Robotics Outreach Programs in a College of Engineering

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Abstract

The Wichita State University (WSU) College of Engineering leads three robotics programs that encourage young students to explore, experiment, and experience STEM (science, technology, engineering, and mathematics) concepts and skills by participation in team-based robotics activities and competitions. Kansas BEST Robotics, which focuses on high school students, began twelve years ago and has approximately 500 student participants each year. Since 2001, the Shocker MINDSTORMS Program has supported elementary and middle school teachers and students by providing training, mentoring, and an annual competition for students using the LEGO® MINDSTORMS NXT. For the last five years, the College of Engineering has also offered weeklong robotics summer camps where student learn to design and build robots. All three programs provide students with exposure to engineering, and opportunities to visit a university campus and interact with industry professionals, faculty, college students, and peers. This paper focuses on the Shocker MINDSTORMS program and provides a history and framework for a successful robotics outreach program that impacts hundreds of young students each year. This paper presents the motivation, content, and the outcomes of the program.

Motivation

The College of Engineering at Wichita State University (WSU) is committed to increasing the number of engineering graduates each year. There are two primary motivating factors for this emphasis. The primary factor is the need to increase the number of engineering graduates as evidenced by the recent report from the President's Council on Advisors on Science and Technology and the President's goal of one million STEM graduates in ten years[1]. Another report by the same group discusses a two-pronged strategy: 1) to prepare students in STEM subject matter and 2) to inspire students to study and pursue STEM careers[2]. This prepare and inspire strategy is central to achieving WSU College of Engineering's goal. The second factor is preparing the general population to be technically literate. "Are we providing students with the intellectual skills and background they will need to appreciate and continue learning about SME&T [Science, Mathematics, Engineering, and Technology] throughout their lives?"[3] Much effort is underway to encourage students to pursue careers in science, technology, engineering, and mathematics. There is a growing base of infusing these necessary skills and attitudes to pursue these avenues as careers. There is also much effort aimed at addressing the diminishing skills in math and many of the sciences. Technology is becoming more and more prevalent in todays classrooms. The skills and knowledge necessary to utilize this technology is being provided to students. However, there is little effort to build a broad base of understanding and appreciation of engineering principles that lie behind much of our technology today.

Much has been made of building business understanding, communication skills, and the ability to work in teams into engineering undergraduates. At a recent conference of industry leaders, one CEO stated that he wanted engineers with business knowledge ("that know how to calculate a rate of return"). Nevertheless, he also wants business graduates to have a basic grasp of engineering principles ("to understand and appreciate the engineering design

process"). van der Vink[3], stated that we need our politicians and business managers to consider engineering concepts in their decision making process, "…Our long-term future depends on citizens understanding and appreciating the role of science in our society."

One mechanism to prepare and inspire students is to use LEGO® bricks, which have long been a favorite of many children. LEGO® bricks provide a mechanism to understand and do for many concepts. Seymour Papert introduced the "MINDSTORMS" concept, which revolutionized much of the way computers were used in teaching[4]. Papert's book was the inspiration for those at LEGO® to develop what is now called, 'LEGO® MINDSTORMS.' LEGO® has been used in many classes to teach a wide variety of concepts from spatial relationships[5] to embedded computer control of mobile robotics platforms and data acquisition[6]. There is even a national competitive event using LEGO® MINDSTORMS called the FIRST® LEGO® League[7]. The popular press has numerous books on using LEGO® MINDSTORMS from basic ideas to construct that enable thoughtful and creative modification[8], to books that deal with using additional programming languages[9] and interfacing[10]. Turbak and Berg have developed a "Robotic Design Studio," to introduce Engineering to Liberal Arts Students[11]. Nickels and Giolma[12], use LEGO® MINDSTORMS to teach non-engineers about science and technology. Several use LEGO® MINDSTORMS to teach engineering to engineering freshmen and to integrate engineers of different disciplines[13-15]. Garcia and Patterson-McNeill[16] use LEGO® MINDSTORMS to teach software development. There is, therefore, a broad base of knowledge using LEGO® bricks to expose students to a wide variety of concepts.

