Do K12 robotics activities lead to engineering and technology career choices?

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Using Robotics as a Tool to Engage Students in Technical Curriculum

Abstract

Student engagement is a necessary but complicated variable within STEM education, especially when dealing with technical curriculum. There are fewer curriculum resources available for teachers which are structured around a Technology and Engineering (T & E) STEM focus, and integrating robotics activities into teaching strategies for technical subjects provides an exciting and relevant learning platform. Experiential, "hands-on", programs that incorporate robotics provide practical experiences that positively influence a student's academic pursuit of STEM, and may help "hook" youth into technical college and career pathways and ultimately, the technical workforce. Students working with robotics have the opportunity to experience a team-based learning environment and are introduced to "real" engineering thought processes using problem based learning approaches on a robot with predictable behavior patterns. Students exposed to these types of experiences in a controlled environment gain an increased appreciation for the application of STEM topics learned in the classroom, and are introduced to the technical and engineering world of work and the challenges and successes that engineering teams face in their careers.

Potential Benefits of Integrating Robotics into Technical Curriculum

This paper discusses practices that expose students to the types of experiential activities that working with robotics provides. Findings using perception outcomes from students and their parents about one type of popular robotics experience, summer "robotics" camps, are shared. While robotics activities provide a way for teachers and students to integrate technology and engineering into secondary technical, science and mathematics classes, these activities are typically not offered as part of traditional school curriculum. Thus, reliance on early exposure to robotics through camps, clubs, afterschool programs, and competitions help introduce students to the world of automation and high tech industries. Exposure to robotics at an early age is also a first step toward the preparation of tomorrow's highly skilled workforce for advanced manufacturing industries.

Employers throughout the U.S. continue to struggle with finding skilled workers who can contribute to their economic growth and competitiveness (Society of Manufacturing Engineers (SME), 2012). Through robotics camps, students have the opportunity to explore high tech industrial careers and inventive concepts and applications that would help provide a pipeline of workers to help fill the gap in the American workforce (Lord, 2010). Kids, teachers, and parents alike seem to be interested in robots and technology; almost everyone loves to see robots in action, but how are they relevant, perhaps even critical to Science, Technology, Engineering, and Math (STEM) and technical education?

A positive perspective towards high tech college and career pathways is supported by the use of robotics as a tool to engage students. Many times students are unaware of the interesting, high tech, and well paid nature of jobs in fields such as advanced manufacturing, and early exposure can help dispel the myths of "dirty work" which still cloud perceptions of today's modern advanced manufacturing environment. Hands-on, problem based learning activities such as those featured in robotics camps for kids and workshops for teachers can provide practical experiences that positively influence a student's academic pursuit of STEM. Learning coupled with "hands on" activities and applications with robots helps put practical meaning behind STEM school curriculum: in pre and post surveys collected from 510 students attending summer robotics camps, there was a + 51% positive change after attending the robotics camp for student ratings of "very familiar (4)" or "extremely familiar (5)" for familiarity with science, technology, engineering/robotics, mathematics (STEM) courses needed in middle and high school in order to prepare for careers in engineering and advanced technology college programs. Awareness of career options in advanced manufacturing saw a + 108% positive change after attending the robotics camp for student ratings of "very aware (4)" or "extremely aware (5)." A positive trend was also noted in perceptions of how realistic students feel careers in advanced manufacturing are for women, likelihood of taking a course in engineering, technology, or robotics in school next year, and career interest in advanced manufacturing. Camps helped 87.5% of surveyed students better understand how science, technology, engineering, and math (STEM) are used in industry, and 78% of students surveyed expressed that learning to program the robot by thinking logically will be "Very (4) or Extremely

(5) helpful when solving other problems in science, technology, engineering, and math (STEM) subjects in school (Table 1.).

Table 1. Pre and Post Robotics Camp Surveys (n=510)

Scale for Surveys:

1=Not at all 2= A Little 3= Somewhat 4= Very 5= Extremely

PRE CAMP SURVEY QUESTIONS	Question	1	2	3	4	5	Total
6. Please rate your awareness of career options in advanced manufacturing.	6	53	130	173	114	40	**510**
7. Please rate your interest in a career in advanced manufacturing.	7	37	131	163	123	56	**510**
8. Please rate how realistic you feel careers in advanced manufacturing are for women.	8	15	43	190	142	120	**510**
9. Please rate your familiarity with the Engineering Technology AS Degree program.	9	248	128	71	39	24	**510**
10. Please rate your familiarity with science, technology, engineering/robotics, mathematics (STEM) courses needed in middle and high school in order to prepare for careers in engineering and advanced technology college programs.	10	56	109	146	129	70	**510**
11. How likely are you to take a course in engineering, technology, or robotics in school next year?	11	38	78	99	129	166	**510**
12. I've been considering a career in advanced manufacturing or related technical industries.	12	21	52	212	135	90	**510**
POST CAMP SURVEY QUESTIONS							
1. Please rate your awareness of career options in advanced manufacturing.	**1**	11	23	133	190	131	**488**
2. Please rate your interest in a career in advanced manufacturing.	**2**	28	88	182	102	88	**488**
3. Please rate how realistic you feel careers in advanced manufacturing are for women.	**3**	8	21	144	140	175	**488**
4. Please rate your familiarity with the Engineering Technology AS Degree program.	**4**	110	99	135	96	48	**488**
5. Please rate your familiarity with science, technology, engineering/robotics, mathematics (STEM) courses needed in middle and high school in order to prepare for careers in engineering and advanced technology college programs.	**5**	28	39	120	145	156	**488**
6. How likely are you to take a course in engineering, technology, or robotics in school next year?	**6**	26	49	97	106	210	**488**
7. I am now considering a career in advanced manufacturing or related technical industries.	**7**	21	48	162	155	102	**488**
8. The camp helped me better understand how science, technology, engineering, and math (STEM) are used in industry.	**8**	1	9	51	197	230	**488**
9. The field trip helped me make the connection between the camp activities and real world applications.	**9**	5	9	88	219	167	**488**
10. Programming the robot helped me to see how automated systems are programmed and controlled.	**10**	2	3	40	205	238	**488**
11. Learning to program the robot by thinking logically will help me when solving other problems in science, technology, engineering, and math (STEM) subjects.	**11**	4	14	89	216	165	**488**
12. The camp provided opportunities for teamwork and collaborations with others.	**12**	8	9	51	178	242	**488**

Prop Open a Door to Support Student Interest in Technology

Robotics opens a door for students interested in technology, and often this door is first opened through summer robotics camps. A next step after "camp" may be after school clubs or after school competition programs such as those promoted by FIRST® Robotics, whose vision includes "inspiring young people to be science and technology leaders by engaging them in exciting mentor-based programs that build science, engineering and technology skills that inspire innovation" (FIRST, 2015). Summer camps, after school clubs, and robot competition activities are growing in popularity (Vermillion, 2014). Why? Kids love robots! And when students ask to be part of an activity that teaches not only STEM curriculum, but emphasizes learning and teamwork, parents love robots too. 96.2% of over 200 parents responding to satisfaction surveys over the past five years were very or extremely satisfied with the camp and would recommend the camp to others. Any dissatisfaction typically centered on transportation logistics.

XXXXX's Robotics camps have been an important part of XXXXX outreach to middle and high school students since 2005. Supported by the National Science Foundation and supplemented by outside contributions, XXXXX Advanced Manufacturing/Robotics Summer Camp models and materials have provided a unique experience in advanced technology education for over 1,000 campers. In 510 collected post camp surveys, results from students report positive impact (Table 2).

Table 2. Student Perception Averages from Post Camp Surveys (n=510)

Scale for Surveys:

1=Not at all 2= A Little 3= Somewhat 4= Very 5= Extremely

	Question	Avg.
1. Please rate your awareness of career options in advanced manufacturing.	1	3.8
2. Please rate your interest in a career in advanced manufacturing.	2	3.3
3. Please rate how realistic you feel careers in advanced manufacturing are for women.	3	3.9
4. Please rate your familiarity with the Engineering Technology AS Degree program.	4	2.7
5. Please rate your familiarity with science, technology, engineering/robotics, mathematics (STEM) courses needed in middle and high school in order to prepare for careers in engineering and advanced technology college programs.	5	3.7
6. How likely are you to take a course in engineering, technology, or robotics in school next year?	6	3.9
7. I am now considering a career in advanced manufacturing or related technical industries.	7	3.6
8. The camp helped me better understand how science, technology, engineering, and math (STEM) are used in industry.	8	4.3
9. The field trip helped me make the connection between the camp activities and real world applications.	9	4.1
10. Programming the robot helped me to see how automated systems are programmed and controlled.	10	4.4
11. Learning to program the robot by thinking logically will help me when solving other problems in science, technology, engineering, and math (STEM) subjects in school.	11	4.1
12. The camp provided opportunities for teamwork and collaborations with others.	12	4.3

Day by Day in a Robotics Camps

The core of these robotics camps is a series of five robotic "challenges" that are based on fundamental science and math principles. After assembling the basic robot with simple directions students are introduced to robots used in industry and commercial application, especially those used in manufacturing. The goal in this early section is broaden the students' ideas about robots being primarily "humanoid". Dispelling this pop culture conception helps

motivate the young campers to expanding thinking about what their robots might be able to do. Students work in teams of two designing their challenge programs, testing and reworking with a limited time. Time constraints are a big part of working in modern industries. The engineering heuristic "do the best job you can do with the materials and information you have in the timeframe given" is the overarching experience of the robotics challenges.

