What do Engineering Students Gain from Robot Competitions?

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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, 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 2004-2006 time period. 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. Overall, the responses on the quality of the robot competition experience from the students' perspective were very good. One of the key results from the student survey was the positive feedback concerning the value of working in a student team.

1. 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 incorporate 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. Each course has educational objectives which are satisfied by the competition event. The EDG 100 course generally focuses on the design and project management aspects of the contest design, where the digital design course focuses more on software design, microcontrollers, and sensor interfacing.

The Robo-Hoops 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. The competition is divided into 2 phases. In the first phase, each robot is operated in solo or 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. The contest is open to students in K-8, high school, and college divisions, and robots compete within the same division. Information about the specifics of the rules can be found on the Robo-Hoops robot website [1]. The Robo-Hoops contest has been offered every December (on a Saturday) since 1995. Typically, 30 to 40 teams across all divisions (K – college) participate. Of those, 6 to 10 teams are composed of Penn State Abington lower-division engineering students. Figure 1 below is a picture from the Robo-Hoops contest.

The firefighting robot design contest requires computer-controlled mobile robots to navigate autonomously though a maze 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 categories of K-8, high school, and senior (college and beyond). This contest is a regional contest for the international Trinity College Firefighting Robot Contest [2, 3]. As in the Robo-Hoops contest, there are approximately 40 or more robots entered annually in the Firefighting contest and Penn State Abington generally fields 5 to 10 robots in the senior division. Figure 2 shows a picture of a robot competing in the firefighting robot contest.

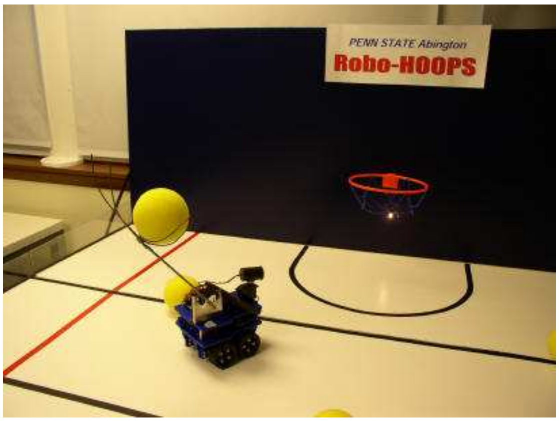

Figure 1: Penn State Robo-Hoops Contest

Figure 2: Penn State Firefighting 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, our freshman engineering design course will 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) and C-based programming languages.

2. Survey Questions

An anonymous student survey for the undergraduate engineering majors was developed and implemented to investigate the outcomes of four robot competition events (Robo-Hoops contests in 2004, 2005, and Firefighting contests in 2005, 2006), all offered at Penn State Abington. 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.

Below is the set of survey questions for the Firefighting contest. The questions for the Robo-Hoops were similar with the exception of one question (#9) which dealt with a specific feature of the firefighting contest.

1. What is your intended major?
2. Including the spring 2005 semester, how many semesters of college have you completed?
3. What was the name of your firefighting robot?
4. Have you ever entered a previous Firefighting robot contest before spring of 2005? Yes No
5. Did you personally attend the Abington campus firefighting robot contest on Sunday, April 3, 2005? Yes No
6. What robot controller did your robot use in spring 2005 Firefighting robot contest?
    a. Handyboard
    b. LegoMindstorms RCX
    c. Palm PDA
    d. Basic Stamp
    e. Other? Please specify:
    f. Not sure
7. 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. Other? Please specify:
    e. Not sure
8. What were the primary building or construction materials used in your robot?
9. What mechanism did your robot utilize to extinguish the candle flame?
    a. Electric motor powered fan
    b. Inflated balloon
    c. Other: please specify:
10. How many members were on your team?
11. Was there a single team leader? Yes No
12. Based on your experience, what do you personally consider to be the optimal size (number of students) for a team for this task?
13. How many hours (approximately) per week did you spend on the robot?
14. For how many weeks (approximately) did you work on this robot?
15. Do you think it is an advantage to work on a team? Yes No Briefly explain.
16. What was your personal primary role or roles in the team?
17. In your opinion, what was one of the most difficult technical problems you faced designing this robot?
18. In your opinion, what was the most important idea, concept, or lesson that you learned from this entire robot design and competition experience?

