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Robotics Education in the K-12 Environment

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Abstract

Robotics programming is becoming increasingly popular in the K-12 environment; robotics competitions and clubs are proliferating. This article addresses two related issues. First, are K-12 students effectively learning and employing sound design and programming practices and two, what efforts are required by educators, sponsors and competition organizers to ensure the quality and enhance the educational experiences of participants.

Introduction

Interest in robotics is intensifying; robotics programming provides a means for introducing ideas from engineering, computer programming, and physics. The attractiveness of robotics from the programming perspective is apparent: the semantics of programs are immediately recognized. For this reason, robotics programming is becoming more popular in secondary school education. In introducing robotics in the school environment, one is faced with the following problems:

1. Formulating a clear definition of robots. Is a joystick-controlled automaton a robot? If we define a robot as a machine whose behavior can be programmed, is a VCR an autonomous robot? Should we develop puppet robots or autonomous robots in class? Mobile or non-mobile?
2. The area is too wide (Mechanical Engineering, Electrical Engineering, and Computer Science)
3. Resources. It takes too many resources (time and money) to develop hardware and software from scratch

Recently, a new generation of computerized robot kits, such as Lego® Robotics Invention System™ opened up new possibilities for learning by doing to solve the above questions. One can create real autonomous mobile robots, which are built and programmed using the kit. It simplifies many difficult ideas of various disciplines and addresses item 3 above, since it is quite affordable.

A major question is how to use such kits in classes to maximize students' learning while not overburdening the instructor. We propose class contests as a major teaching paradigm, which will facilitate collaborative learning as well as motivate an interest in various robotics disciplines. Contests can be formulated to simulate real-world engineering constraints: resources, tools (development environments), and time [1]. Contests also provide an existing public forum to demonstrate participants' creations.

The first author has organized two such competitions: FIRST's FLL (First Lego League) [2,3] and Lawrence Tech's RoboFest [4] (the second author has acted as an official in both events). Young students demonstrated problem solving techniques, mathematics, logic, creativity, team work, mechanics, physics, electrical engineering and computer programming & technology from those events. However, we had the following questions when employing Lego robots for grade level robot education and robot games.

- Lego Midstorms are recommended for ages 12 and up. When is the best time to introduce a student to Lego robots. Some still consider Lego Mindstorm robots plain toys.
- Which programming language should be selected. There are problems inherent with the default programming languages, RCX code and RoboLab. To

some, the language is overly complex and to others overly restrictive.
- Do we need regular curriculum development in robotics at the grade school level or is after school time sufficient? No curricular implies there is no systematic development of ideas.
- Is it desirable to use fixed size playing fields? For example, during FLL 1999 and 2000, many students did not use any sensors. Many games are not designed to use feedback loop controls, since the dimension of the playing field is fixed and known in advance.
- What is the best team size? For example, FLL allows 7 members per team.
- What is the role of coaches? How much help should a coach provide?

In order to analyze the current status of robotics contest for young people, the authors prepared the following survey which was distributed to all competing teams at a FLL 2000 regional competition at Lawrence Technological University in Michigan.

Questionnaire

Dear Coaches:
Robots and robot games provide a wonderful motivation for science, engineering and technology education. In order to maximize our goals and improve learning environments, we need your valuable input, which will be summarized in a paper for AAAI Spring Symposium on Robotics and Education, Stanford University, Palo Alto, California, March 26–28, 2001.
Thank you so much for your cooperation.
Chan-Jin Chung, Assistant Professor, Math and Computer Science Department, LTU

Please check all that apply:

