RoboParade: a Fun and Effective Way to Promote STEM Education

CJ Chung* and Christopher Cartwright**

Department of Math and Computer Science, Lawrence Technological University
21000 W. Ten Mile Rd, Southfield, MI 48075
(*) cchung@LTU.edu (**) ccartwrig@LTU.edu

Abstract

RoboParade is an annual event in which students design, build, program, and decorate autonomous robotic floats that follow a parade route. The students must program their robots to obey a speed limit, follow a black line, and avoid other robots using sensors. RoboParade provides a hands-on experiential approach where students may improve learning science, technology, engineering and mathematics (STEM) skills. A controlled experiment shows that students who participated in RoboParade 2012 showed greater improvement on a pre-post STEM multiple choice test compared to students who did not participate.

Introduction to RoboParade

(Figure 1) Thanksgiving RoboParade 2012 at Macomb Community College Expo Center in MI

RoboParade is a program to engage, inspire, challenge, and prepare 4th-12th grade students to pursue careers in Science, Technology, Engineering, and Mathematics (STEM). RoboParade was built on the experience and infrastructure of Robofest (www.robofest.net), an annual autonomous robotics competition originated at Lawrence Technological University (LTU) for pre-college students [Chung & Sverdlik 2001, Chung & Anneberg 2003, Chung 2005, Chung 2006, Chung 2007, Chung 2008, Chung 2009, Chung 2010, Chung & Cartwright 2010, MacLennan 2010, Chung 2011a, Chung 2011b, Chung & Cartwright 2011, Crocker 2011, Chung & Cartwright 2012].

RoboParade was developed in 2006 after recognizing the following issues from Robofest competitions:

- It seems too late for many students to develop an interest in STEM-related subjects by the time they reach late high school grades. Research has shown that early exposure to STEM initiatives and

activities positively impacts students' perception and dispositions [Dejarnette 2012; Bagiati, Yoon, Evangelou & Ngambeki, 2010; Bybee & Fuchs 2006]. Since older students lose interest in math and science [Ward-Able & Lewis 2012, Gordon 2011], [Swift & Watkins 2004] emphasize that "effective science and mathematics instruction must begin in the early grades." Students who express interest in STEM in eighth grade are up to three times more likely to ultimately pursue STEM degrees later in life than students who do not express such an interest [Tai, Liu, Maltese & Fan 2006; PCAST 2010].

- Tightly defined robotics competition rules may limit students' imagination and creativity. Fred Martin, one of the inventors of LEGO robots, suggested open-ended exhibitions might promote more creativity than fixed game competitions [Martin 2000].
- There is a need to support more local underrepresented students, especially within the city of Detroit. Statistics show that the high school graduation rate was below 50% in Detroit [Wilk 2009].
- Women are still underrepresented in fields such as engineering, computer science, and the physical sciences [National Science Board 2010, PCAST 2010].
- Some researchers found female students in particular are more likely to appreciate learning with robots than traditional STEM teaching techniques [Nourbakhsh et al. 2005, Rogers & Portsmore 2004].

Our annual RoboParade was designed to complement the competition-oriented Robofest, targeting younger students and inner city teams by providing an entry level robotics program into STEM, and freeing them from the stress of competition. The required tasks are relatively simple – line following and obstacle detection. Believed to be the world's only *autonomous* robot parade, this event has featured miniature robotic floats with moving parts, sparkling lights, and all sorts of bells and drums rolling down a parade route without remote controls (see Figure 1). RoboParade videos since 2006 can be found online at http://www.robofest.net/roboParade.htm

The artistic and non-competitive nature of the event seems to attract more female participants, with over 30% female participation rate as opposed to 25% in Robofest competitions [Chung & Cartwright 2012].