The five challenges during the week are based on use of various sensors and sensor responses. All successful challenges require programs based on fundamental logic operations. In addition to these Boolean algebra based thought processes, most of the programming activities require the students to use basic math and related science principals. Students build their confidence as well as their knowledge base and skills over the week to end with a final, more integrated challenge. In addition to the robotics challenges, the students tour a high tech manufacturing facility in the local area, learn first hand about the manufacturing and high tech industry in Florida, explore 3D modeling and additive manufacturing, and participate in a simulated factory producing their own products in "company teams".

Table 3. Typical 5-Day Introductory Robotics Camp Block Schedule

Day	8 to 9	9 to 10	10 to 11	11 to 12	Lunch	1 to 2	2 to 3	3 to 4
1	Intro Orientation	Lesson #1 Robotics: What Do You Know? (1hr)	Lesson #2 Brief History of Robotics (30 mins)	Lesson #3 Introduction to Robotics (1 hr)		Lesson #4 Full Speed Ahead (1-2 hrs)	Made in Florida DVD, Website	Our Company.. Manufacturing Flip Chart
2	Report to group Hello My Name Is....	Lesson #5 Wheels and Distance (2 hrs w/ flex)	Team Challenge A The Bottle Touch (2 hrs w/ flex)	Team Challenge A cont.		Team Challenge A Recognize the winning team Reflection journals	Solid Works/3D Printing Introduction/Name Tag	Solid Works /3D Printing Introduction/Name Tag
3	Tour	Tour	Tour	Tour		Review (4&5) Lesson #6 Right Face (1-2 hrs w/ flex)	Lesson #6 cont./Team Challenge B Obstacle Course	Team Challenge B Obstacle Course
4	Team Challenge B Obstacle Course Reflection Journals	Lesson #8 Clap On Clap Off	Lesson #8 Clap On Clap Off Cont. Morning Break	Introduction to Team Challenge C Guided by Sound/Discuss the Variables		Team Challenge C Guided by Sound	Team Challenge C Guided by Sound Reflection Journals	Manufacturing Process Team Activity
5	Review Lesson #10 Follow the Guidelines (1 hr)	Lesson #11 Faster Line Tracking (1 hr) Morning Break	Team Challenge D (2hrs w/ flex)	Team Challenge D cont. Reflection Journals		Team Challenge E The Final Challenge		

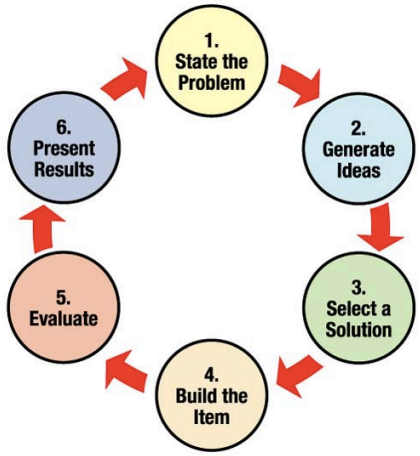
The Case for Bringing Robotics into the Classroom

Putting robots "through their paces" and troubleshooting results leads to a problem based learning approach which incorporates the engineering process for STEM students of all levels (Table 3.). Integrating the use of robotics into technical as well as into mainstream science and math curriculum provides a relevant way to explore high tech careers, and provides a way to introduce students to technical career pathways. Integrating academic standards and the higher level thinking skills associated with robotics provides an academic integration that can increase opportunities for students. Using robotics curriculum, students encounter problem based learning activities where they learn to design, troubleshoot, build, test, and evaluate the actions of their robot. Are robots not performing as anticipated? It's all part of the process. Failure can be an important part of the learning process. Robot simulations teach students that failing doesn't mean giving up; it means troubleshooting and redesign. A variety of math applications such as algebra, geometry, and trigonometry are involved in programming robots and discovering more efficient designs. Additionally, when comparing different robotic designs, students discover the relevance of scientific principles through hands-on experimentation and demonstration. Knowing or unknowing, during robotics activities, lessons or competitions, students explore the material properties, form and fit, precision measurements, inertia, center of gravity, force, momentum and many STEM principals. Activity-based robotics modules support

STEM, drive meaningful discussions, and provide career path information. Students gain real world experience by using problem solving, critical thinking, and communication skills as they work with their robots, such as applying the engineering process (NASA, 2015).