19. Did this robot activity and design contest impact your decision to stay in your major in any way? Yes No
    If yes, briefly explain.
20. Would you recommend participation in the Abington firefighting robot contest to other students in your major? Yes No Not Sure
21. 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
22. Overall, how could the Penn State Abington firefighting robot contest be improved?
23. Did you compete in both the Abington Firefighting robot contest and the Abington Robo-Hoops contest? Yes No
    If yes, how would you compare the experiences?
24. If you answered yes to the above question, how would you compare the Robo-Hoops design experience to the Firefighting design experience?

The student survey was anonymous, web-based, and was completed on a voluntary basis. Of the overall 116 students invited to participate over the 4 contest events, 45 (39%) responded. The student response data is provided in Table 1.

Table 1: Survey Response Statistics

Contest	Course participation	# Students invited	Student Participation
Robo-Hoops 2004 (fall)	CSE 275, EDG 100	26	11 (42%)
Robo-Hoops 2005 (fall)	CSE 275, EDG 100	42	15 (33%)
Firefighting 2005 (spr)	Engr 297H, EDG 100	24	8 (33%)
Firefighting 2006 (spr)	Engr 297H, EDG 100	24	11 (46%)
TOTAL		**116**	**45 (39%)**

Below is the distribution of intended majors from the total population of students responding to the robot contest surveys.

Major	Number	%
EE	18	40
ChemE	4	8.9
CompSci	4	8.9
IST	3	6.7
ME	3	6.7
Aero	2	4.4
ArchE	2	4.4
Engr Sci	2	4.4
BioE	2	4.4
Cmpen	1	2.2
Civil	1	2.2
Engr	1	2.2
Education	1	2.2
Undecided	1	2.2
TOTAL	**45**	**100**

Table 2: Distribution of Major

3. Key Results

In this section I will present some of the key results from the survey. 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 competition. The results presented here will focus on the team skills, important lessons learned, and overall quality.

Contest	Team Size (Range)	Team Size (Avg)	Optimal Team Size (Avg)	Single Team Leader? Yes No	Advantage to work in a Team?
Robo-Hoops 2004 (fall)	1 - 4	2.8	2.6	36% 64%	Yes (90%)
Robo-Hoops 2005 (fall)	3 - 6	3.9	3.4	20% 80%	Yes (100%)
Firefighting 2005 (spr)	2 - 3	2.8	2.6	13% 87%	Yes (100%)
Firefighting 2006 (spr)	2 - 5	3.9	3.9	9% 91%	Yes (100%)

Table 3: Student Team Responses

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, nearly 100% (40 out of 41 responses for this question) of the students indicated that there was an advantage to working in a team for these robot design and competition events.

Below are listed a sample of student responses on the advantages of working in a team:

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. *I think it is an advantage to work on a team. Not one of my team members, including myself, could have completed this task completely on their own. We fixed each other's problems and put in our two cents when needed.*
4. *Yes, because the task can be split evenly and no one person have to do all the work.*
5. *Yes, it can spread a task out and get it completed quickly.*
6. *Yes, each member of the team contributes their ideas and opinions on improving the robot.*
7. *Yes, as long as your teammate is on the same page/level. Otherwise the "team" becomes one-sided and one member is left to pull all of the weight*
8. *Yes, I think working as a team is an advantage because you can achieve more things if you work together.*
9. *Yes, because some members are better at building robots than writing the program the robot utilizes (and vise versa), in a team there is something for everyone to do.*