Intended Learning Outcomes

Basic RoboParade requires an autonomous robotic float to follow a line. If it detects another robotic float in front, the robot must stop, wait, and re-start when it is cleared without any human help. In addition, the robot must observe speed limits, minimum 7 cm/second and maximum 17 cm/second. It is also required to display current average speed. Through these tasks, students are learning, experiencing, and reinforcing STEM subjects such as proportion, arithmetic operation, arithmetic mean, linear function, unit conversion, ratio, circles, logic, data analysis, speed calculation, sensors, gears, motors, force, friction, center of gravity, and many others. To join the official parade, teams must pass a qualifying test that includes a written qualifying exam. (see Appendix)

RoboParade 2012 Assessment Results

1. Research Question

Hypothesis H_1: Students who participate in the RoboParade have higher STEM scores than students who do not participate. RoboParade program improves STEM scores.

Null Hypothesis H_0: There is no statistical difference in STEM scores between RoboParade students and students who do not participate in the program. RoboParade students do not have higher STEM scores than non RoboParade students. RoboParade program does not improve STEM scores.

Independent variable: Group membership - participation in the RoboParade program (the experimental group) vs. no participation in the RoboParade program (the control group).

Dependent variable: STEM scores on mathematics, science, engineering, and computer technology multiple choice test.

2. Assessment Methodologies and Tools

H_1 was tested by administering similar pre- and post-assessment tests to an experimental group and a control group (cf. Barker & Ansorge, 2007; Trudell & Chung, 2009).

An eight-item multiple choice test was developed for the anonymous pre-assessment. The following STEM topics were covered in the test:

- Five 5^{th} ~ 8^{th} grade level math questions relating to proportion, arithmetic operation, arithmetic mean, linear function, unit conversion, ratio, and circles based on the Grade Level Content Expectations (GLCEs) for Michigan public schools.
- One question relating to gears (engineering)
- One question relating to robot sensors (science)
- One question relating to logic and computer programming (technology)

The test also included demographic questions, which determined student grade, gender, and STEM subject interest. (see Appendix)

The post-assessment test had the same questions but they were modified while maintaining the same difficulty level. (see Appendix)

3. Procedure

This research was approved by the Institutional Review Board at Lawrence Technological University. This time, we conducted pre- and post-assessments using only paper, not online, tests.

Two schools were chosen to obtain control group students: one in a suburban area and the other in downtown Detroit. Teachers from each school invited a class to complete the pre- and post-assessments.

The pre-assessment test for the experimental group was given October 12 and 13, 2012 to students who participated in RoboParade workshops at LTU. Additional RoboParade students joined the research on November 5 and 9.

The post-assessment for the experimental group was conducted the same day as RoboParade, November 17, at Macomb Community College. Four teams who were unable to attend RoboParade participated in the post-assessment on November 27.

The pre-assessment test for the control group was given October 23 and 24, 2012 during class at two schools.

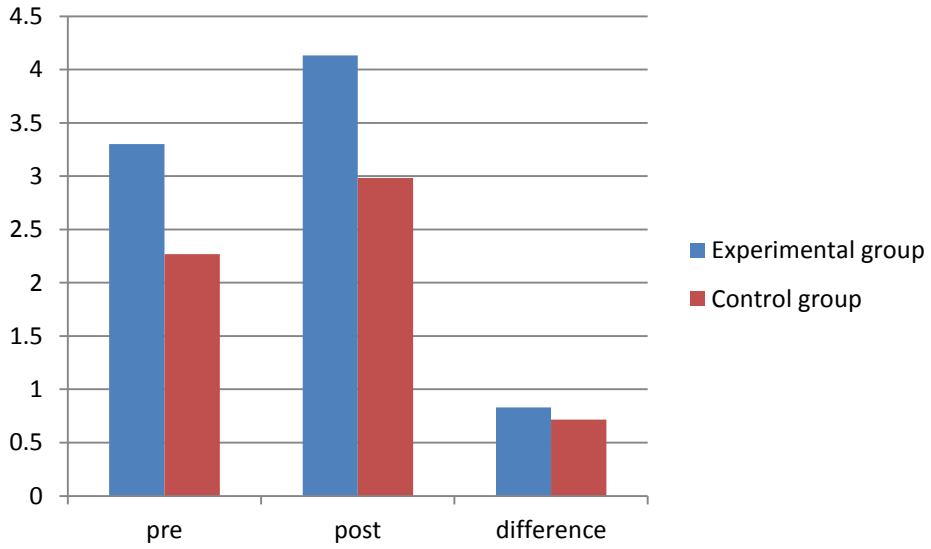
The post-assessment test for the control group was given November 29 and 30, 2012 during class at two schools.

