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A Robotics Competition to Interest Minorities in Engineering

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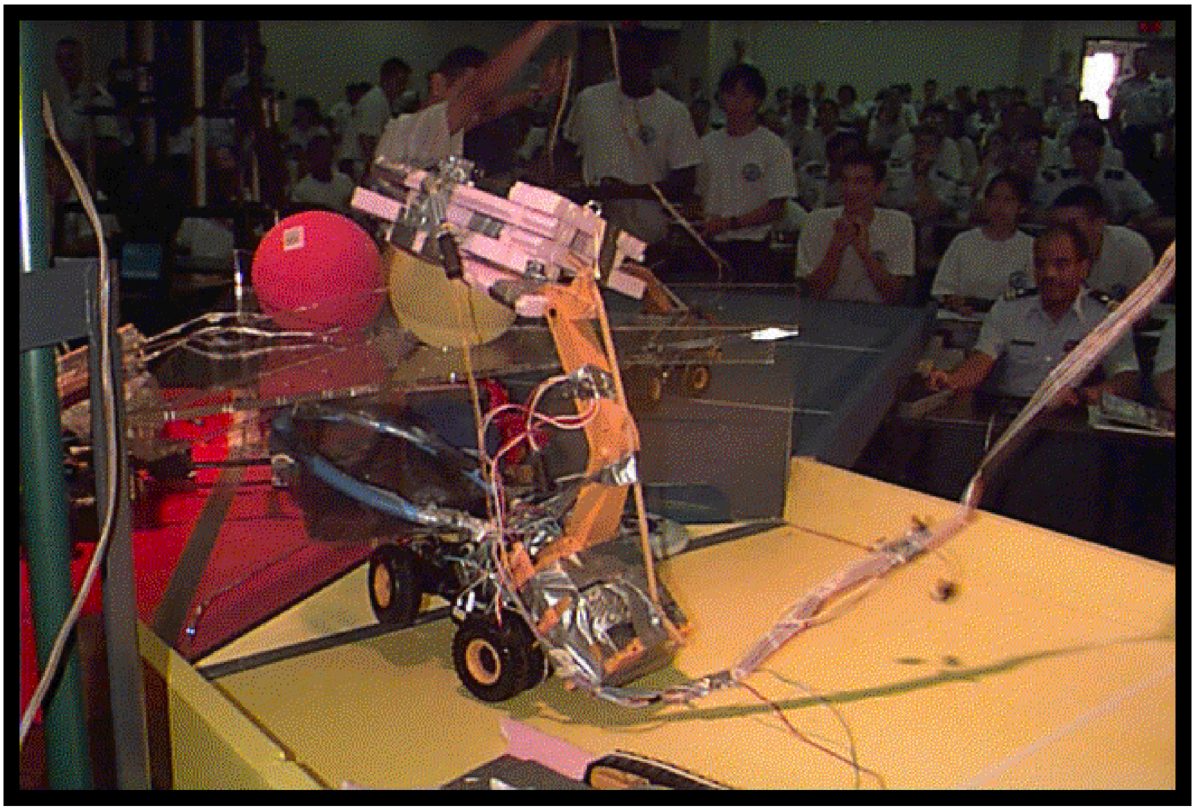


Abstract

Each summer, minority students from across the country receive scholarships to attend a week long introduction to engineering program at the U.S. Coast Guard Academy in New London, CT. During the week, these talented high school seniors participate in a variety of engineering design projects including boat building, bridge building, and robot design/construction. The robotics construction project, originally designed by Dr. Joseph Johnson (of Delphi Interior Lighting in Pontiac, Michigan) has been used as a tool to motivate students to consider engineering as a career option. This paper discusses the rationale behind using engineering games as a motivation tool for students and details the experience of using the game concept for this group of minority students. In brief, the high school students responded to the challenge of the project, experienced the design process first hand, and favored the competition as an activity to introduce the engineering profession.

Introduction

It is widely recognized that freshmen students select college majors based on their life experiences, and many fail to pursue engineering degrees because they lack role models from the engineering profession. Many studies have investigated the challenges of increasing the number of minorities enrolled in science and engineering education. A common conclusion is that for minority students to successful, they must be well prepared and enrolled in programs that are supportive and inclusive[1].