Table 4. Elementary Diagram of the Engineering Process (NASA, 2015)

1. State the Problem	• Explain the problem • Explain the guidelines • Set goals or desired results (teacher explanation)
2. Generate Ideas	• Brainstorm with others • Read books • Search the Internet
3. Select a Solution	• Sketches • Trial and error
4. Build the Item	• Use resources
5. Evaluate	• Test, revise; test, revise • Make adjustments/changes • Improve
6. Present Results	• Verbal explanations • Share models



Robotics camps are popular and effective for igniting students' interest in STEM college and career pathways. Imagine what could be accomplished if robotics were part of mainstream curriculum for K-12 students? School budgets may present an obstacle for providing state-of-the art "hands on experiences" using equipment in the classroom, a problem that has contributed to the technology and engineering gap in secondary technology education. Current models for incorporating technology into the classroom have high schools working in partnership with businesses and community and state colleges for laboratory resource sharing, dual enrollment for technology students, and partnerships with vendors (Boyette, Batton & Barger, 2014). Mentors from local companies provide technical acumen and explanations of how robots are used in industries such as manufacturing, and continue to provide encouragement for students seeking to enter technical fields upon graduation (Jackson, 2013).

Teacher Focus

Including robotics in technical programs can translate into STEM applications, awareness, and enjoyable experiences for students. However, education is managed and provided by instructors who are charged with motivating students to learn and grow. Therefore, it's important to engage the teachers themselves in robotics experiences and curriculum. By providing professional development workshops to K-12 educators, teachers "catch" the excitement and are better able to translate their enthusiasm into learning experiences for students. As a provider of professional development workshops nationwide, post workshops surveys that ask participants for topics of interest for future workshops return a consistent #1 answer…Robotics! Teachers eagerly embrace as many robotics and automated process experiences, as we are able to offer.

Introducing middle and high school teachers to advanced technology curriculum, such as 3-D modeling, and providing teachers with the background, learning resources, and partnerships they need to emphasis a Technology and Engineering, "sTEm", relevant curriculum using robotics and automated processes is key to offering robotics programs to students and is a critical consideration for promoting technology relevant robotics curriculum in schools. To this end, XXXXX hosts Engineering Technology Summer Institutes, Summer Camps for Teachers, and sTEm workshops for teachers. Teacher workshops in recruitment strategies for girls to STEM curriculum and "Green" technologies are popular with advisors as well as teachers, and al workshops promote advanced technology education strategies and skills. As a parent recently shared, "[robotics] is a program that should and could be incorporated in the school systems – it is learning, fun, and hands on which is needed in our students education." Involving all levels of education providers, as well as parents in awareness of the relevance of technology, engineering, and robotics is critical to building education programs that will supply tomorrow's high tech workforce.

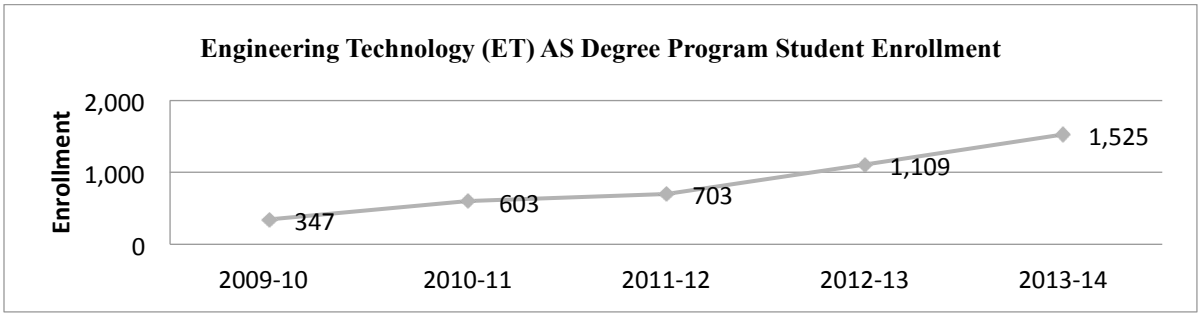
Florida's Statewide Scaffolding System for Technology Education

Does the use of robotics in the classroom move students toward STEM careers represents the baseline question of this paper. The answer to that question is yes! Motivating secondary student interest in STEM/technical coursework provides important stepping-stones toward high-tech careers. Robotics provides students with a means for exploring more advanced technical applications used in advanced manufacturing jobs such as robotic arms, programmable logic controllers, and motors and controls. Students must be exposed to career options in order to consider them as well as learn and practice their STEM skills.

