Assessing the Impact of an Autonomous Robotics Competition for STEM Education

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Abstract

Robotics competitions for K-12 students are popular, but are students really learning and improving their Science, Technology, Engineering, and Mathematics (STEM) scores through robotics competitions? If they are, how much more effective is learning through competitions than traditional classes? What is the best robotics competition model to maximize students' STEM learning? One robotics competition designed to promote the use of math and science is Robofest. Robofest is an autonomous robotics competition with some unique features for STEM education. An example is that students need to solve unknown problems on the day of the competition. The Robofest competition requires the use of mathematics and sensors which discourages dead reckoning. Results from 5th-12th graders who completed a STEM assessment before and after the Robofest competitions found students in the Robofest group showed improvement and achieved higher scores in math and science after the competition. These results suggest robotics competitions modeled after Robofest have the potential to improve STEM learning.

Introduction

We believe computer programming and robotics are powerful learning tools for children (Papert, 1980). Robots first appeared in U.S. classrooms for educational purposes more than 20 years ago (Bers & Portsmore, 2005; Cejka, Rogers & Portsmore, 2006; Chambers & Carbonaro, 2003; Groff & Pomalaza-Raez, 2001; Kolberg & Orlev, 2001; Whitman & Witherspoon, 2003). More recently, several informal learning environments have started to combine computers and robots through such programs as after-school, computerized, autonomous robotics programs and robotics competitions (Barker & Ansorge, 2007; Chung & Anneberg, 2003). Robotics competitions engage participants in fixed and open-ended activities, and as suggested by Fred Martin (2000), one of the inventors of the popular LEGO robotics platform, open-ended exhibitions might promote more creativity than fixed game competitions. Furthermore, the use of autonomous robotics in formal and informal learning environments improves math and science learning, as well as critical thinking and problem solving skills (Matson, DeLoach & Pauly, 2004; Robinson, 2005; Weiss, 2004; Ricca, Lulis & Bade, 2006; Wagner, 1998).

The characteristics of robotics-based pedagogy provide at least the following five key advantages over traditional pedagogy in teaching the theory and practice of STEM: (1) integration of STEM topics in a multidisciplinary fashion, (2) efficient transformation of abstract concepts into concrete learning modules for students, (3) combination of STEM theory with its practice, (4) hands-on learning that is active and engaging, and (5) a highly enjoyable and motivating learning environment.

Beginning in 2000 and continuing annually over the next fourteen years, we have utilized the robotics-based pedagogy through an autonomous robotics competition, Robofest (www.robofest.net), to teach STEM skills to over 12,000 pre-college students (Chung, 2011; Chung & Sverdlik, 2001; MacLennan, 2010). Robofest has become an international competition, engaging teams from 13 US States (Michigan, Ohio, New Hampshire, Texas, Florida, California, Washington, Missouri, Hawaii, Colorado, Indiana, Minnesota, and Louisiana), and 8 countries (Canada, Mexico, United Kingdom, South Korea, Singapore, France, India, and China).

Goals and features of Robofest

Robofest challenges student teams to design, build, and program autonomous robots that embrace and naturally associate with STEM components. The two ultimate goals of Robofest are:

- Goal 1: Get students interested in STEM subjects and careers
- Goal 2: Increase preparedness for successful college education by increasing knowledge of STEM topics

To accomplish our goals effectively, we have introduced the following unique and innovative features into Robofest.

Affordable for all students

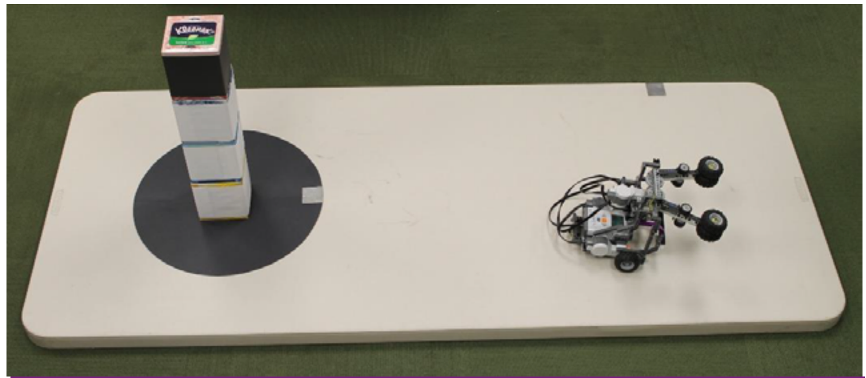
Robofest is one of the most affordable autonomous robotics competitions in the nation. The registration fee is just $50 per team. There are no restrictions on the brand of robot kit that can be used, or on building materials, actuators and sensors, and software. Since Robofest participants can use any type of programming language software, many teams are using free, downloadable advanced and professional programming language such as C or Java. Furthermore, the playing field materials are affordable, modular, and easy to transport and store, allowing student teams to practice anywhere at their convenience. Robofest encourages recycling of all the logistic materials which helps to control costs.