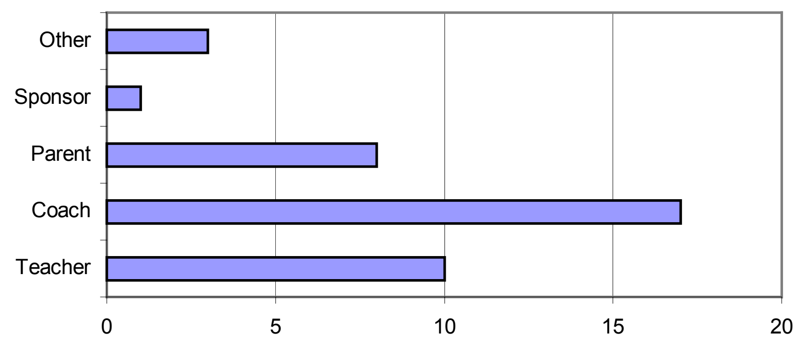
1. Who are you? ❑ School Teacher ❑ Coach ❑ Parent ❑ Financial Sponsor ❑ Other:______
2. What is your role? ❑ Coaching ❑ Programming Help ❑ Construction Help ❑ Other:______
3. How many total hours have you spent to help your team? ❑ 1-19 ❑ 20-39 ❑ 40-59 ❑ 60-79 ❑ 80+
4. Who built the playing field? ❑ Coach ❑ Parents ❑ School ❑ Purchased
5. Where did your team practice? ❑ At a home ❑ School ❑ Other: _________
6. How many team members are there on your team? _____________
7. What do you think is the ideal team size for Lego Robot Games? ____________
8. Programming Language Used: ❑ RCX code ❑ RoboLab ❑ Other: _________
9. Sensors Used: ❑ Touch ❑ Light ❑ Rotation ❑ None
10. Who wrote programs? ❑ 1 team member ❑ 2 members ❑ 3 members ❑ 4+ members
11. Who helped with the writing of the programs? ❑ Coach ❑ Parent ❑ none ❑ Other: __________
12. Specify the percentage of programming time that your team received outside help : ❑ None ❑ 10-20% ❑ 20-30% ❑ 30-40% ❑ over 40%
13. Who build the robot body? ❑ 1 team member ❑ 2 members ❑ 3 members ❑ 4+ members
14. Who helped with the robot body construction and design ? ❑ Coach ❑ Parent ❑ none ❑ Other: __________
15. Specify the percentage of design and construction time that your team received outside help : ❑ None ❑ 10-20% ❑ 20-30% ❑ 30-40% ❑ over 40%
16. What areas do you feel are enhanced through Lego robotics? (Please rank 1 to 7) ❑ math ❑ science ❑ creativity ❑ team-work ❑ engineering ❑ computer programming ❑ other ______
17. Do you think you need to take a special course on (Lego) robots?: ❑ yes ❑ no ❑ do not care
18. Where did you receive your funding ? ❑ School ❑ Parent ❑ Corporate Sponsor ❑ Other:______
19. Suggestions to improve technology education through autonomous robotics: _________________

Survey Results

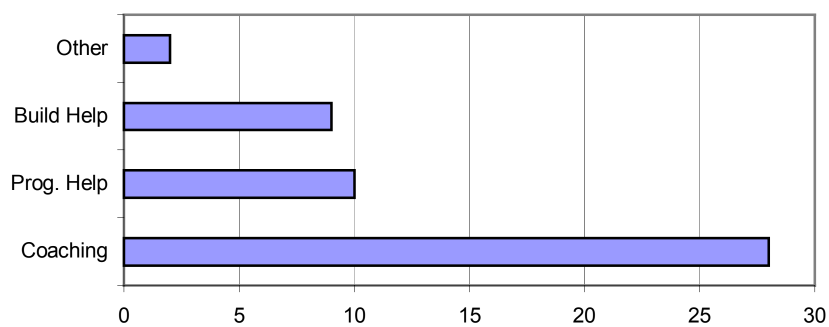
Michigan was number one state in number of Lego teams participated in 2000 FLL (FIRST Lego League). Approximately 250 teams registered for FLL 2000. Michigan was one of three states that offered Regional Tournaments leading up to the State Tournament. In Michigan's eight regionals, 189 teams actually competed and 70 of those teams advanced to the State Tournament [2, 3].

The above questionnaire was given to team leaders who checked-in their teams in the morning of Dec. 2, 2000 at Lawrence Technological University (an FLL Regional Competition site). Thirty-one teams were registered, but twenty-five teams showed up to compete. Twenty-one questionnaires were answered on that day. In addition, team leaders answered nine questionnaires on Dec. 16 at University of Detroit in Michigan, where the state final was held. One was sent by a mail. Therefore the following results are from a total thirty-one teams in Michigan. The intent of the questionnaire was to ascertain in what manner coaches, parents and others were involved the development of each teams robot. The data will be used to assess student learning for future robotics events.