In Florida there exists a scaffold that provides an integrated academic pathway for students interesting in pursuing any engineering-related technician career. Introductory programs in various STEM middle schools have a smooth transition to Career and Technical Education or Career Academies in high schools. The high school program in Automation and Production Technology (APT) provides viable entry path to the college and career pipeline for the advanced manufacturing industry. This program plus related adult vocational programs are both aligned with the Manufacturing Skill Standards Council, Certified Production Technician (MSSC-CPT). This articulation of national certifications into college coursework is now known as "the Florida Plan," with MSSC as the first, 2007, and example adopted articulated certification in Florida. The APT (with embedded MSSC) program is available for implementation by Florida high school programs, including dual enrollment, career academies, and technical schools. Secondary school students earning the MSSC as part of their program of studies earn 15 college credit hours toward the A.S. Engineering Technology degree supported by the Florida Department of Education and offered by colleges within Florida's State College System. Secondary students earning the MSSC are better equipped upon graduation to find good jobs due to holding a valuable industry recognized certification in addition to getting a significant jump-start on a college degree.

This scaffold of technical career path school programs is available to all students across the state, but attaching these young people continues to be challenging. In addition to robotics activities, summer robotics camps, robotics competitions and clubs, presentations, professional development for educators and industry tours, XXXXX's newly developed Engineering Technology (ET) Experience for high school students in XXXX's high tech engineering technology lab provides a model which is easily duplicated by other community and state colleges with high tech labs. All these experiences help raise awareness and change perceptions about technology and engineering education and careers. Students visiting the ET lab see and touch equipment that is used in modern industry and in the college programs with robots (such as the robot arm) in a starring role. Florida is seeing a steady and positive trend in engineering technology enrollment, and activities incorporating high tech initiatives such as robotics camps help support this trend (Table 4.) and help close the technical manufacturing skills gap.

Table 5. Enrollment Trend for Florida ET AS Degree Enrollment (14 Colleges)



Conclusion

While math and science subjects abound at the secondary level, technology and engineering subjects, especially in middle school, are typically harder to find. Robotics camps and extracurricular robotics programs are stepping up to fill this void in technical and engineering education for the average secondary school student. Parents of students enrolled in summer robotics camps have let XXXXX know, through surveys, that if schools offered technology, engineering, and robotics curriculum and coursework, then they would encourage their children to enroll in those technical programs. In response to this articulated need, XXXXX has developed curriculum focused on industry

connected high tech manufacturing scenarios (based on real Florida companies), written Best Practice Guides covering its robotics camps and tours to high tech industries, and has expanded summer robotics camp offerings to reach special populations.

The main idea behind XXXX's robotics camps is:

> *Technology is more fun when you actually know what is going on*, and based on the science, technology, engineering and mathematics needed to actually "know what's going on" with the emphasis on the T&E components of the camp's STEM activities. The camp's "*Tool"* is robotics, its "*Toy"* is the Lego Mindstorm™ robot, and its "*Trick"* is to dissolve the robots into an environment where the technology is the star and seeing the results of their own engineering decisions is the reason campers are having fun (Barger, Gilbert & Boyette, 2011).

While surveys from students and parents prove that summer robotic camps do indeed perform the "trick" of engaging students in technical curriculum and STEM studies, integrating robotics into the classroom environment would meet a need that camps and activities held outside of school may not. Robotics programs in the classroom would increase access supporting greater levels of student diversity and participation. Potential exists for students from underrepresented populations and varying abilities using robotics in mainstream school curriculum to be exposed to experiential learning which supports and strengthens foundational STEM as well as communication skills, and thus better prepares students for high tech careers. Using robots can support remedial work, such as mathematics, in a way that is fun, yet challenging. Gifted students are encouraged in high-level thinking and inventiveness. Robotics may also help integrate rigorous academic applications into technical education (CTE) courses. Through programming and using robots, students learn how to think critically, solve problems, explore, create, and apply what they have learned. Part of XXXXX's National Science Foundation mission is to provide education and experiences promoting Florida advanced manufacturing college and career pathways, and for many students, the educational technology punch packed by integrating robotics into mainstream curriculum and extracurricular activities is an ideal way to jumpstart the process.

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