At the U.S. Coast Guard Academy (USCGA), the Minority Introduction to Engineering (MITE) program was established nearly two decades ago to introduce engineering to high school students that otherwise might not consider engineering as a career. The USCGA MITE program offers a full scholarship, including transportation, room and board, to high school minority students to attend a one week long series of engineering activities on the USCGA campus. In addition to the engineering projects, the unique aspects of a service academy, including physical training, precision marching, and sailing instruction, are also introduced to the students.

In 1997, over 170 minority high school seniors attended this program which is typically held in July. The program is jointly administered by the USCGA admissions office (as a recruitment program), the engineering department (as an engineering outreach program) and by the director of cadet training (as a leadership opportunity for current cadets). During the week, the group of 170 students is broken up into groups of 25 students, and each group is led by a cadre of four USCGA cadets who are entering their junior year at the Academy. In this role, the cadets serve as mentors for the students and the close relationship that develops between the high school students and the cadre is a great strength of the MITE program.

During each day of the week, the students are involved in one or two three-hour engineering activities, athletic competitions, physical training, and other team based exercises. Needless to say, it is a demanding schedule and busy week. The week concludes with an engineering competition day, followed immediately by an awards banquet. The program has had limited success as a recruitment tool: one third of last years participants were accepted to enter the USCGA, and only 6% of the participants ended up accepting appointments. Despite this low yield, it has been documented that the program has a significant impact on the students' view of the engineering profession, and. as such, this annual program continues to be offered at the USCGA.

In 1997, the Mechanical Engineering Section and the Electrical Engineering Section of the USCGA Department of Engineering offered a joint robotics project during the MITE program. Briefly, the students, working in teams of eight, had six hours to design, build, test, and redesign (as necessary) a small, remotely controlled vehicle that was capable of playing a game that can be best described as a mechanical version of kickball. At the end of the week, the 21 different teams tested their designs in an exciting, head to head competition game entitled Robo-Guard.

Robotics Games As a Tool

Games are fun and sports are exciting. By presenting engineering as a sport, engineering can be viewed as an inclusive, interesting, and exciting activity. While having roots as the MIT 2.70 Design Course, many institutions have recognized the value of hands-on design competitions to teach engineering design. Nationally, the original MIT 2.70 design contest has been developed as an engineering outreach project known as FIRST (For Inspiration and Recognition of Science and Technology) that teams industry engineers with high school students to build sophisticated robots capable of playing mechanical sports. University teams have been recruited to participate in this program as industry-university-high school teams or as university-high school teams. This program has been very successful, and is making a positive impact on how students view math and science education[2,3,4,5].

Using the game concept for motivating students to consider engineering careers has been captured by one of the partnerships involved in FIRST, the team of Pontiac-Central High School and Delphi Interior and Lighting from Pontiac, Michigan. To introduce other corporations and high schools to the rewards of participating in FIRST, this partnership team, led by Dr. Joseph Johnson, developed a robotics competition that can be completed, start to finish, in a single day. The Pontiac-Central High School and Delphi Interior and Lighting FIRST team graciously provide the USCGA with all the components, rules, and equipment needed to locally duplicate the engineering game they developed.

Briefly, each team of eight students had to design a robotic device, using only the material provided in a standard kit of parts given to each team. Their designs had to transport rubber kick-balls and frisbees around a 4’ by 8’ playing surface. To accomplish this task, the teams of students passed through each phase of the design process. Using the design process modeled by Eide, et. al.[6], the teams of students had to define the problem they had to solve, identify possible solutions, analyze the strengths and weaknesses of each proposed solution, and finally select one design to build, test, and use in the competition. Thus, under the veil of a fun, challenging, and exciting competition, the students experienced the engineering design process and created what had not existed before.

The Game

The local version of the adopted Pontiac-Central and Delphi Interior and Lighting game was called Robo-Guard. The teams of eight minority high school seniors were led by one or two USCGA juniors, and were presented with the following game scenario: “Welcome to a top notch engineering team that will design the next generation of U.S. Coast Guard resources to combat narcotics smuggling. This next generation is not like the present, for this generation will be cyber, automated, and robotic. With your help, you can transform the U.S. Coast Guard into the MITE Robo-Guard. You need to design, build, and compete your own robot to capture narcotics smugglers and position Coast Guard aircraft far offshore.”

