ASSESSMENT AND OUTCOMES OF ROBOT COMPETITIONS AT PENN STATE ABINGTON

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Abstract

Penn State Abington campus hosts several mobile robot design competitions each academic year to support project-based design activities in freshman and sophomore level engineering courses, a junior-level robotics course in information sciences and technology (IST), and also to provide outreach to K-12 institutions in the Philadelphia, PA area. A student survey for the Abington undergraduate engineering majors was developed and implemented to investigate the outcomes of two robot competitions offered at Penn State Abington during the 2004-2008 time period. Students were asked questions concerning technical challenges, the benefits of working in a team, key lessons learned, educational quality, and suggestions for improvements in the robot competition activity. Overall, the responses on the quality of the robot competition experience from the students' perspective were very positive. Students identified key benefits of working in a team and acquired valuable lessons in the design process.

Introduction

Penn State Abington campus (Abington, PA) hosts several mobile robot design competitions each academic year (since 1995) to support project-based design activities in freshman and sophomore level engineering courses, and also to provide outreach to K-12 institutions in the Philadelphia, PA area. The robot design activities are highly interdisciplinary and include topics such as engineering design, mechanical engineering, electrical engineering, computer science, sensors, systems engineering, project management, teamwork, and creative problem solving. Undergraduate engineering courses which have incorporated the robot design and competition activity include a freshman engineering and graphics design course (EDG 100), an introductory digital design course (CSE 271/CSE 275), and a special topics robotics course for lower-division engineering students (ENGR 297). More recently, a junior-level information sciences and technology (IST) course in emerging technologies (IST 402) was developed to incorporate hands-on robotics and involvement in the campus robot competitions. Each course has specific educational objectives which are satisfied by the competition event. The EDG 100 course generally focuses on the engineering design and project management aspects of the contest design, where the digital design course focuses more on software design, microcontrollers, and sensor interfacing. The IST course focuses more on systems engineering, robotics applications, software, and project management.

The Robo-Hoops robot contest challenges student teams to design and implement autonomous, computer-controlled mobile robots which are capable of picking up and shooting or dunking small (4-inch diameter) foam balls into a basketball net, which is positioned 12 inches above the playing surface. The competition is divided into 2 phases. In the first phase, each robot is operated in solo (unopposed) matches, with the goal to score as many points as possible within a 60 second time limit. In the second phase of the contest, the robots compete head-to-head in a double elimination contest. Robots, at the start of the contest, are restricted in size, 12 inches by 12 inches by 18 inches (high), and must be fully autonomous for the high school and senior divisions. The contest is open to students in K-8, high school, and college, and robots compete within the same division level. The contest allows participants to choose any hardware or software or combination of technologies for the robot design. The Robo-

Hoops contest was first offered in 1995. Information about the specifics of the rules can be found on the Robo-Hoops robot website [1]. Typically, 30 to 40 robot teams across all divisions (K – college) participate. Of those, 4 to 6 teams are generally composed of Penn State Abington lower-division undergraduate students. Figure 1 below is a picture of the Robo-Hoops playing field.

The firefighting robot design contest requires computer-controlled mobile robots to navigate autonomously though a maze (8 foot by 8 foot arena with 13-inch high walls) consisting of four rooms connected by a hallway. A lit candle is randomly placed in one of the four rooms, and the goal is to have the robot locate and extinguish the candle in the minimum time. As with the Robo-Hoops contest, this contest is open to the public and robots compete within the divisions of K-8, high school, and senior (college and beyond). This contest event is a regional contest for the international Trinity College (Hartford, CT) Firefighting Robot Contest [2, 3, 4]. Also similarly to the Robo-Hoops contest, there are approximately a total of 40 or more robots entered annually in the Abington regional Firefighting contest, and Penn State Abington generally fields 5 to 10 robots in the senior division. This regional firefighting robot contest was first offered at Penn State Abington in spring of 1995. Figure 2 shows a picture of a robot competing in the firefighting robot contest.

Both robot competitions allow for the use of any choice of hardware and software solutions, and this enables educators to choose the appropriate technology to achieve desired educational outcomes. For example, the freshman engineering design course have typically use Lego Mindstorms™ robot kits and ROBOLAB™ programming (visual, icon-based programming language based on LabView), while the digital design sophomores and special topics robotics course students use more sophisticated hardware (examples: Handyboard, Basic Stamp, Palm PDA, Pontech SV203 board, VEX) and C-based programming languages.

Survey Questions

A voluntary student survey for the undergraduate students was developed and implemented to investigate the outcomes of eight robot competition events (Robo-Hoops contests offered in fall of 2004, 2005, 2006, 2007, and Firefighting contests offered in spring of 2005, 2006, 2007, 2008), all at Penn State Abington campus. All of these students were taking courses in which the robot contest was integrated into the course objectives and schedule. In all cases, the contest event occurred in the last 2 or 3 weeks of a 15-week semester, and students generally spent between 4 to 8 weeks preparing for the contests. Pictures of undergraduate students working on robot designs in various course environments are shown in Figure 3.