Shocker MINDSTORMS

The Shocker MINDSTORMS program at WSU utilizes LEGO® MINDSTORMS to encourage young students to explore, experiment, and experience STEM (science, technology, engineering, and mathematics) learning in a hands-on constructionist environment[17]. Shocker MINDSTORMS began in 2001 as a collaboration among faculty and staff in the WSU Colleges of Education and Engineering, WSU engineering students, and local industry. The intent was to involve teachers and students in hands-on learning by providing a framework that included teacher training, teacher and student support, and an annual culminating event where students would showcase what they learned by participating in a series of competitions, and interact with professionals and role model in STEM fields. This basic thrust continues today, however, over the last 12 years, Shocker MINDSTORMS has grown to include workshops for parents and other potential "coaches", robotics summer camps, and significant involvement from industry professionals and higher education faculty and staff.

Workshops

The College of Engineering hosts workshops for teachers, mentors, and parents who are interested in adding robotics to their teaching curriculum or coaching a robotics team to compete in the Shocker MINDSTORMS Challenge.

A Beginner Workshop introduces newcomers to MINDSTORMS Robotics and provides tips on forming and preparing a team to participate in the Shocker MINDSTORMS Challenge. Participants learn about different robotics kits and software, build a basic robot, and are introduced to sensors and programming.

A more advanced Building and Programming Workshop focuses on how to design, build, and program MINDSTORMS robots. This workshop gives participants a chance to build and program robots to compete on actual Shocker MINDSTORMS Challenge courses that were part of previous competition events.

Workshops are free and are led by an experienced teacher and successful robotics coach. These workshops are part of an overall effort to encourage and support teachers and others interested in using robotics as a tool to engage students, teach STEM skills, and encourage teamwork.

Summer Camps

A key component of the College of Engineering's K-12 outreach program is its summer camps program. At least six week-long camps are offered each year for students in grades 4-12. Camps are filled with hands-on activities that promote learning, collaboration, and fun while introducing students to the science, engineering, and technology that is practiced by real engineers. In addition to robotics camps, offering include camps focused on bioengineering, building with Arduinos®, or designing and programming computer games. The majority of the camps include at least one MINDSTORMS activity.

The Engineering with LEGO® Robotics Camp is for students who want to learn how to build, program, and run LEGO® robots through a series of competitions. Once they have mastered the fundamentals, campers build robots to complete specific challenges. They learn about basic programming, problem solving, and teamwork. The camp is mostly hands-on with campers building LEGO® robots and then expanding their robots to include sensors that respond to different environments. There are sections for both beginner and advanced robotics students. The camps culminate in a competition with actual courses from the Shocker MINDSTORMS Challenge. Each camper receives a personalized LEGO® name badge and brick and an award brick for each activity mastered.

MINDSTORMS Challenge

The Shocker MINDSTORMS Challenge began twelve years ago with a core group of dedicated educators and engineering students possessing the desire to provide students with an opportunity to learn about robotics in an exciting venue and fun environment. The first competition in 2001 included about 120 students. Although the event was open to anyone who wanted to attend, the venue was small and not conducive to spectators. There was very little promotion of the event that was staffed by WSU faculty, staff, and students. Attendees at the first Challenge included mostly teachers, students, and a few parents and faculty. The courses were placed in a line of classrooms and student teams worked on tables or the floor in the connecting hall. A lot has changed since the inaugural offering.

Today, the annual Shocker MINDSTORMS Challenge continues as a collaboration among the WSU Colleges of Engineering and Education at WSU and industry professionals. The Challenge provides young students with the opportunity for practical application and exhibition of math, science, programming, and engineering skills, as well as promoting teamwork, dedication, and sportsmanship. Teams of fourth through eighth grade students from across the state of Kansas have the opportunity to complete courses designed by WSU engineering students and demonstrate what they have learned to professional engineers and educators in oral presentations, team displays, and notebooks. Sportsmanship and spirit are judged throughout the day to promote collaboration and teamwork. In 2012, 35 teams, over 350 students, participated in the MINDSTORMS Challenge. The Challenge is a community event and all are invited and encouraged to attend. Spectators, parents, grandparents, friends, classmates, and interested engineers and educators are invited and welcome. The Challenge provides an excellent exhibition of young people's efforts, dedication, knowledge, and skills. This is the culminating event of many months of planning and learning by students, coaches, teachers, and volunteers at all levels.