4. Results

STEM scores from 4th-10th grade experimental and control group students were analyzed. The following table shows the data from the sample populations.

		Experimental Group	Control Group
Pre Assessment	Population size	63	67
	Mean school grade	6.25	5.94
	Mean test score	3.30	2.27
	Median	3	2
	Standard deviation	1.71	1.37
Post Assessment	Population size	60	62
	Mean school grade	6.1	5.93
	Mean test score	4.13	2.98
	Median	4	3
	Standard deviation	1.48	1.38
Unpaired *t*-test probability		0.0047	0.0038
Mean test score difference (improvement)		0.83	0.72

As shown in the data above and Figure 2 below, RoboParade students' mean STEM scores improved from 3.30 to 4.13 ($p < .0047$). We also found that the improvement of the Robofest group is greater than that of the control group (0.83 > 0.72). These results suggest H_0 can be rejected in favor of H_1: STEM scores are improved through participation in RoboParade programs.



(Figure 2) RoboParade 2012 STEM assessment results

Conclusion

RoboParade is a fun activity designed to encourage students at a critical age to consider careers in STEM. RoboParade is an entry level robotics event, and targets younger students and underrepresented students (inner city and female), who tend to lose interest in science and mathematics before high school. RoboParade has been shown to be effective for STEM learning in a controlled experiment in which students that participated in RoboParade had increased gains in STEM scores compared to students who did not participate. We believe the speed display requirement and the written qualifying test asking about

speed calculation (Appendix 4) embedded into RoboParade program contributed to the greater improvement of the RoboParade group.

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Appendix

The following documents were used for RoboParade 2012 season in Michigan from Oct ~ Nov, 2012. The final Thanksgiving RoboParade was held at Macomb Community College Expo Center on November 17, 2012.

1. *RoboParade Pre-Assessment*
2. *RoboParade Post-Assessment*
3. *RoboParade Qualifying Test Checklist 2012 - List of qualifying tasks to join the official RoboParade*
4. *Written Qualifying Test*

1. RoboParade Pre-Assessment, 2012

This assessment can only be taken one time, once you have submitted it you cannot take it or view it again. This assessment will be completely anonymous.

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* Required

Q1*What grade are you in?

- 4th Grade or Below
- 5th Grade
- 6th Grade
- 7th Grade
- 8th Grade
- 9th Grade
- 10th Grade to12th grade

Q2*What is your gender?

- Male
- Female

Q3*Are you interested in a career or job involving Science, Technology, Engineering, or Mathematics? (one or more of the four areas?)

- Not at all interested
- Probably not
- Not sure
- Somewhat interested
- Very interested

Q4*If your dad drives 60 miles per hour for 2 hours, how many miles did he drive?

- 30
- 60
- 120
- 3600
- I don't know

Q5*If at noon your mom's car is at mile marker 20 and at 2:00 PM your mom's car is at mile marker 100, what is the average speed of your mom's car?

- 20 miles per hour
- 40 miles per hour

- 80 miles per hour
- 100 miles per hour
- I don't know

Q6*A toy car moves forward 15 cm for one rotation of two identical wheels. How many rotations are needed for the same toy car to move forward 75 cm?

- 5
- 15
- 60
- 75
- I don't know

Q7*Choose one that is *not* correct

- 5.4 is greater than 13.0
- 5.4 is less than or equal to 13.0
- 1.8 is less than or equal to 1.8
- 2 is greater than or equal to 1.8
- I don't know

Q8*What is the radius of a circle when its circumference is 30 cm?

- 3.09 cm
- 3.14 cm
- 4.77 cm
- 9.55 cm
- I don't know

Q9*A toy car has a wheel with a diameter of 5 cm. How many rotations of the wheel are required for the car to travel a distance of 30 cm?