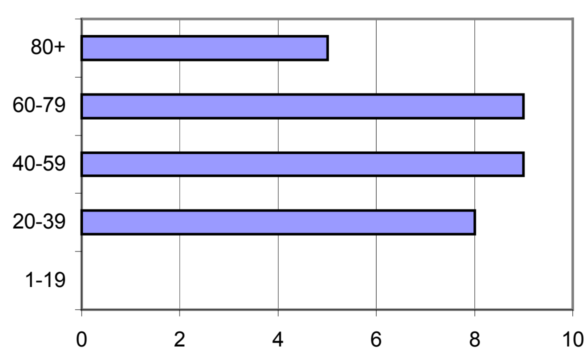
Q1. Who are you?



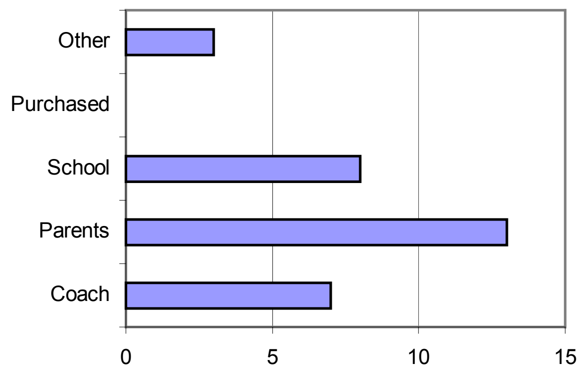
Q2. What is your role?



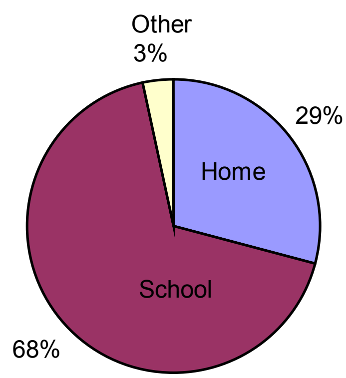
Q3. How many total hours have you spent to help your team?



Q4. Who built the playing field?



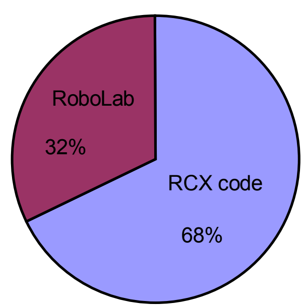
Q5. Where did your team practice?



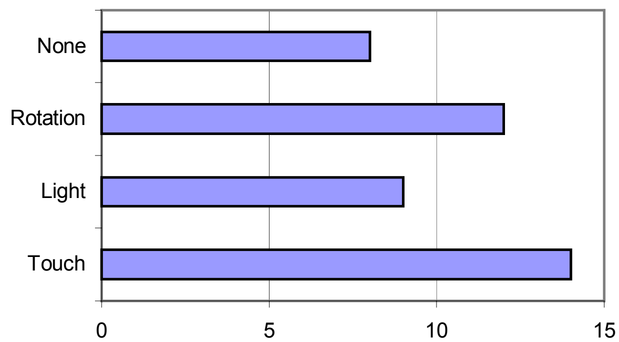
Q6. How many team members are there on your team?
Minimum 3, Maximum 20, and Average: 8.9

Q7. What do you think is the ideal team size for Lego Robot Games?
7.8 (68% said smaller than their current size)

Q8. Programming Language Used

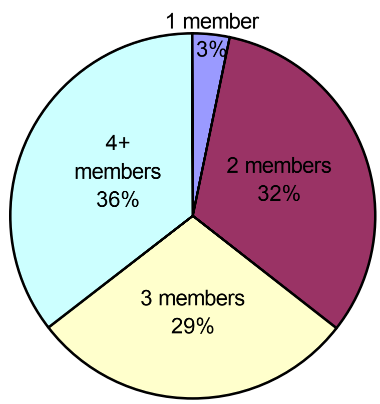


Q9. Sensors Used



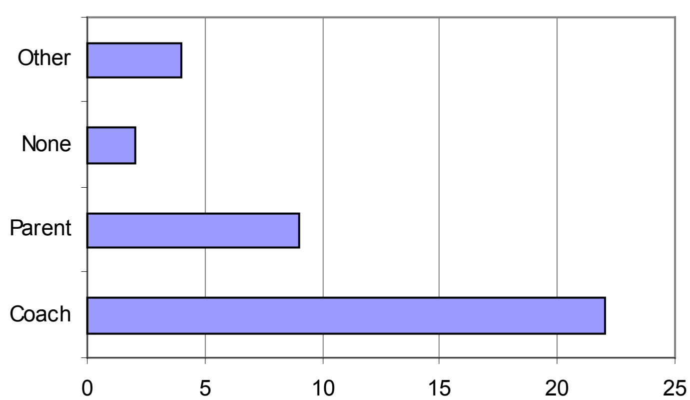
Note that 25% of teams did not use any sensors!