Each student was asked to provide the most important concept or lesson learned from the entire robot design and robot competition event. 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 software skills, the importance of testing, listening to your team members, time management, and others. The benefit of working in a team was a common thread for the major lessons learned. Overall, the lessons learned indicate the depth to which students were engaged in a real-world design effort. 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. *That simple is better, and the more complex you make things the more chance there is for it to go wrong*
7. *group participation. It is really important to work together and have a common goal. Everyone has to put their skills into play so that we can achieve our goal.*
8. *with team work comes creativity , and with hard work and dedication comes a great reward.*

These comments 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 co-op, internship, and full time employment.

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

Contest	N	Recommend to another student? Yes	No	Not Sure	N	Overall Quality 5=exc; 4=good; 3=avg 2= below avg; 1=poor
Robo-Hoops 2004 (fall)	11	100%	0%	0%	11	4.5
Robo-Hoops 2005 (fall)	15	100%	0%	0%	12	4.3
Firefighting 2005 (spr)	8	88%	0%	12%(1)	8	4.1
Firefighting 2006 (spr)	11	100%	0%	0%	11	4.2
All contests	45	98%	0%	2%	42	4.3

Table 4: Overall Quality

The overall quality was rated at 4.3 on a scale of 1 (poor) to 5 (excellent). Also, 98% of the students (44 out of 45) 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 four robot design and competition experiences.

4. Summary and Conclusions

Based on overall quality as judged by the students, the Robo-Hoops and Firefighting contests appear to be very successful as an educational tool. One hundred and sixteen

(116) lower-division students from three separate Abington undergraduate engineering courses participated in the robot contests in the fall 2004 to spring 2006 period at Penn State Abington. 45 students (39%) participated in the anonymous, voluntary survey to assess the outcomes of these robot events.

The overall quality, across all four contests, was judged to be 4.3 on a scale of 1(poor) to 5(excellent). According to the survey, 98% of the participants (that is, 44 of the 45 students surveyed) would recommend the robot contest activity to another student.

One of the key results of the survey was the strong response in the area of teamwork. Students overwhelmingly concluded that there were advantages to working in a team (98%; 40 out of 41 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 related to working in a group. This result is significant in that teamwork is an educational goal of the participating courses, and an important experience for the students in preparation for internships, co-op experiences, and full-time careers. This is especially important in that these students are lower division students in their freshman and sophomore years. These experiences provide a level of confidence and set a foundation for future project work.

Both the Robo-Hoops and Firefighting competitions successfully support a wide range of engineering courses, educational objectives, and equipment (hardware and software). Survey results do not indicate an educational advantage of one contest versus the other. Both contests were highly regarded by the students.

I intend to continue to survey our undergraduate engineering students in future robot design competitions at Penn State Abington. Based on this set of survey results there will be several modifications and improvements to the survey tool. Gender information could also be collected in future surveys to provide any insights into effectiveness based on male versus female student responses. There is also an opportunity to survey the K-12 student participants to measure the effectiveness of a robot competition in promoting interest in science and engineering careers.

5. Acknowledgements

I would like to acknowledge Cynthia Lang, Penn State engineering instructor, for her support of the robot projects at Abington.

6. References

[1] Robo-Hoops Contest website: http://cede.psu.edu/~avanzato/robots/contests/
[2] Penn State Firefighting Robot Contest website: http://cede.psu.edu/~avanzato/robots/contests/
[3] Trinity College Firefighting Robot Contest website: http://www.trincoll.edu/events/robot/

Biography:

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 robot program and outreach effort and also serves as the program coordinator for the Information Sciences and Technology (IST) degree at Abington. Prior to Penn State, Bob worked as an engineer at the GE Advanced Technology

Laboratories in the areas of software simulation, digital signal processing, and artificial intelligence. Bob's research interests are in the areas of robotics, mobile computing, and fuzzy systems.

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