STEM Education
Students Touch Space Through Free Robotics Programming Competition

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Abstract: This position paper discusses the use of the Zero Robotics Summer Program competition as a tool to teach programing to students in middle school (ages 11-14). The benefits of teaching programing at that age are discussed, including grasping the student attention early on and providing a useful skill. Zero Robotics is a free programming competition where students program microsatellites to compete with other student-programmed satellites in a virtual game using an online simulation. The finalists see their code compete on the SPHERES satellites aboard the International Space Station, during a final competition transmitted live. The game and curriculum teaches students physics, mathematics, and programming concepts. This position paper argues that it is possible to engage students in programing by providing the right incentive (space) through a competitive environment where teachers have a curriculum to back them up, without becoming a standard classroom exercise.

1 INTRODUCTION

Zero Robotics Middle School Program is a programming competition which culminates with the top teams demonstrating their software aboard the International Space Station (ISS). The Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES) are used inside the ISS, controlled by programs developed by grade-school students. The SPHERES satellites have operated aboard the ISS since 2006 to carry a wide range of algorithm development by graduate students (Saenz-Otero, 2005) (Wertz, 2000). Starting in 2009 the Zero Robotics program has leveraged the resources of SPHERES as a tool for Science, Technology, Engineering, and Math (STEM) education through a unique student robotics competition (Saenz-Otero, 2010).

Participants in Zero Robotics write their programs using an online programming environment accessed via a web browser, which does not require the installation of any special tools, nor the purchase of software licenses or entry fees. Thus, the "zero" stands for "zero-cost" and "zero-configuration" in addition to "Zero"-gravity. This no-cost model eliminates potential barriers that often limit the participation of under-served and under-represented populations in robotics competitions.

The program has grown over four years into an international tournament involving more than two thousand student competitors and has given hundreds of students the experience of running experiments aboard the ISS. The main goal of the program is to teach students STEM topics by showing them real world applications and opportunities for future involvement, to increase their awareness for space and technology, and to encourage them to explore these topics.

National Aeronautics & Space Administration (NASA), Defense Advanced Research Projects Agency (DARPA), and Center for the Advancement of Science in Space (CASIS) sponsor the Zero Robotics Middle School Summer Program. It is run by the MIT Space Systems Laboratory (SSL), the Massachusetts Afterschool Partnership (MAP), Aurora Flight Sciences Corporation (AFS), and Top Coder (TC). The Education Development Center, Inc. (EDC) led the 2013 curriculum development.

In 2013 the Zero Robotics Middle School Program expanded outside the state of

Massachusetts to include California, Florida, Georgia and Idaho. The 2010 Middle School pilot program utilized MIT undergraduate mentors who became daily instructors at each of the ten pilot locations. As ZR expands, the MIT mentor model is not sustainable and new methods of developing program quality must be applied. The MIT SSL and MAP partnered with EDC to develop and pilot a downloadable and free Zero Robotics curriculum geared towards middle school summer programs. The guide provides a structured outline of objectives and activities to support summer educators in presenting lessons and key concepts.

This paper presents the results observed from high school competitions and how the lessons learned have been applied to the middle school program. This position paper argues that it is possible for middle-school students to get interested in programing if (a) an exciting incentive, such as space, is used as initial attraction (b) the students are presented with a challenge/competition, and (c) the teachers are provided with a curriculum that does not require them to be an expert in computer science.

2 BACKGROUND

There are two different types of programming competitions, short-term competitions and long-term competitions. Short-term competitions usually take place over a day or weekend, and long-term competitions take place over several weeks or months. In this position paper, we will focus on long term programming competitions. For the purpose of this paper, our definition of middle school is grades six through nine (ages 11-14).

Programming competitions targeted towards middle school students are important for the following reasons:

1) *Students Need to Learn Programming because Programming Opens up a lot of Doors for Future Opportunities.*

According to Code.org, there are plenty of opportunities for students that learn programming. They estimate that there will be 1.4 million computing jobs by 2020, which equates to about $500 billion opportunity.

2) *Programming should be taught Starting in Middle School.*

Students must get involved in engineering and programing at a young age. There is precedent globally that students as young as first grade are capable of learning programming. Last year, the Estonian Tiger Leap Foundation (Wilson, R, 2012) launched a program called "ProgeTiiger" where programming is introduced to students starting in first grade. Estonia Tiger Leap Foundation decided to start this project because they saw how many companies struggle to find decent programmers. Estonia is proud of its programmers developing Skype, which has been acquired by Microsoft. ProgeTiiger starts in first grade. Therefore, it is not too early to start in middle school.

3) *We Believe that Teaching Students to Program by Competition is an Effective Method.*

The Zero Robotics Middle School Competition is based on the idea of gaming and wining. At the same time, it includes multiple features that encourage *friendly* competition. Field trip events bring students together, introducing students with similar interests to each other, creating a community of student programmers. Within this community, students support each other through messages in the Zero Robotics forum. This gives students a glimpse of collaboration, highly relevant to future careers at universities and in industry. In addition, the long-term competition format, gives students the opportunity to create and evolve their solutions similar to processes in universities and in industry. Microsoft Education blogger notes that long term programming competitions make students design well thought-out solutions that closely resemble industry or formal research tool development. (Microsoft, 2013)

2.1 Thesis

It is possible for middle-school students to get interested in programing if (a) an exciting incentive, such as space, is used as initial attraction (b) the students are presented with a challenge/competition, and (c) the teachers are provided with a curriculum that does not require them to be an expert in computer science.