Q10. Who wrote programs?

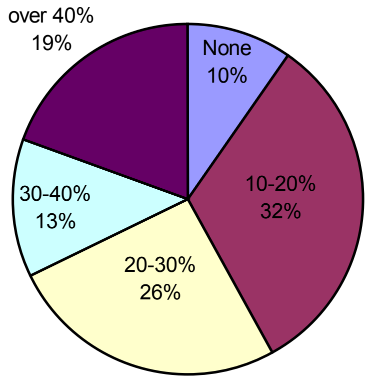


Question 10 reveals that a majority of team members were not involved in writing code.

Q11. Who helped with the writing of the programs?

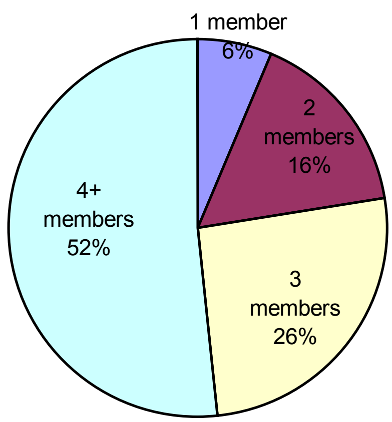


Q12. Specify the percentage of programming time that your team received outside help



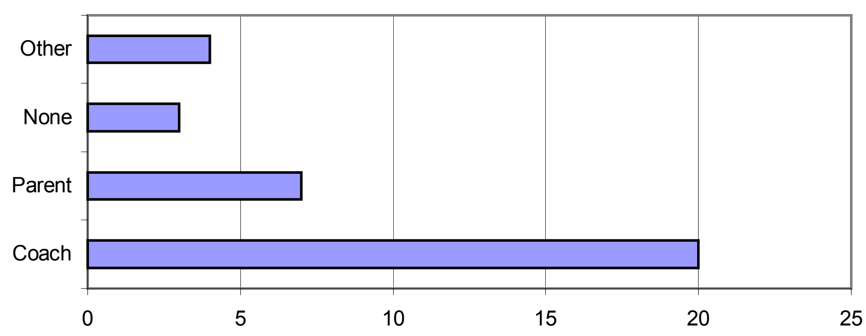
We witnessed many coaches and parents writing code during the competition. In most cases, students were not watching. The veracity of these responses might be in question.

Q13. Who build the robot body?

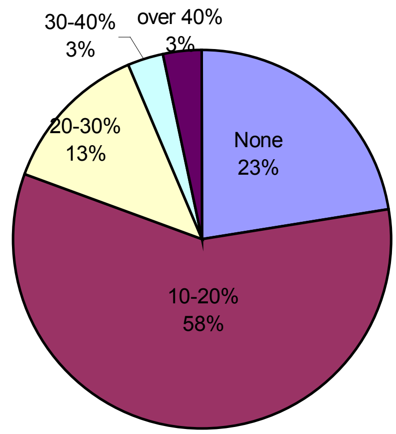


We can see that a lot of members participated in robot construction.

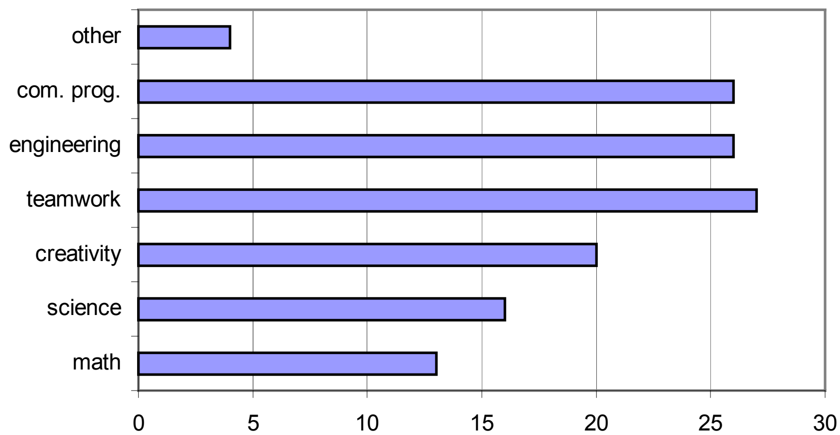
Q14. Who helped with the robot body construction and design?