Preparation

The Shocker MINDSTORMS Challenge Steering Committee plans and coordinates the annual event. The Committee includes WSU faculty and staff from the College of Education and the College of Engineering, WSU engineering students, and volunteers from the community and local industry. This committee meets almost every week of the year to prepare for the event.

The Challenge has grown to include teams from across the central portion of the state of Kansas. With three levels of competition on two different levels of courses, the competition takes up the entire Heskett Center gymnasium on the WSU campus. This area is the equivalent of three full sized basketball courts, a running track, a long jump, high jump, and exercise area. Due to the impact on the community as well as the educational opportunities, the Shocker MINDSTORMS Challenge has received the support of the entire WSU community and the use of these campus facilities.

The Steering Committee coordinates with campus services for facilities, tables and chairs, security (provided by the WSU Police Department) and all other logistics for an event that hosts more than 700 participants, volunteers, and spectators. Plans begin a full year in advance in order to secure the appropriate facilities, staff, and support. A theme is selected in order to begin promotion of the event, planning the professional courses, and to build excitement for teams.

Participation

There is no charge for teams to participate in the Shocker MINDSTORMS Challenge. Participation in the event has grown dramatically over the years. Thirty-seven teams (over 350 students) participated in 2012 and had the opportunity to interact with professional engineers and WSU engineering students as they prepared for and completed courses. Team registration opens eight weeks before Challenge Day and closes three weeks before Challenge Day to allow final preparations to be made for the number of teams and students participating

Teams

All team members must be currently enrolled in grades 4^{th} – 8^{th}, or be 9 – 14 years of age. One unique coach (18 or over) must sponsor and lead each team. Multiple coaches are encouraged to work with a team, but one unique coach must represent each team. The coach does not have to be a teacher. He/she can be any adult who mentors, provides support, and guides the team as they prepare for the Shocker MINDSTORMS Challenge. Teams may be formed students at a particular school, homeschools, Girl/Boy Scout troops, after-school groups, neighborhood friends, etc.

Divisions

When a team is registered, the coach is required to indicate at what division level the team will compete.

Beginner Level – Beginner teams compete on three Apprentice courses. In order to be considered for Beginner Level Awards, a team must score points on all three Apprentice courses, complete the Team Display and Notebook, and be judged in Spirit and Sportsmanship. Beginner teams must have 5-10 registered team members.

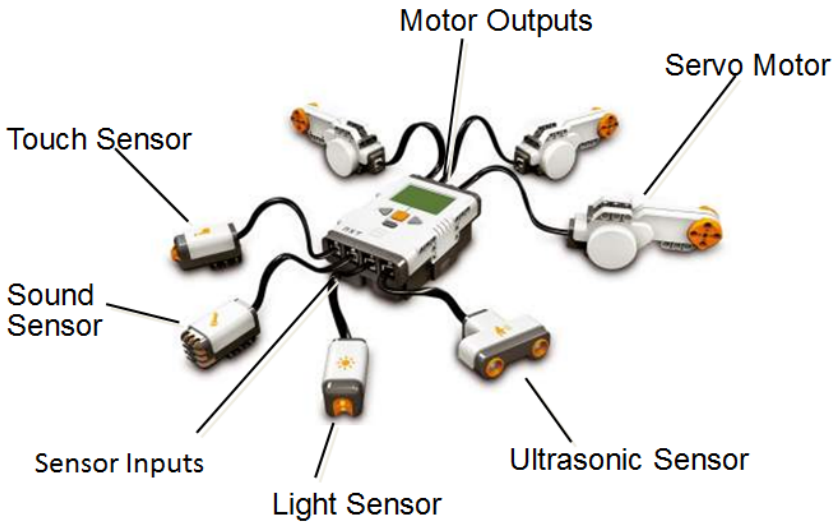
Intermediate Level – Intermediate teams compete on the Professional courses. In order to be considered for Intermediate Level Awards, a team must score points on three Professional courses, complete the Team Display and Notebook, be judged in Spirit and Sportsmanship, and make a Presentation to a panel of judges. (Each team may run all Professional courses, but only the best three scores will count towards their total score.) Intermediate teams must have 8-15 students registered team members.