The object of the competition was for each MITE team, working with cadets and the USCGA Engineering Department faculty and staff, to build their remotely controlled machine from the standard kit of parts. The playing field, three 4’ x 8’ areas, each 120 degrees from one another, represented the ocean. Standard kick balls, originally placed on a shelf at the center of the playing field, represented drug ships, and frisbees represented Coast Guard aircraft. The object of the game was to navigate the ocean (playing field), capture various drug ships (balls), and move Coast Guard aircraft (frisbees) in such a manner to score more points than the other machines. The layout of the field, as well as the relative size of the balls and their arrangement on the shelf, can be seen in some of the photos accompanying this paper.

Points were awarded for the final resting positions of the balls and frisbees, in general with more points given for moving the drug ships (balls) closer to the shore (the robot starting position) and for moving the frisbees as far offshore (near the balls’ starting position) as possible. The matches were played with three teams competing at once, and each match lasted 90 seconds. Referees were on hand to judge the matches and to determine the official scores. of each match.

Design, Build, and Test

The competition was unveiled to all 170 participants at the same time on the Sunday night when they first reported in for their week of engineering activities. At that time, the teams viewed the actual playing field, were introduced to the components included in their kits of parts, and were presented with a 10 page rule book that described the competition. Included in the kit of parts were the main components for the robots (a toy truck chassis, a toy bulldozer chassis, a toy back hoe arm, automotive actuators, a toy winch, and the necessary electrical connectors and controllers), and an assortment of other unusual items (such as a collection of nuts and bolts, elastic tubing, foam insulation, duct tape, and poster board). A motorcycle battery and a set of controllers that could be connected to the provided motors was also contained in each kit. Using only these components, the teams had to assemble a robot that was capable of moving the balls and frisbees.

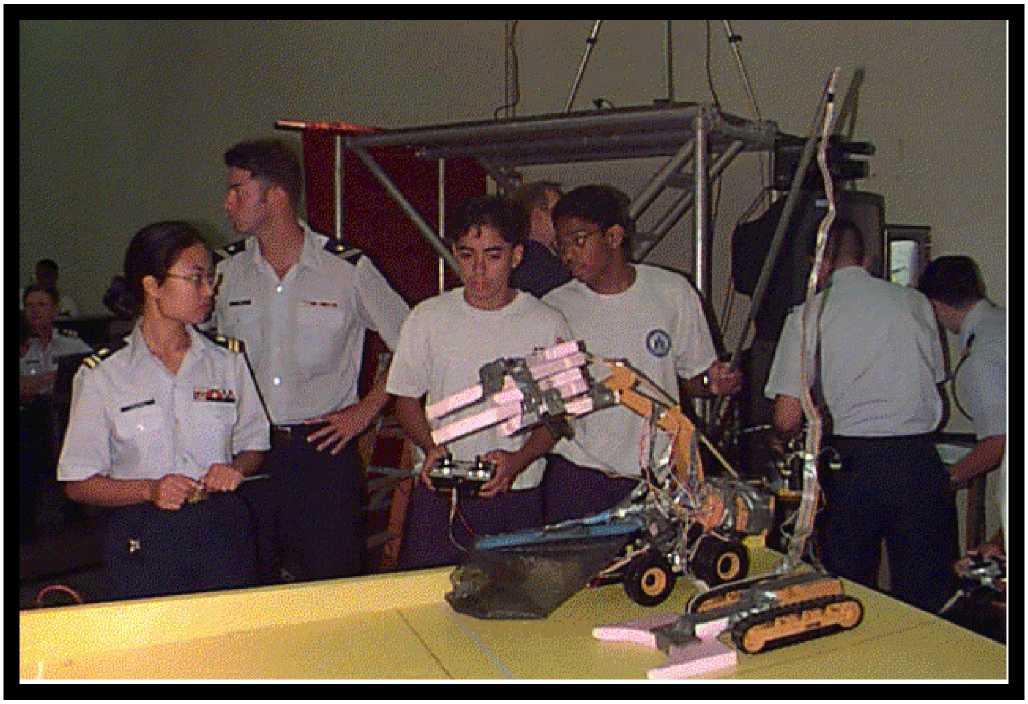
After first being introduced to the game on Sunday evening, the teams of students had six hours, broken down into two three hour work sessions, to design, build and test their robots. In each work session, attended by one group of 25 MITE students at a time, faculty and staff from the Mechanical Engineering and Electrical Engineering sections explained the function of some of the components in the kits and provided idea starters for making mechanisms from the components. Since each group of 25 minority high school students was broken down into teams of 8, each team designed its own robot. The four USCGA cadet leaders of each group of 25 students provided guidance to their teams but let the high school students design and construct the robots themselves.