Autonomous robots

Robofest students are required to program an on-board computer to physically control the robot to achieve its missions without human assistance—absolutely no joysticks or remote controls are allowed. Robofest robots must be programmed to sense and respond intelligently in real-world environments comprised of unknown, changing and unstructured characteristics. Autonomous robots require computer programming to "make the robots come alive," and we believe STEM learning is reinforced and maximized more when students program and test robots, compared to when they play with robots by using remote controls.

Rigorous math and science application

Robofest games are designed in such a manner that students can learn math and science through a hands-on robotics educational experience which has direct links to concepts in physics and mathematics. For example, math and science topics in robotics include numbers and operations, algebra, calculus, geometry, trigonometry, measuring, and data analysis. Physics topics include motion, vectors, forces, friction, Newton's laws, torque, work, energy, power, and simple machines. For instance, a 2011 Robofest game, Block The Oil Spill (BTOS), requires participants to solve a system of equations involving the Pythagorean Theorem (see detailed examples of Robofest's use of math and science in the section below). In evaluating student performance in Exhibition, and RoboFashion & Dance, Robofest judges consider math and science components as the number one criteria.



(Figure 1) Robofest 2013 Junior Game Competition

Use of unknown problems on the day of competition

Robofest presents students with small challenges which are not disclosed until the beginning of each game competition. These challenges are referred to as Unknown Problems/Factors, and their solutions are directly related to math and/or physics. Adults are not allowed in the competition work area after the unknown problems are unveiled. Accordingly, student teams must demonstrate their ability to work independently and solve problems without the assistance of a coach or parent. Unknown problems involve dynamic rearrangement of parts of the robotic playing field, and solutions require students to rapidly program their robots to reliably work on the fly.

Promotion of life-long educational goals

Robofest's innovative approach to robotics-based pedagogy not only covers STEM areas, but also extends higher education into a realm of invaluable life-long skills such as confidence, discipline, teamwork, problem-solving, critical thinking, communication, and leadership skills. Additionally, since Robofest encourages innovation and creativity, students will develop entrepreneurial mindsets.

Advanced category

Beginning in 2007, Robofest launched Vision Centric Robot Challenge (VCRC) (Crocker, 2011). VCRC is an advanced competition category in which students design and build mini intelligent robotic cars with on-board vision systems. VCRC is structured for more advanced high school students who are proficient at computer programming and who might be interested in computer science.

Fun and exciting opportunities for every student

Robofest meets the needs of a variety of children based on their respective age, gender, learning methods, and difficulty levels. While Junior Division is for students in 4^{th} –8^{th} grades, Senior division is for students in 9th- 12th grades. Students younger than the minimum grade may participate in Robofest if the coach submits age requirement waiver forms. Since some students prefer not to compete with other teams, Robofest also offers an opportunity for teams to display any robotics project at science fair like Exhibition competitions.

Diversity

To address research suggesting that female students, in particular, are likely to appreciate learning with robots more than traditional STEM teaching techniques, we created specific elements of Robofest to attract more diverse students: Thanksgiving RoboParade was started in 2006, and RoboFashion & Dance Show was started in 2007 (Nourbakhsh et al., 2005; Rogers & Portsmore, 2004). These elements have contributed to a diverse population of children participating in Robofest educational opportunities for STEM teaching (Chung, 2010). For example, since 2005, more than 20 percent of Robofest students have been female.

Robofest rewards participation

While adult, coach and teacher mentorship is encouraged in all phases of preparation, students make all decisions and perform all robotic programming during the competition. Since Robofest ensures that the students understand the problem and conduct the construction and programming, every student is considered to be a winner in the STEM learning experience. Accordingly, Robofest rewards student participation by providing an IEEE-sponsored medal and a personalized certificate to each participant.

Examples of Math and Science in Robofest Games

Robofest game competitions are comprised of challenges that encourage the use of mathematics and sensors, rather than trial-and-error learning (Silk, Higashi & Schunn, 2011). Specifically, for the Robofest 2013 game competition, light sensors were necessary to enable the robot to navigate the edge of the table by detecting bright aluminum foil tape, which distinguishes the lighter table from the dark edge (see Figure 1). Light sensors were also used to distinguish between the lighter table and the dark object (circle for Jr., right triangle for Sr.)