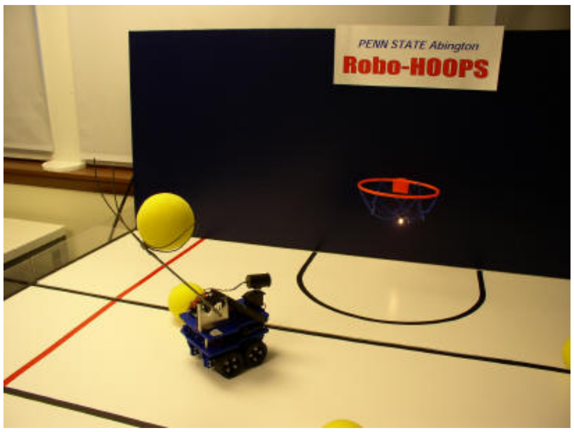

Figure 1: Penn State Robo-Hoops Contest.

Figure 2: Penn State Firefighting Contest.

Figure 3: Student teams in lab.

An assessment tool, in the form of an on-line survey, was developed in which students were asked questions concerning technical challenges, working in a team, time management, key lessons learned, and suggestions for improvements in the robot competition activity. Student survey data from fall 2004 to spring 2006 was also presented in [5] and is reproduced here for continuity. The data presented in the sections below extends the results and analysis to include survey data from an additional 4 robot contests from fall 2006 through spring 2008.

Below is the key set of survey questions for the Firefighting contest. The questions for the Robo-Hoops were similar with the exception of one question (#10) which dealt with a specific feature of the firefighting contest.

1. What is your intended major?
2. Please indicate your gender: male/female
3. Including the spring 2008 semester, how many semesters of college have you completed?
4. What was the name of your robot?
5. Have you ever entered a previous Firefighting robot contest before spring of 2008? Yes No
6. Did you personally attend the Abington campus firefighting robot contest on Saturday, April 3, 2008? Yes No
7. What robot controller did your robot use in spring 2008 Firefighting robot contest?
   a. Handyboard
   b. LegoMindstorms RCX
   c. LegoMindstorms NXT
   d. Palm PDA
   e. Basic Stamp
   f. VEX
   g. Other? Please specify:
   h. Not sure
8. What is the name of the software programming language that was used for this robot?
   a. ROBOLAB
   b. Not Quite C (NQC)
   c. Interactive C (IC)
   d. PocketC (Palm)
   e. EasyC (Vex)
   f. Other? Please specify:
   g. Not sure
9. What were the primary building or construction materials used in your robot?
10. What mechanism did your robot utilize to extinguish the candle flame?
    a. Electric motor powered fan
    b. Inflated balloon
    c. Other: please specify:
11. How many members were on your team?
12. Was there a single team leader? Yes No
13. Based on your experience, what do you personally consider to be the optimal size (number of students) for a team for this task?

14. How many hours (approximately) per week did you spend on the robot?
15. For how many weeks (approximately) did you work on this robot?
16. Do you think it is an advantage to work on a team? Yes No Briefly explain.
17. What was your personal primary role or roles in the team?
18. In your opinion, what was one of the most difficult technical problems you faced designing this robot?
19. In your opinion, what was the most important idea, concept, or lesson that you learned from this entire robot design and competition experience?
20. Would you recommend participation in the Abington firefighting robot contest to other students in your major? Yes No Not Sure
21. Do you think hands-on experience with robotics could encourage students to pursue majors and careers in a technical field? Yes No Not Sure
22. How would you rate the overall educational value of the Abington Firefighting robot contest?
    1= poor; 2= below average; 3=average; 4=good; 5=excellent
23. Overall, how could the Penn State Abington firefighting robot contest be improved?

The student survey was anonymous, web-based, and was completed on a voluntary basis. A survey was developed for each contest, and the students were invited to participate in the survey shortly after the completion of the robot contest event. Of the overall 200 students invited to participate over the 8 contest events, 76 (38%) students responded to the survey. The overall student participation in the voluntary surveys is provided in Table 1. Gender information was gathered only in the surveys for the last four contests (Robo-Hoops 2006/2007 and Firefighting 2007/2008). A total of 2 female students participated in the surveys out of a total of 6 female students who participated in the four contests.