Expert Level – Expert teams compete on the Professional courses. In order to be considered for the Expert Level Awards, a team must score points on five Professional courses, complete the Team Display and Notebook, be judged in Spirit and Sportsmanship, and provide a Presentation to a panel of judges. (Each team may run all Professional courses, but only the best five scores will count towards the total score.) Expert teams must have 8-15 registered team members.

Equipment

Participants use a LEGO® NXT or RCX brain with an embedded microprocessor and 100% LEGO® components to build each robot. The programmable brain has various outputs for attachments such as motors and lights, and input options to read input from light, touch, and ultrasonic sensors. Each team will build a uniquely designed robot using LEGO® parts contained in their MINDSTORMS kit or any official LEGO® piece. Each team may use

multiple RCX/NXTs on Challenge Day. Only one RCX/NXT can be included or contained in any robot that is used for official runs. Robots may contain an unlimited number of official LEGO® parts including motors, sensors, tires, bricks, etc. (Packing used in LEGO® kits or any other items that are not "official LEGO®" parts cannot be used.)



While there are no limits to the software language that can be used to program a robot, its operation must be strictly autonomous. No form of remote control can be used to guide the robot to complete the courses, including the LEGO® remote control that can be purchased separately. Each robot must be programmed to perform within its own environment using sensors available for the LEGO® MINDSTORMS equipment and can have NO human contact of any kind during the course run unless it is specified in the guidelines. Any use of a Bluetooth device to control any NXT will be cause for disqualification.

Challenge Structure

Each year, the Shocker MINDSTORMS Challenge includes three Apprentice courses and five or six Professional courses.

Apprentice courses are basic challenges designed for entry-level teams that are just getting started. The Apprentice courses are the same each year: Line Follower, Table Runner, and Ramp-It.

Line Follower – The purpose of the Line Follower is for the robot to utilize the light or color sensor capability of the NXT/RCX unit. Scoring is based on how far the robot makes it through the course by following a line. Additional points are achieved for passing each successive checkpoint along the designed path. Bonus points are given based on time for completing the entire course.

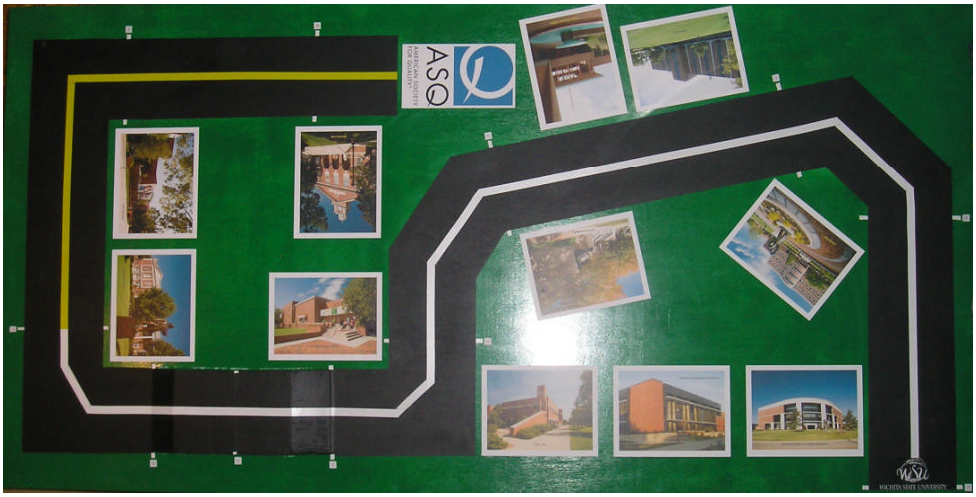
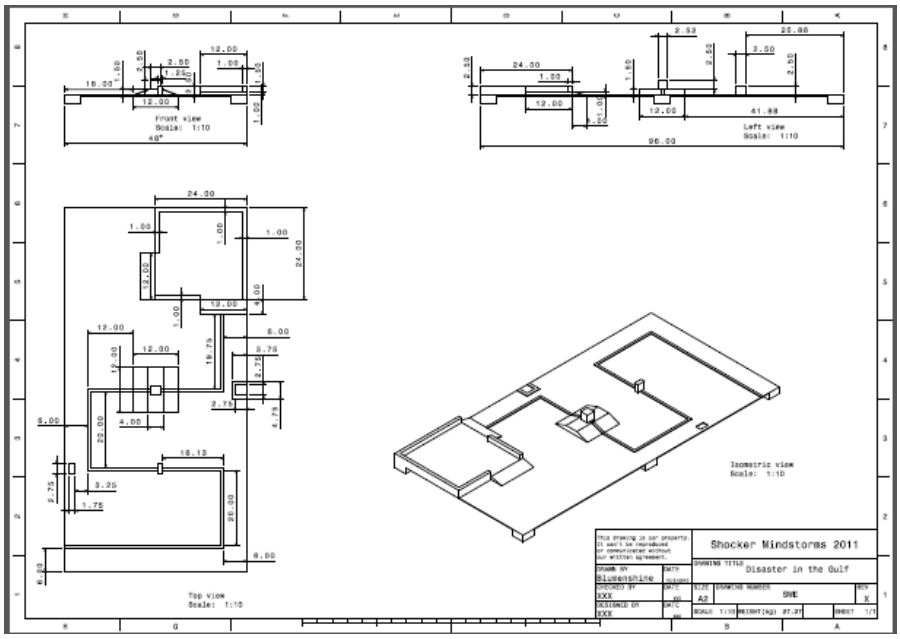