Robofest competitions also promote STEM learning by requiring participants to use mathematics to solve game challenges. For example, the Robofest 2013 game required Jr. students to compute the area of a circle based on measurements of the amount of rotations of the wheels to follow the circumference of the circle. Students had to use light sensors to follow the circumference. This involved the students being able to use the following mathematical relationships:

r=degrees rotated, d= diameter of the wheel, C=circumference of circle
R=radius of circle, A=area of circle

Given r and d, compute A based on the following three equations:

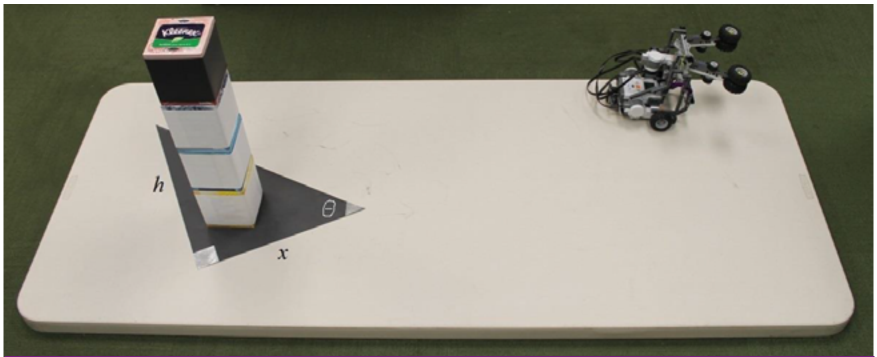
$$\begin{cases} C = d * \pi * \dfrac{r}{360} \\ C = 2\pi * R \\ A = \pi * R^2 \end{cases}$$

The Robofest 2013 game required senior division students to use trigonometry to compute the area of a triangle given the measurements of one side and one angle. Students had to use light sensors to measure the side x and the angle θ as shown in Figure 2.

Area of the right triangle can be calculated based on the following relationships and equations.

D=wheel travel distance, x=base of triangle, r_1 =degrees rotated for D, r_2 =degrees rotated for x, d= diameter of the wheel, θ =angle, h=height of triangle, w=width of robot,

$$\begin{cases} D, x = d * \pi * \dfrac{r_{1,2}}{360} \\ \dfrac{\theta}{360} = \dfrac{D}{\pi * w} \\ \tan\theta = \dfrac{x}{h} \\ A = \dfrac{1}{2} x * h \end{cases}$$

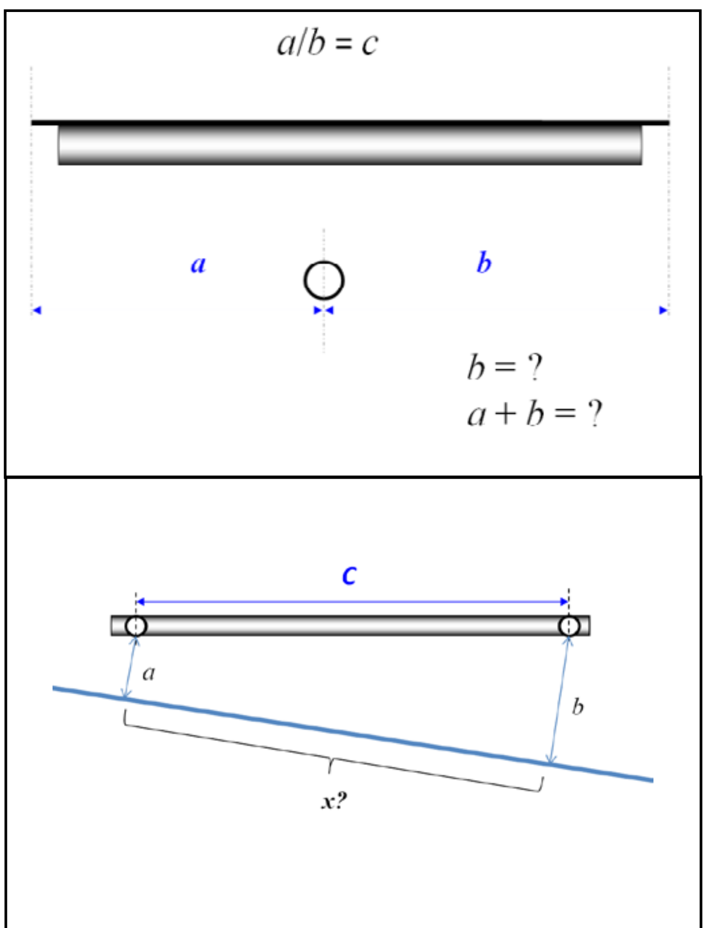


(Figure 2) Robofest 2013 Senior Game Competition

The Robofest 2011 game required both Jr. and Sr. students to solve a system of equations (see Figure 3, left). Specifically, students were given the value c, and had to use light sensors to measure the distance $d = a + b$. Next, students had to solve the following system for *a* and *b*:

$$\begin{cases} a+b & = & d \\ a/b & = & c \end{cases}$$

The Robofest 2011 game required Sr. students to use the Pythagorean Theorem: Students were given the values *C*, *a*, and *b* (see Figure 3, right), and then had to solve the equation $x^2+y^2=C^2$ for *x*, where $y=b-a$. The starting location for the distance *x* had to be located using light sensors.



(Figure 3) BTOS challenges involving math: Jr. and Sr. students (top); Sr. students only (bottom)

Research Question

In this article, we are trying to assess our Goal 2 mentioned in previous section, which is to increase preparedness for successful college education by increasing knowledge of STEM topics.

Hypothesis H_1: Students who participate in the Robofest robotics competition have higher STEM scores than students who do not participate.

Null Hypothesis H_0: There is no statistical difference in STEM scores between Robofest students and students who do not participate in the program.

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

Dependent variable: STEM scores on a multiple-choice test.

Assessment Methodologies and Tools

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

For the 2011 assessment, a 19-item multiple-choice test mapped to the Grade Level Content Expectations (GLCEs) for Michigan public schools was developed (see Appendix 1). The following mathematics topics were covered in the test:

5th grade: applications of math, arithmetic mean
6th grade: linear function evaluation, unit conversion
7th grade: direct proportion, derived quantities, rectangles, proportion, real number properties, and slope of linear functions
8th grade: ratio units, rational number properties, circles, Pythagorean Theo rem, and systems of equations

These topics were chosen because they coincided with topics covered in the "RoboMath" curriculum developed for Lawrence Tech's summer robotics camps, and these topics were used at various times during Robofest competitions.

Demographic questions were also included in the test to determine student grade, gender, years of Robofest experience, and if the student had competed in Robofest 2011. Responses on the latter question determined group membership.

For the 2013 assessment, the multiple-choice test was revised to be more concise to focus on mathematics specifically used for the 2013 competition, as well as to include science and engineering questions so that a broader spectrum of STEM learning could be captured.

The eight-item multiple-choice test contained six mathematics questions mapped to the Grade Level Content Expectations (GLCEs) for Michigan public schools (see Appendix 2). The following mathematics topics were covered in the test:

5th grade: applications of math
6th grade: unit conversion
7th grade: direct proportion, derived quantities, triangles, proportion, real num ber properties
8th grade: ratio units, rational number properties, circles, systems of equations

Two science and engineering questions were included covering angular and linear velocity and torque of a gear system and reflective properties of light from light sensors that are shown on different types of materials and at varying distances. Technology questions were not included since robotics technologies are not a regular part of the curriculum and to ask a question specifically about robotics would have been unfair to the control group.

Demographic questions were also included in the test to determine student grade, gender, and the student's level of interest in a STEM career. This last question was included to try to gather evidence about whether robotics competitions may increase interest in STEM as well as STEM ability.

Procedure

This research was approved by the Institutional Review Board at Lawrence Technological University. For the 2011 assessment, the multiple-choice test was administered as a Google document by providing coaches in the Robofest database with a hyperlink to the test. Coaches were instructed to invite students participating in the Robofest 2011 program to complete the test before and after the competition (i.e., the experimental group). The same link was given to teachers with students who did not plan to participate in Robofest (i.e., the control group). A timestamp recorded upon completion of the test was used to identify students. Students for whom parental consent was provided were eligible for participation in this research.

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 online. All of the control students were from southeast Michigan, while the experimental group was much more random, as students from several states had the opportunity to participate.

The pre-assessment was opened January 31, 2011, and closed on February 28, 2011. The post-assessment was opened April 6, 2011 following the last qualifying competition (first round), and closed on May 7, 2011 (the final day of the Robofest 2011 competition season).

