact that it was a competition have any positive or negative impression. Five out of the six girls liked it.

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They all said they especially enjoyed seeing what everyone else at the tournament had to say or had built. One girl said the competition was her favorite part especially talking to the other players. “I liked that we got to compete against other schools and meet people that are interested in the same things we are”. One girl, who was the exception, had been on the mixed team and had dropped out after a few weeks. She had no additional comments other than saying competition was a negative for her. The rest of the girls indicated that they were not shy about the public display, agreeing that, in the words of one girl, “going out on the floor in front of all those people from everywhere was kind of cool – like being in a band!”

The boys seemed to like the competitiveness as well. One boy said “I didn’t think of it as a competition, it was just something fun we were doing. I liked the work.” Another remarked, “I like it because I’m not athletic and so this is like my competition. I like that everyone starts with the same materials and everyone has the same opportunities.” Another summed it up by stating that “Anything not competitive is pointless.” Still another remarked, “The competition of Botball is mild enough to still form friendships”.

At the end of each focus group we asked whether the students would want to be on a same sex team or a mixed team next time. Almost all the girls wanted to be on an all-girl team, with the exception of one who said that “Boys have good ideas – they’re more ‘out there’”. Not surprisingly, the girls from the mixed team were most vehement in their desire to be on an all-girl team next time.

The boys from the all-boy team initially said they wanted to be on an all-boy team again “because boys understand boys better”, but changed their minds after listening to the boys from the mixed team. After discussion, all the mixed team boys wanted to continue being on a mixed team. As one remarked, “Mixed, because you need to have a variety of ideas – there needs to be a balance.”

We asked if there were some things about robotics that may have an image as being either male or female. All the girls said there was nothing about robotics that had an image either way. The boys also said there was nothing male or female about robotics, one stating that there were “some misconceptions out there.” Another boy added, “There is a stereotype that girls do graphical design more, but these girls wanted to learn more so they could achieve more.”

Discussion

The authors acknowledge the very limited sample involved in this study and would like to see more work done with a larger sample. Also, the focus group model, although more convenient, is not as strong as individual interviews, since there may be things that subjects do not wish to discuss or admit in front of peers. The authors also acknowledge that this study only looked at perceptions, not what really happened. For example the girls in the mixed group who didn’t mention the questionnaire and who appeared to feel marginalized did mention missing a number of meetings due to basketball. Unfortunately, other girls from that team were not available to participate in this study, which would have provided at least somewhat of a better understanding of what actually happened.

Looking back at early assumptions that parents would have an influence on the child’s participation in Botball, we discovered that this did appear truer for girls than for boys. While

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boys viewed parents as transportation, girls were quick to volunteer that parents strongly encouraged them to participate. We have no way of knowing whether the boys' parents were just as encouraging and the boys either did not recognize this, did not feel like sharing this, or it just wasn't nearly as important as the transportation aspect and therefore not mentioned. Although girls' parents were encouraging, each girl mentioned an appealing facet of the program as her reason to participate – not one said she joined simply because her parents wanted her to.

Our assumption that girls would join Botball for the social aspects of it proved mostly wrong. Although one girl joined because her friend was involved, all the others named very particular reasons inherent in the program itself, such as the building, competition and computer programming. The girls said they enjoyed the social aspects, especially the social aspects of the competition, however that did not seem to be the primary reason they tried Botball.

One assumption that did hold true was that most girls at this age would prefer to be on all-girl teams again next time. The boys all ended up feeling they would prefer to be on mixed teams, however, contrary to our early assumption.

Welty and Puck [5] state that "young women tend to gravitate toward situations that value cooperation in contrast to competition". The authors assumed the girls might be turned off by the competitive nature of Botball. However this was not the case. The majority of girls and boys embraced the competition and several girls particularly stated that this was their favorite part. This is fascinating in light of expectations, and the authors feel more research is warranted in this area. In particular it would be interesting to look at whether girls who chose not to participate in Botball were in fact deterred because of the competitive aspect.

Although this was a small study, it does shed some light on team processes for middle school hands-on team activities. It would be helpful to look at a larger group with all participants from each team involved. A new investigation could examine the amount and type of adult involvement in the team dynamics, which was not addressed in this study. Future research might include individual interviews with entire teams, rather than samples, videoed documentation of actual team interaction, and further exploration of leadership, roles, and attitudes about competition. In addition, it would be valuable to compare middle school to high school students as well as suburban to rural students.

An interesting dilemma is posed by the girls wanting to be on all-girl teams and the boys wanting to be on a mixed team. Since a registration fee is involved, unless a school can afford more than one team, it is most likely that a school will simply end up with a mixed team, so it is crucial to learn more about how mixed teams can be optimized so that everyone can participate equitably in a role they enjoy. The authors would like to see more research leading to a better understanding of how girls and boys can work together harmoniously and productively at this age so that each individual feels valued and adds positively to the group experience.

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