Table 1: Survey Response Statistics,

Contest	Course Participation	# Students invited	Student Participation
Firefighting 2005	ENGR 297, EDG 100	24	8 (33%)
Firefighting 2006	ENGR 297, EDG 100	24	11 (46%)
Firefighting 2007	ENGR 297	16	6 (38%)
Firefighting 2008	ENGR 297, IST 402	16	7 (44%)
Robo-Hoops 2004	CSE 275, EDG 100	26	11 (42%)
Robo-Hoops 2005	CSE 275, EDG 100	42	15 (33%)
Robo-Hoops 2006	CSE 275, IST 402, EDG 100	41	13 (32%)
Robo-Hoops 2007	CSE 275	11	5 (45%)
TOTAL		**200**	**76 (38%)**

Below is the distribution of intended majors (in order of decreasing contribution) from the total population of students responding to the robot contest surveys. (Please note that not every student who participated in the survey answered this question regarding intended major.)

Intended Major	Number of Students Responding	%
EE	29	39
IST	9	12
CompSci	8	10.7
ChemE	6	8.0
ME	6	8.0
Aero	3	4.0
Cmpen	3	4.0
ArchE	2	2.7
Engr Sci	2	2.7
BioE	2	2.7
Civil	1	1.3
Structural/Constr. Engr Tech	1	1.3
Engr	1	1.3
Education	1	1.3
Undecided	1	1.3
TOTAL	**75**	**100%**

Table 2: Distribution of Major.

Key Student Survey Results

In this section, a set of key results from the survey will be presented. The focus here is to determine some of the overall benefits and gains from student participation in the robot competition and the design phase leading up to the competitions. The results presented here will focus on the team skills, important lessons learned, overall educational quality, and future areas of improvement.

As can be seen from the Table 3, the optimal team size on average varied between 2 and 4 and was somewhat correlated to the actual size of the teams participating. Importantly, 97% (74 out of 76) of the student responses indicated that there was an advantage to working in a team for these robot design and competition events. The majority of respondents reported that there was no single team leader for the robot design teams.

Contest	Actual Team Size (Range)	Actual Team Size (Avg)	Optimal Team Size (Avg)	Single Team Leader? Yes	No	Advantage to work in a Team?
Robo-Hoops 2004 (n=11)	1 - 4	2.8	2.6	36%	64%	Yes (91%)
Robo-Hoops 2005 (n=15)	3 - 6	3.9	3.4	20%	80%	Yes (100%)
Robo-Hoops 2006 (n=13)	2 - 5	3.5	3.3	13%	87%	Yes (100%)
Robo-Hoops 2007 (n= 5)	1 - 4	2.8	4.0	40%	60%	Yes (80%)
Firefighting 2005 (n=8)	2 - 3	2.8	2.6	13%	87%	Yes (100%)
Firefighting 2006 (n=11)	2 - 5	3.9	3.9	9%	91%	Yes (100%)
Firefighting 2007 (n=6)	2 - 3	1.8	3.3	67%	33%	Yes (83%)
Firefighting 2008 (n=7)	2 - 3	2.7	2.6	29%	71%	Yes (100%)
All contests						**Yes (97%)**

Table 3: Student Team Responses.

Below are listed a sample of student responses on the advantages and some disadvantages of working in a team. The observations were generally consistent across all of the contests surveyed.

1. *Yes, working in teams allows for more ideas to be considered before the actual construction begins. Teams also make refining ideas and executing objectives more attainable as well as less stressful.*
2. *No. It is difficult to find people on the same technical level.*
3. *Yes, more minds = more thoughts = better design, concept and implementation.*
4. *Yes because sometimes your partners think of ideas that you would never think of, or they pick up on your mistakes.)*
5. *It is an advantage because you have two or three minds to pull new ideas from or to improve existing ideas. Plus, not every group member is available at all times, but generally speaking at least one member has time to work on the robot.*
6. *No, because sometimes you depend on others and they don't do what they claim they will.*
7. *Yes, different people bring different ideas and have different skills they can offer.*
8. *Yes and no. For this particular task, it's necessary to have a team to complete it on time. However, when you're on a team, you tend to rely on people to do their job and they tend to not do it.*
9. *Yes because everyone can bring different areas of knowledge and ideas. Your weaknesses may be someone else's strengths.*
10. *Yes, useful to bounce ideas of each other, more time efficient, delegate tasks/ responsibilities, more enjoyable, makes life easier*

Each student was asked to provide the most important concept or lesson learned from the entire robot design and competition experience. This concept or lesson is likely what the student will take away with himself/herself after the event and the course. The concept or lesson could be of any nature – technical, project management, working in a team, the design process, etc. The student responses included comments concerning the importance of testing, simplicity in design, listening to your team members, time management, and others. Overall, as with the teamwork comments above, the major lessons learned were generally consistent across all robot contest events. A collection of representative student responses is presented in the list below:

1. *Keep all designs simple and stay flexible with the predetermined building specifications.*
2. *The difference between theory and reality. "It should work" often doesn't mean it will. There were a multitude of challenges that we faced that were not directly tied to our original goal.*
3. *Listen to your teams' ideas, they might just have a good one that needs work.*
4. *How to develop and test many different ideas and pick the one that works the best*
5. *Time management and organization, expecting the unexpected, adapting to changes.*
6. *Basically I feel the whole process of programming and engineering the robot was the most important thing I gained from the experience.*
7. *I learned that testing and validation is the most important part of the building process and that a fully tested, mediocre design is usually more successful than an untested, extraordinary design.*
8. *Keep it simple*.
9. *Consistency is more crucial to achieving victory than advanced technology or complex programs.*
10. *Teamwork and patience.*

These comments (especially in the areas of simplicity of design, teamwork, and time management) represent critically important lessons to be acquired at an early stage of the educational process and will prove invaluable in later stages of the academic program and for coop, internship, research, and full-time employment.

Students were also asked to rate the overall educational value of the robot design and competition experience and whether they would recommend the experience to other students in their major. The results are in the table (Table 4) below.

Contest	N	Recommend to other students? Yes	No	Not Sure	N	Overall Educ. Value 5=exc; 4=good; 3=avg 2= below avg; 1=poor
Robo-Hoops 2004	11	100%	0%	0%	11	4.5
Robo-Hoops 2005	15	100%	0%	0%	12	4.3
Robo-Hoops 2006	13	69%	0%	31%(4)	13	3.9
Robo-Hoops 2007	5	100%	0%	0%	5	4.6
Firefighting 2005	8	88%	0%	12%(1)	8	4.1
Firefighting 2006	11	100%	0%	0%	11	4.2
Firefighting 2007	6	100%	0%	0%	6	4.3
Firefighting 2008	7	100%	0%	0%	7	4.7
All contests	**76**	**93%**	**0%**	**7%**	**73**	**4.3**

Table 4: Overall Educational Value.

The overall educational value was rated at 4.3 on a scale of 1 (poor) to 5 (excellent). Also, 93% of the students (71 out of 76) indicated that they would recommend the robot design and competition activity to another student. There were no significant differences in the overall ratings among the eight robot design and competition experiences. Of the 5 participating students identified as IST majors in an IST 402 emerging technology course on robotics, the average overall educational value was reported as 4.2, consistent with the overall average for all participants.

Students participating in the firefighting robot design and contest in spring 2008 were additionally asked the question, “Do you think hands-on experience with robotics could encourage students to pursue majors and careers in a technical field?” In response, all of the students (N=7; 100%) indicated “yes” to this question.

Summary and Conclusions

Based on overall quality as judged by the students, the Robo-Hoops and regional Firefighting autonomous, mobile robot contests appear to be successful as an educational tool. Two hundred students overall from three, separate, lower-division undergraduate engineering courses and one, junior-level IST emerging technology course participated in the robot contests in the fall 2004 to spring 2008 period at Penn State Abington. 76 students (38%) participated in the anonymous, voluntary surveys to assess the outcomes of these robot events.

The overall educational value, across all eight contests, was judged to be 4.3 on a scale of 1(poor) to 5(excellent). According to the survey, 93% of the participants (that is, 71 of the 76 students surveyed) would recommend the robot contest activity to another student. Due to statistically low number of female participants in the surveys, it was not possible to determine any gender related trends or outcomes.

One of the key results of the survey was the strong response in the area of the value of teamwork. Students overwhelmingly indicated that there were advantages to working in a team (97%; 74 out of 76 responses). Optimal team sizes suggested by students fell generally in the 2 to 4 person per team range. Many of the key lessons learned in the contests were also positively related to working in a group. Other lessons learned included the importance of simplicity, testing, and time management in the design process. These experiences provide a level of confidence and set a solid foundation for future academic coursework, research, and employment.

Both the Robo-Hoops and Firefighting competitions successfully support a wide range of engineering courses, educational objectives, and robot resources and technologies. The flexibility in hardware and software solutions for the participating robots supports the integration of both of these contests into a variety of coursework and activities. The generally positive results from the involvement of the IST course suggest the value of robot design for non-engineering students. I intend to continue to survey our undergraduate engineering and information science students in future robot design competitions at Penn State Abington to further evaluate educational outcomes and explore other issues such as the impact of the robotics experiences on retention. There is also an opportunity to survey the K-12 student participants from the contests to measure the effectiveness of a robot competition in promoting interest in science, technology, engineering, and mathematics (STEM) majors and careers, and as a recruitment tool.

References

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Biographical Information

Bob Avanzato is an associate professor of engineering at Penn State Abington College. He teaches courses in digital design, robotics, IST, and programming. Bob is the coordinator for the Abington robot program and outreach effort. Prior to Penn State, he worked in industry in the areas of software simulation, digital signal processing, and artificial intelligence. Bob's research interests are in the areas of robotics, mobile computing, intelligent systems, and education enhancement.