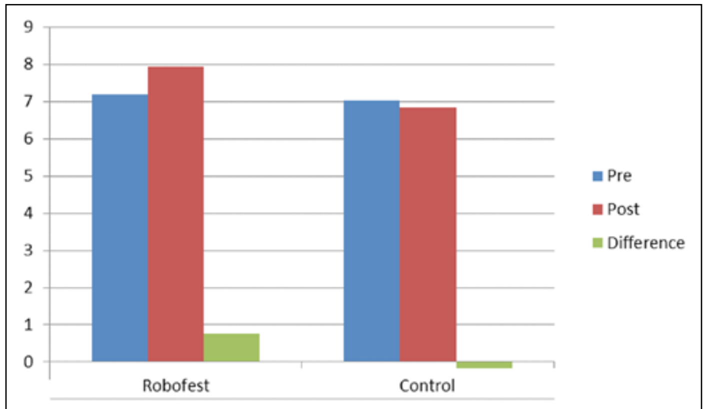
For the 2013 assessment, the multiple-choice test was administered as two Google documents, one for the control group and one for the experimental group. Coaches in the Robofest database were provided with a hyperlink to the test for the experimental group. Coaches were instructed to invite students participating in the Robofest 2013 program to complete the test before and after the competition (i.e., the experimental group). A separate link (with the same multiple choice questions) was given to teachers with students who did not plan to participate in Robofest (i.e., the control group). Students provided a nickname that allowed the research to remain anonymous but provided a way to compare pre- and post- results from the same students. Students for whom parental consent was provided were eligible for participation in this research.

Five teachers volunteered to give the pre- and post- tests to their students (the control group) during their regular classes: two fifth grade teachers, one in a suburban area and the other in downtown Detroit, and three high school teachers, two from public schools and one from a private school. Three of the teachers had their classes complete the assessments online and the other two teachers gave the assessments as hard copy. As in the 2011 assessment, the control group students were all from southeast Michigan, but the experimental group was drawn from several states participating in Robofest.

The pre-assessment was opened January 30, 2013, and closed on February 17, 2013. The post-assessment was opened April 29, 2013 following the last qualifying competition (first round), and closed on May 21, 2013 (following the final event of the Robofest 2013 competition season).

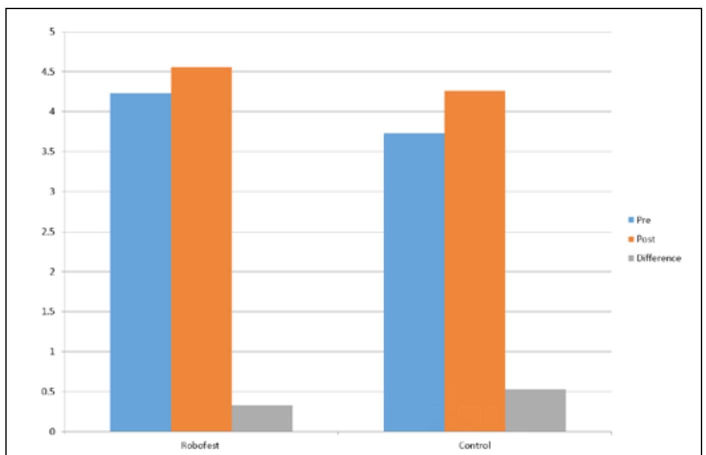
Results and Discussion

For the 2011 assessment, scores from the multiple-choice test (15 mathematics questions) from 4^{th} to 12^{th} grade students who did and did not participate in Robofest 2011 were analyzed. The pre-assessment comparison was comprised of 164 students who participated in Robofest (the experimental group) and 47 students who did not participate (the control group). The post-assessment comparison involved a subset of students who completed the pre-assessment: 51 Robofest students and 40 Control students. As shown in Figure 4, Robofest students' mean mathematics scores improved from 7.19 to 7.94 ($p < .10$), while mathematics scores from students in the control group actually decreased slightly ($p > .10$). These results suggest that mathematics scores are improved through participation in robotics competitions, but since no science, engineering or technology questions were included, a stronger conclusion regarding STEM scores in general cannot be reached.



(Figure 4) Robofest 2011 math assessment results

For the 2013 assessment, scores from the multiple-choice test (6 math, 1 science, and 1 engineering) from 5^{th} to 12^{th} grade students who did and did not participate in Robofest 2013 were analyzed. The pre-assessment comparison was comprised of 167 students who participated in Robofest (the experimental group) and 104 students who did not participate (the control group). The post-assessment comparison involved a subset of students who completed the pre-assessment: 75 Robofest students and 102 Control students. As shown in Figure 5, Robofest students' mean STEM scores improved from 4.23 to 4.56 ($p = .19$) and STEM scores from students in the control group improved from 3.74 to 4.26 ($p < .10$) .