- .95 rotations
- 1.91 rotations
- 6 rotations
- 9.55 rotations
- I don't know

Q10*If a big gear is driving a little gear (this is called gearing up), then the little gear will

- Spin faster, and have decreased torque
- Spin slower, and have increased torque

- Spin faster, and have increased torque
- Spin slower, and have decreased torque
- I don't know

Q11*If you use a light sensor with reflected light mode, which of the following will reflect the greatest amount of light back to the sensor

- black electrical tape, 2cm away
- black electrical tape, 10 cm away
- white computer paper, 2 cm away
- white computer paper, 10 cm away
- I don't know

Submit

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2. RoboParade Post-Assessment 2012

This assessment will be completely anonymous.

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* Required

Q0*Did you take RoboParade Pre-Assessment this fall 2012 during the worshop at LTU *or* your school (Winans Academy, Southfield Christian, MCS, or FLIC)?

- Yes; Go on to the next question
- No; Do NOT take this test

Q1 *What grade are you in?

- 4th Grade or Below
- 5th Grade
- 6th Grade
- 7th Grade
- 8th Grade
- 9th Grade
- 10th Grade to 12th Grade

Q2 *What is your gender?

- Male
- Female

Q3*Are you interested in a career or job involving Science, Technology, Engineering, or Mathematics? (one or more of the four areas?)

- Not at all interested
- Probably not
- Not sure
- Somewhat interested
- Very interested

Q4*If your dad drives 50 miles per hour for 2 hours, how many miles did he drive?

- 25
- 50
- 100
- 250
- I don't know

Q5*If at 1:00PM your mom's car is at mile marker 30 and at 3:00 PM your mom's car is at mile marker 150, what is the average speed of your mom's car?

- 30 miles per hour
- 60 miles per hour
- 120 miles per hour
- 180 miles per hour
- I don't know

Q6*A toy car moves forward 10 cm for one rotation of identical wheels. How many rotations are needed for the same toy car to move forward 40 cm?

- 4
- 16
- 48
- 80
- I don't know

Q7*Choose one that is *not* correct

- 12 is greater than 9.8
- 9.8 is less than or equal to 12

- 3.4 is less than 5.7
- 5.7 is greater than or equal to 9.8
- I don't know

Q8*What is the radius of a circle when its circumference is 20 cm?

- 2.52 cm
- 3.18 cm
- 6.37 cm
- 125.66 cm
- I don't know

Q9*A toy car has a wheel with a diameter of 6 cm. How many rotations of the wheel are required for the car to travel a distance of 48 cm?

- 1.27 rotations
- 2.55 rotations
- 8 rotations
- 15.23 rotations
- I don't know

Q10*If a little gear is driving a big gear (this is called gearing down), then the big gear will

- Spin faster, and have decreased torque
- Spin slower, and have increased torque
- Spin faster, and have increased torque
- Spin slower, and have decreased torque
- I don't know

Q11*If you use a light sensor with reflected light mode, which of the following will reflect the least amount of light back to the sensor

- black electrical tape, 1 cm away
- black electrical tape, 10 cm away
- white computer paper, 1 cm away
- white computer paper, 10 cm away
- I don't know

Submit

3.

ROBOParade

Qualifying Test Checklist 2012

Team-ID: _____

Team Name: _____

Test Item	**Details**	**Pass / No Pass**	**Note**
Line following	Clockwise, counter-clockwise		
Object Detection	Wait and restart		
Speed display			
Speed limit	7cm ~ 17cm		
Rear bumper	1" high from the floor; at least 5"x2.5"		
Length (a unit)	Less than 35cm		For a float with multiple trailers following it, each 35 cm long is OK
Written exam			

Flag Number Assigned: _____ (without passing Written exam, a team may get a flag)

Judge Signature: _____

4. Written Qualifying Test

RoboParade Quiz (Type A)

Team ID: _____ Team Name: _____
Student Names:

Q1. The above toy car drove straight 8 wheel rotations for 4 seconds. What was the average speed (cm / sec)? The circumference of the wheels is 20cm. Assume there is no slip or idle rotations.

Q2. How many centimeters will it drive forward straight for 5 seconds if the average speed is 15cm per second? Assume there is no slip or idle rotations.