Table Runner – The purpose of Table Runner is to utilize the touch sensor capability of the RCX/NXT unit to recognize when it reaches/touches the edge of the course. The robot must stay in motion, touch the edge of the table multiples times without falling off, change direction after touching the table edge, and touch all four table edges two separate times (cannot earn points by touching the same side twice in a row). Bonus points are awarded for completing all edge touches within specified time limits.

RampIt – This RampIt course requires the robot to use traction, gearing, sensors, and programming options to get to the top of a ramp while avoiding pegs along the sides and center of the ramp. If the robot successfully climbs the ramp, it must touch a "wall" at the top and change directions to begin its descent. Additional points are awarded for returning to the bottom without falling or sliding uncontrollably. Bonus points are awarded for weaving a specific path both up and down around the center pegs.

Professional courses are different each year. These courses are designed and built by College of Engineering student groups. Beginning in 2011, engineering students have the option to design and build a course as part of a service learning class for the College of Engineering's Engineer of 2020 Program. The designing, building, and running a LEGO® Robotics course requires the student to learn about LEGO® Robotics and complete two of the "apprentice courses." Student mentors use the engineering design process as they design a course to a specified theme (for 2011, it was a sustainability theme entitled, "Saving the World: One

Brick at a Time"). The design and build of all Professional courses undergo a rigorous review by professional Engineers and Quality practitioners to ensure accuracy in measurements, drawings, and presentation. Approval is required at each step in the process.



Details about the Professional courses are released on the MINDSTORMS website eight weeks before Challenge Day. Teams are provided with the rules for each course, detailed dimensioned drawings, bill of materials, detailed build instructions, and photos of the course. Each course is accompanied by a story line consistent with the theme of that year's event. Teams that have been practicing the fundamentals of building and programming can then prepare their robots to compete on the actual courses. The detail provided also allows teams, if they choose, to replicate the course for their own practice and use.

On Trial Day, three weeks before Challenge Day, the student-built courses are displayed for a day of practice. Teams have the opportunity to actually see and practice on the courses they will run on Challenge Day. They can test their robots and make any needed modifications to their design, build, and program. They also can ask detailed questions about the courses and visit with the course designers. The courses are placed in the exact location they will be placed on Challenge Day, so teams can make adjustments for light, surface, etc.

On Challenge Day, in addition to competing on the courses, teams are required to compete for the Team Display and Notebook; Spirit and Sportsmanship; and Presentation (Intermediate and Expert teams only).

Team Display and Notebook – Each team is provided a table to place a display and a notebook of drawings, pictures, charts, graphs, etc. that document the process their team took to prepare for the Challenge. Displays and notebooks are judged on creativity, variety, organization, accuracy, and knowledge. This is an opportunity for teams to display their "personality" as they design displays and notebooks that are set up for review by all on Challenge Day.