(Figure 5) 2013 Math, Science and Engineering Assessment results

The higher participation rate from the control group (98 percent of the control group students took both the pre- and post- tests while only 45 percent of the Robofest students that took the pre- test also took the post-test) was a result that the control group took these assessments as part of their regular classroom, while the Robofest students took these assessments outside of the classroom. The control group students' average grade increased from 7.89 to 7.91 from the pre- to the post-test, while the Robofest students' average grade decreased from 7.17 to 6.55. The experimental group shows that even though the average grade actually decreased, which would tend to decrease the scores, the average scores still increased even though the population in the sample was younger. The Robofest students, even though they were younger on average, had higher average scores for both the pre- and post-tests.

There are several limitations to this study. The control and experimental groups came from fairly different populations. The control group was localized to southeast Michigan, and had a gender balance close to that of the U.S. population (45 percent female). The experimental group had much greater regional diversity (the actual diversity is unknown because of the anonymity of the survey and the self-selection process) but had the gender imbalance more typical of those pursuing STEM majors (24 percent female). The experimental population also appeared to be more naturally inclined to STEM (82 percent on average identified themselves as "somewhat" or "very interested" in STEM) while only 57 percent on average of the control group was "somewhat" or "very interested" in STEM, with no statistically significant change in opinion in either population from pre- to post-test. Another limitation may have been a lack of motivational factor for the students to do well on the assessments. There was no concrete incentive to students in 2011, and we had hoped that offering a raffle prize to 2013 students might have encouraged them to take the assessment more seriously, but we do not see that the results indicated that the possibility of a raffle prize was enough of an incentive.

Conclusion and Future Research

This research demonstrates that pre-college students who participate in Robofest, a robotics competition that stresses autonomous robots, computer programming, unknown problems, and mathematics and science, achieved higher STEM scores, although there is not conclusive evidence as to how these benefits compare to children who do not participate in a robotics program. We believe that robotics competitions modeled after Robofest have the potential to improve STEM learning and the following factors of the Robofest competition contributed to the achievement in STEM scores for students in the experimental group:

- Explicit math components in the game competition
- Unknown problems in the game competition
- Judging criteria requiring using Math and Science components in science fair like Exhibition and RoboFashion & Dance categories

To explore more fully the characteristics of robotics competitions that promote STEM learning, future research is warranted that compares STEM score differences between:

- Autonomous robotics vs. non-autonomous robotics competitions
- Games that provide fixed rules vs. Exhibitions which is open-ended

References Cited

Barker, B.S., & Ansorge, J. (2007). Robotics as means to increase achievement scores in an informal learning environment, *Journal of Research on Technology in Education, 39*(3), 229–243.

Bers, M.U., & Portsmore, M. (2005). Teaching partnerships: Early childhood and engineering students teaching math and science through robotics. *Journal of Science Education and Technology, 14*(1), 59-73.

Cejka, E., Rogers, C., & Portsmore, M. (2006). Kindergarten robotics: Using robotics to motivate math, science, and engineering literacy in elementary school. *The International Journal of Engineering Education, 22*(4), 711-722.

Chambers, J.M., & Carbonaro, M. (2003). Designing, developing and implementing a course on LEGO robotics for technology teacher education. *Journal of Technology and Teacher Education, 11*(2), 209-241.

Chung, C. (2010). RoboParade – An opportunity to develop your imagination while having fun. *Robot Magazine, 78-79*.

Chung, C. (2011). ROBOFEST 2010 - Little robots perform big missions for STEM. *Robot Magazine*, 60-65.

Chung, C., & Anneberg, L. (2003). Robotics contest and computer science and engineering education. *Proceedings of ASEE/IEEE Frontiers in Education (FIE) 2003 Conference*, November 5-8, Boulder, CO.

Chung, C., & Sverdlik, W. (2001). Robotics education in the K-12 environment. *Proceedings of the American Association for Artificial Intelligence Spring Symposium Series*, March 26 -28, 2001, Stanford University, CA, 37-45.

Crocker, N. E. (2011). Robofest 2011 vision centric challenge update, *Robot Magazine,* November-December, 80-83.

Groff, B. H., & Pomalaza-Ráez, C.A. (2001) Robot Omnium Horarum: A robot for all seasons. *Proceedings of the American Association for Artificial Intelligence Spring Symposium Series*, March 26 -28, 2001, Stanford University, CA.

Kolberg, E., & Orlev, N. (2001). Robotics learning as a tool for integrating science technology curriculum in K-12 schools. *Proceedings of the 31st Annual Frontiers in Education Conference*, October 10 -13, 2001, Reno, NV, 1, 12-13.

MacLennan, J. (2010). Robofest 2009 - Motivating young minds to master the machine. *Robot Magazine*, 70-73.

Martin, F. (2000). Robotic explorations: A hands-on introduction to engineering. Prentice Hall. 1st edition.