The first hour of the first session was spent getting orientated to the game and the components in the kit. The next hour usually focused on the design of the robot, and the third hour was devoted to creating the design from the kit of components. During the second session, the first hour was spent completing their designs, and the remaining time spent on practicing with their robots on the actual playing field. With two drivers for each robot and a third student to tend to the power cables leading from controllers to the robot, the driving team had to learn teamwork as well. At the very beginning of the project, the teams were prompted to allow plenty of time for their drivers to practice, and the most successful teams followed that advice. During these six hours, the students completed the entire design process, and learned the importance of and necessity for teamwork. They completed the challenging task of building something that works from the strange collection of components in the kit.

The Competition

The competition was structured to resemble a sports competition. The playing field filled the stage of an auditorium, referees were in uniform on the playing field, a time clock/buzzer marked the competition duration, and an large-screen projector showed real time video footage of the competition. A pair of emcees kept the audience informed with a constant play by play of the on-field activity, and in between rounds, student designed paper beams were tested to their failure point. This environment was very conducive to cheering, and each team developed its own following of supporters.

The competition started with a series of seeding rounds, with three teams competing at once. The seeding rounds were important to enable the teams to practice their strategy and test their design in the face of competition. Each team competed four seeding matches. The results from each seeding match was scored using the following algorithm: three points for a first place finish, one point for second place, and zero points for third place. To keep track of the activity, one person ran a projected score board that posted each score following a match, and a second person entered the results into a spreadsheet that tracked the progress of each team.



The results of the seeding rounds were used to establish their competitors for the double elimination tournament which immediately followed the seeding rounds. In the first round of the double elimination tournament, a top team competed with a weak team and a midpoint team. In the double elimination tournament, with three teams playing simultaneously, only one team would win and the other two would lose the match. Once a team lost twice, it was finished playing in the competition.

The activity during the double elimination tournament was intense. Teams would scout other teams and then modify their own strategy to out maneuver an opponent. In between rounds, they would modify and repair their designs. Approximately 20 faculty and staff participated in the competition as announcers, timers, referees, video crew, traffic management, electricians, and as coordinators. Since all of the faculty and staff volunteers also participated in the robot construction periods of the project, there was familiarity between the faculty/staff and team members, and this familiarity often led to faculty/staff cheering for their favorite teams.

Observations

The engineering game format is a perfect platform to motivate all students, including minorities, to pursue careers in science and engineering. Games are fun, usually involve teams, and have a central focus. By giving the students a challenging task and the tools to complete the task, you are providing them with the opportunity to experience the engineering design cycle. They must design a device, build that device with the materials at hand, and then evaluate how well their design works. In terms of the current emphasis on outcomes and assessment, the desired outcome of the activity is easily prescribed, and the assessment is provided by the level to which the task is achieved.

When done correctly, an engineering based game can be of great value to students who are contemplating an engineering career. Results collected from the MITE students rated the robot competition as the favorite engineering activity of the week (only to be beaten out as the favorite overall activity by sail training). The interaction between the high school students and the cadet engineering mentors was noted on the post-week survey as a strong point of the program. As such, it is cautioned to avoid conducting such an engineering outreach program with only faculty and staff and without university student mentors.

At the present time, engineering games are expensive (in time and money) to put on. In the example cited in this paper, the game itself and all of its components were produced and assembled by a small group of engineers, technicians and high school faculty in Pontiac, MI. The complete set of components, batteries, and construction supplies for 21 robot kits, and the equipment needed to support the competition cost nearly $10,000, though some of the material can be recycled for other competitions. As for the time costs associated with the project, over 500 man-hours were needed at the USCGA to run the project from start to finish. Without the equipment loaned by the Pontiac-Central/Delphi FIRST team, the USCGA could not have offered this program.

Recently, the USCGA has leveraged its experience with engineering outreach, and teaming with the American Society of Mechanical Engineers Board on Women and Minorities, has designed a portable version of an engineering game similar to that described in this paper. This project is aimed at elementary school students and follows the same operating principle as the engineering game described here. Working with an educational version of a common construction toy (which includes building components, motors, and pneumatic systems), a table top engineering game has been designed, as well as an instructional module to accompany the game. Early results of this project are very promising, and indicate the engineering game concept has value for elementary school age students as well as high school age students.

Acknowledgments
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