Spirit and Sportsmanship – The Shocker MINDSTORMS Challenge encourages inter-team and intra-team cooperation and support and student participation from each team member. This competition is equally as important as any other, including the competition on the courses. Judges roam freely during the day and observe and score the teams on teamwork/collaboration, sportsmanship, respect, and integrity. Each student should contribute to the team individually and as part of the team. Although coach and parent support is encouraged and necessary, it is important that students do their own work.

Presentations – The Presentation allows teams to demonstrate to a panel of judges what they have learned from their experiences preparing for the Shocker MINDSTORMS Challenge. Teams are asked to define a problem they encountered and describe their strategy for approaching and solving the problem. They are scored on their knowledge, the organization of their presentation, their visuals, and their delivery. Presentations should be technical in nature, and an opportunity for each team to demonstrate the process they went through in preparation for the courses.

Scoring

Each part/competition of the Shocker MINDSTORMS Challenge is worth 1000 points, including the Team Display and Notebook, Spirit and Sportsmanship, and Presentation that have defined and published rubrics. These rubrics are the basis for scoring by the judges for each activity. Each of the courses has a scoring table with specific elements of the course worth a specified number of points.

On Challenge Day, teams may practice on the courses at the judges' discretion. Priority is given to teams that are ready to run the course for points (official runs). The time period and number of sequential practice runs is up to the judges' discretion based on the time available and the number of teams waiting in line for practice runs. Points on the courses are only given when a team states to the judges that they are making an official run for points prior to the beginning of their attempt. Teams can make TWO official runs and would be awarded the points for the highest of the two runs.

Volunteers

Many student organizations, faculty members, professional educators, engineers, quality leaders, and industry professionals volunteer their time to make this event a success. Spirit AeroSystems and WSU's College of Engineering provide funding for the program. They also provide a significant portion of the volunteers needed to put on the event. Additional volunteers come from local industry and the parent chapters of the student organizations that build the Professional courses. Volunteer opportunities include judging on the courses; judging for Team Display and Notebook, Spirit and Sportsmanship, or Presentations; help with set-up and tear-down; t-shirt sales; and many other needs throughout the day.

Industry Involvement

Local industries not only provide volunteers for the event, but also provide the opportunity to expand the promotion of the event to a larger audience. Professional organizations are involved in the competition, during the event and in preparation for the event. ASQ (American Society for Quality) is responsible for reviewing and approving each course design to engineering standards as well as measuring the final courses to assure that pre-defined tolerances are maintained between the design and the build.

In addition to reviewing the designs and measuring the courses, ASQ Wichita Section 1307 has provided judges for the event, built courses, and provided financial support for the Shocker MINDSTORMS Challenge.

Reward and Recognition

Coaches and team members each receive a 1x8 LEGO® 4-brick name badge that includes his/her name, team name, Wichita State University, and the MINDSTORMS year (for example, MINDSTORMS Challenge 2012). T-shirts reflecting the theme and logo of the event are also offered for sale.

The day's events culminate in an Awards Ceremony to recognize students and coaches and celebrate their successes. A large teaching hall is filled with coaches, teams, parents and other family members, volunteers and more for the Awards Ceremony. The event begins with a slide show of photos and video that was taken throughout the day. These are always met with cheers from the audience. Each of the division winners receives a trophy made of LEGO® bricks. All first place division winners receive a unique trophy, also made of LEGO® bricks and designed to reflect the theme of the annual competition. Individual bricks are awarded to each member of a team selected for the Team Display and Notebook, Spirit and Sportsmanship, Presentation, and the top four teams in each division; Beginner, Intermediate, and Expert.

The last several years, FlightSafety has selected teams for a special field trip to their facility in Wichita and time in a flight simulator. This allows the students the opportunity to see the culmination of many engineering functions; electrical, computer, mechanical, industrial, ergonomic, and aerospace, all working together in a real world environment with a defined purpose. They also get to have some well-deserved fun; sitting in a cockpit in control of a simulator.

Summary

The College of Engineering at WSU has focused on preparing and inspiring students to engineering careers. Competitions are an important method to generate and maintain interest in mathematics and science, which prepare students to begin the pursuit of an engineering degree. This paper described a middle school LEGO® robotics competition, which encourages students in STEM and involves middle school students and teachers, undergraduate engineering students, engineering faculty, and practicing engineers.

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