Matson, E., DeLoach, S., & Pauly, R. (2004). Building interest in math and science for rural and underserved elementary school children using robots. *Journal of STEM Education*, 5 (3&4), 35-46.

Nourbakhsh, I., Crowley, K., Bhave, A., Hamner, E., Hsium, T., Perez-Bergquist, A., Richards, S., & Wilkinson, K. (2005). The robotic autonomy mobile robots course: Robot design, curriculum design, and educational assessment. *Autonomous Robots, 18*(1), 103–127.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas.* New York: Basic Books, Inc.

Ricca, B., Lulis, E., & Bade, D. (2006). Lego Mindstorms and the growth of critical thinking. *Intelligent Tutoring Systems Workshop on Teaching With Robots, Agents, and NLP.*

Robinson, M. (2005). Robotics-driven activities: Can they improve middle school science learning? *Bulletin of Science, Technology & Society, 25*(1), 73-84.

Rogers, C., & Portsmore, M. (2004). Bringing engineering to elementary school. *Journal of STEM Education, 5*(3&4), 17–28.

Silk, E.M., Higashi, R., & Shunn, C.D. (2011, June). Resources for robot competition success: Assessing math use in grade-school-level engineering design, *Paper to be presented at the annual meeting of the American Society for Engineering Education*, Vancouver, BC, Canada.

Trudell, E., & Chung, C. (2009). Development of methodologies to assess the impact of autonomous robotics competitions in science, technology, engineering, and math education. *Proceedings of the International Technology, Education and Development Conference (INTED 2009)*, March 9-11, 2009, Valencia (Spain).

Wagner, S.P. (1998). Robotics and children: Science achievement and problem solving. *Journal of Computing in Childhood Education, 9*(2), 149-192.

Weiss, S. (2004). Teachers' knowledge and skills are key to improving student achievement in science, math. *The Progress of Education Reform, 6*(1), Education Commission of the States.

Whitman, L.E., & Witherspoon, T.L. (2003). Using LEGOs to interest high school students and improve k12 stem education. *Proceedings of the 33rd Annual Frontiers in Education*, November 5-8, 2003, 2, F3A 6-10.

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Dr. Matthew Cole is Assistant Professor in the Department of Management and Marketing, Chair of the Institutional Review Board, and Co-Chair of the Research Support Services Committee at Lawrence Technological University. Dr. Cole teaches Business Statistics, Research Design-Quantitative Methods, Industrial/Organizational Psychology, and Principles of Management. He received his Ph.D. from Wayne State University (Detroit, MI) in Cognitive and Social Psychology across the Lifespan (CaSPaL), where he conducted research on longitudinal growth modeling of risk behaviors and perceptions among adolescents from the U.S. and Vietnam. Dr. Cole also holds an M.A. in Biopsychology from Wayne State University, and an M.S. in Clinical Behavioral Psychology from Eastern Michigan University.

APPENDIX 1

Robofest Post-Assessment 2011

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.

Q0: Did you take the Robofest Pre-Assessment?
If you did not take the Robofest Pre-Assessment in January ~ Feb, 2011, do NOT take this assessment
A. Yes (Go on to question 1)
B. No (Do NOT take this assessment)

Q1: What grade are you in?
A. 5th Grade or below
B. 6th Grade
C. 7th Grade
D. 8th Grade
E. 9th Grade
F. 10th Grade
G. 11th Grade
H. 12th Grade

Q2: What is your gender?
A. Male
B. Female

Q3: How many years of Robofest robotics experience do you have?
A. none
B. less than one year
C. one year
D. two years
E. three years
F. four or more years

Q4: Did you compete in Robofest 2011?
A. I competed at a Robofest Qualifying event in 2011
B. I did not compete in Robofest in 2011

Q5: If your dad drives 50 miles per hour for 2 hours, how many miles did he drive?
A. 25
B. 50
C. 100
D. 250
E. I don't know

Q6: 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?
A. 30 miles per hour
B. 60 miles per hour
C. 120 miles per hour
D. 180 miles per hour
E. I don't know

Q7: What is the perimeter of a rectangle with width 4 ft and length 5 ft?
A. 9 ft
B. 18 ft
C. 20 ft
D. 40 ft
E. I don't know

Q8: How long will it take a robot to move around a track if it is moving at a constant speed of 3 meters/second and the entire track is 720 meters long?
A. 4 min
B. 8 min
C. 12 min
D. 24 min
E. I don't know

Q9: A toy car moves forward 16 cm for one rotation of two identical wheels. How many rotations are needed for the same toy car to move forward 64 cm?
A. 4
B. 16
C. 48
D. 80
E. I don't know