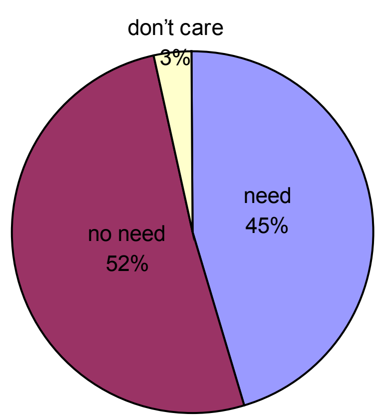
Q15. Specify the percentage of design and construction time that your team received outside help



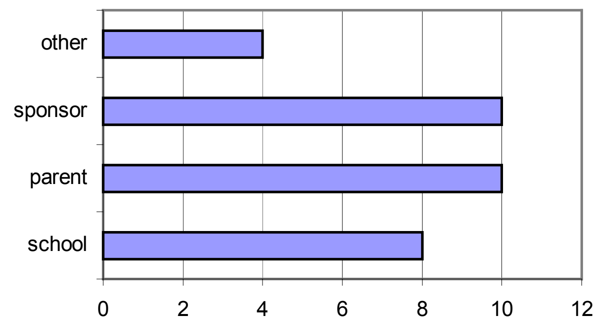
Q16. What areas do you feel are enhanced through Lego robotics?



Q17. Do you think you need to take a special course on (Lego) robots?



Q18. Where did you receive your funding?



Q19. Comments

Many teams complained about the complexity of playing fields. Other comments were: Rules need to be made more concise. Judging needs to be more consistent. More accurate playing fields as well as practice tables must be used for contests. Equal attention to journals and presentations. Better programming environment. Need programming helpers.

Conclusion

Interest in robotics is growing; in Michigan, approximately 2000 official Lego team members as well as over 500 teachers, parents, and mentors were involved in the FLL 2000 contest. Both collaborative and competitive learning appear to be both effective and efficient.

In considering robotics curriculum and competitions, we should consider the following in order to achieve pedagogical goals:

- Rules regarding age requirement need to be enforced. The FLL rules state team members should be 5^{th} grade – 9^{th} grade, but we observed much younger participants. During judging, younger members were unable to participate.
- Some teams have 20 team members. It has been our experience that some team members were idle or became cheerleaders. The best team size should be less than the current average, which is 8.9.
- 68% were using RCX code. However, many explained difficulties in understanding the semantics of the languages. Better and clearer programming environment needed.
- It is clear that a lot of talented parents and sponsoring engineers were helping students. However, it is a must for science/math teachers to develop LEGO robot fluency in the future. It is difficult for teachers to understand RCX code multi-tasking programs without having any programming experience.
- Let the team members act by themselves. Parents and coaches should be discouraged to help them directly. They should learn more from failures.
- Problem formation should encourage the use of feedback loop controls. Many teams (25%) were not using any sensors. It is obvious from the previous results that students needed more help in writing programs especially with sensors.
- It seems variable size playing fields as introduced in RoboFest 2000 [4] will be more desirable in many aspects. It will encourage students to use sensors. It could solve the complex problems of constructing fixed sized playing fields.
- Many high-school students in the USA are involved in FIRST robotics competitions employing joystick controllers. In most cases, the machinery is not build by them. Thus, many of the benefits of Lego programming and design are lost. We propose national level "autonomous robotics" competitions for high school students. It is time for us to do something for them together.
- There is a need for standardization of game rules worldwide; perhaps an International Robot Olympics Committee?

References

[1] Fred G. Martin, Robotic Explorations: A Hands-on Introduction to Engineering, 1/e, Prentice Hall, 2001, ISBN 0-13-089568-7
[2] eng-sci.udmercy.edu/precol/fll/
[3] www3.ltu.edu/mcs/fll/
[4] www.robofest.net