Q10: Choose one that is not correct
A. 12 is greater than 9.8
B. 9.8 is less than or equal to 12
C. 3.4 is less than 5.7
D. 5.7 is greater than or equal to 9.8
E. I don't know

Q11: Bob can only eat apples and oranges to survive. He has 14 apples and 15 oranges. Bob must eat 2 apples and 3 oranges a day to survive. How many days can Bob survive?
A. 5 days
B. 7 days
C. 10 days
D. 12 days
E. I don't know

Q12: What is the radius of a circle when its circumference is 20 cm?
A. 2.52 cm
B. 3.18 cm
C. 6.37 cm
D. 125.66 cm
E. I don't know

Q13: What is the length of the diagonal of a square if the distance from the center to a side is 8 cm?
A. 16 cm
B. 23 cm
C. 64 cm
D. 128 cm
E. I don't know

Q14: In a nested loop, the outer loop contains two inner loops. Each inner loop is programmed to play a sound. If the outer loop is executed five times, and one inner loop is executed four times and the other three times, how many sounds will be played by the nested loop?
A. 12
B. 17
C. 35
D. 60
E. I don't know

Q15: If the distance traveled is 28 cm at 3% power, and the distance traveled is 43 cm at 6 % power, which of the following is the correct formula for distance vs. percent power?
A. $3x - 15$
B. $5x + 13$
C. $13x-5$
D. $15x+3$
E. I don't know

Q16: If y gives distance as a function of percent power, and the line of best fit has the equation $y = .4x + 13.5$, what is the distance traveled when power is 50 %?
A. 13.5
B. 33.5
C. 63.9
D. 91.25
E. I don't know

Q17: 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?
A. 1.27
B. 2.55
C. 8
D. 15.23
E. I don't know

Q18: The sum of two integers (a and b, where $b > a$) is 21. The ratio of the these integers is 2/5. What are the two integers?
A. a=2, b=5
B. a=3, b=7
C. a=6, b=15
D. a=7, b=14
E. I don't know

Q19: What is the mean for the following list of values: 17, 11, 17, 12, 15, 19, 12, 17
A. 11
B. 15
C. 17
D. 19
E. I don't know

APPENDIX 2

Robofest Post-Assessment 2013
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.

Q0 ONLY take this test if you also took the pre-assessment in February. Type in the same nickname you used for the pre-assessment in the text box below.

Q1 What grade are you in?
A. 5th Grade or Below
B. 6th Grade
C. 7th Grade
D. 8th Grade
E. 9th Grade
F. 10th Grade
G.11th Grade
H. 12th Grade

Q2 What is your gender?
A. Male
B. Female

Q3 Are you interested in a career or job involving Science, Technology, Engineering, or Mathematics? (one or more of the four areas?)
A. Not at all interested
B. Probably not
C. Not sure
D. Somewhat interested
E. Very interested

Q4 If your dad drives 50 miles per hour for 2 hours, how many miles did he drive?
A. 25
B. 50
C. 100
D. 2500
E. 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 120, what is the average speed of your mom's car?
A. 20 miles per hour
B. 40 miles per hour
C. 50 miles per hour
D. 100 miles per hour
E. I don't know

Q6 Choose one that is *not* correct
A. 5.7 is greater than 9.8
B. 5.7 is less than or equal to 9.8
C. 3.1 is less than or equal to 3.1
D. 6 is greater than or equal to 3.1
E. I don't know

Q7 What is the radius of a circle when its circumference is 40 cm?
A. 3.14 cm
B. 6.37 cm
C. 12.73 cm
D. 251.33 cm
E. I don't know

Q8 If the circumference of a circle is 20 cm, what is its area (in square millimeters)?
A. 31.83
B. 125.7
C. 400
D. 3183.1
E. I don't know

Q9 What is the area of a right triangle with sides of lengths 5, 5, and 7.1?
A. 12.5
B. 17.1
C. 25
D. 177.5
E. I don't know

Q10 If a little gear is driving a big gear (this is called gearing down), then the big gear will
A. Spin faster, and have decreased torque
B. Spin slower, and have increased torque
C. Spin faster, and have increased torque
D. Spin slower, and have decreased torque
E. I don't know

Q11 If you use a light sensor with reflected light mode, which of the following will reflect the smallest amount of light back to the sensor
A. black electrical tape, 2cm away
B. black electrical tape, 10 cm away
C. white computer paper, 2 cm away
D. white computer paper, 10 cm away
E. I don't know

Q12 Enter a passcode using your birth date in MMDD format. (for example, Jan 30 would be 0130). You will need this passcode to claim a raffle prize if you are the winner.