3 IMPACT OF HIGH SCHOOL ZERO ROBOTICS COMPETITION

The Zero Robotics High School competition has attracted over 1500 students since 2009. Its initial growth in teams showed that even with a small number of schools that teach programing in the USA (under 10% of public schools http://code.org/stats), there is an attractiveness in having space as an

incentive. Feedback from participants presents individual data points that demonstrate the impact of space:

"A teacher in a local middle school has followed the progress of team y0b0tics! from their early days as a middle school FLL [First LEGO League] team through their current participation in ZR, on a poster that hangs in his science classroom. The poster's theme is "Start here…" (middle school FLL) and "Go here…" competing in ZR with your code being run by an astronaut on the ISS. Recently, my older son, Richard, attended an event at my younger son's school. While walking through the hall, a middle schooler approached him and said, "[You're] cool!" and explained recognizing him from the poster.

Mt. Olive High School in New Jersey, boasts a football team with 100+ participants and a robotics team with 125+ participants."

Other feedback addresses the ability to introduce new STEM concepts to students through the competition: "I never thought about programming, and wasn't interested in programming at all. However, the thought that I could control robots in space, especially in the International Space Station, caught my interest. And so I participated in Zero Robotics." The space incentive of ISS encourages and attracts students who never thought they could program or would be interested in learning programming. The program growth supports this positive impact. Zero Robotics started with only two teams in 2009, a total of thirteen students, and has expanded this year to 142 teams (includes both USA and European teams) with more than 1600 students.

The competition serves as an effective and incentivizing educational tool when compared to the traditional curriculum: "Several parents and students have expressed to me that ZR competition was one of the most important educational experiences of their entire career. In my opinion, students who participate have far greater understanding of physics, math, and programming than their peers after just a few weeks of a competition…I saw a big improvement in one student who joined the Zero team. For one thing, she now really understands vector concepts far better than other students, and vectors are fundamental to many different concepts in physics so this directly lead to her grades improving. It's on thing to memorize how to take a vector sum or a cross product. [It's] something else entirely to have to use those concepts to solve real problems you are faced with."

In addition, the competition format creates incentives for the students to dig deeper into the subjects: "The competition atmosphere encouraged me to learn as much as I could. Instead of just learning at team meetings, I looked up exercises and tutorials on my own time. Consequently, after the Zero Robotics season was over, I decided to take a formal computer science course. I felt that taking a formal course would enforce and expand upon concepts I gathered through on-the-fly coding during the Zero Robotics season.

"From the first day of my computer science class, I instantly noticed a distinct difference between coding concepts learned in school versus the ones I picked up over the course of Zero Robotics. The biggest difference would definitely be the motivation behind learning in the two different formats (Zero Robotics and traditional classroom setting). I was much more motivated in Zero Robotics because I had to make sure I kept up with students from other teams. The latest Zero Robotics Challenge always posed an interesting problem that required a solution that needed to be innovative. Exercises given in class were often tedious, lacking any real application to tasks one would do in the real world. As a result, I found the classroom methods to be extremely boring. For people driven by problem-solving and creative approaches to learning, I would recommend giving Zero Robotics a try. It definitely provides a fun way to learn something completely new like programming."

By working in teams, rather than individual competitions, ZR enhances the learning experience by encouraging collaboration: "I learned C entirely through Zero Robotics. … I learned to code for ZR while learning to code in Java, which helped in that there is a lot of cross-over. Aside from the generalities, the most crucial thing I learned from programming with ZR is that there are a lot of ways to do a task, so find the most efficient one. … and in general write code that other people on your team have to be able to understand and add to was definitely one of the biggest things I took away from ZR. …about collaboration. Learning to code with others can be a big challenge because most people learn to code on their own, and everyone has their own coding style. Like I said before, there are many ways to write the same program. Everyone wants to write it their own way, and programmers in general are very protective of their code. Learning to accept others' ideas and ways of writing is a valuable asset. In this way, ZR helped me a lot with group projects in robotics club and team programming competitions…"

The successes of the High School Tournament were implemented in the Middle School Summer Program:

- Maintain space as an incentive, including participation of the finalists aboard ISS.
- Make programming the central STEM objective.
- Maintain a *team* competition format which encourages collaboration.

The middle school program differs from the high school program in that it takes place over the summer (five weeks) and provides more support to middle school teachers via a curriculum of structured weekly activities.

4 COUNTERARGUMENTS TO MIDDLE SCHOOL

Counterarguments exists against teaching programing at the middle school level and using competition as a teaching tool. Literature review of the topic yields the following arguments:

1) *Middle School Students are too young to Understand Programming.*

In online blogs, parents advocate that middle school students should "enjoy their childhood years" and not be tied to the computer screen. Students should learn to follow their instincts, use their imagination, and not be taught the rigid world of engineering design (Farr, 2013). There is also suggestion that learning programming languages may sacrifice a student's ability to learn foreign languages (Koerner, 2013).

2) *Students are too young to be Competitive.*

Teachers involved in the Zero Robotics program provided feedback for the *elementary* school level (ages 6-11) that the focus of our program should be on problem solving and not competition.

"These students worked hard to get their programs to work…it would be nice to just 'see' how they did.

"The competition wasn't as important to the students as the sense of accomplishment from seeing that the student code worked."

4.1 Refutes to Counterclaims

Current events and industry activity review refutes the counterclaims:

- 17-year-old British developer Nick D'Aloisio's startup was acquired by Yahoo! D'Aloisio taught himself to code at age 12 (7th grade) and started developing iPhone apps in 2008. After launching his app, D'Aloisio received widespread attention from media and investors including actor Ashton Kutcher and Zynga founder Marc Pincus. (Fell, 2013)
- Microsoft held, Kodu, a game design programming competition, this year for students age nine through twelve. Since the competition, there have been one-half million downloads for the 16,000-plus kid-created games. (Microsoft, 2013)

5 ARGUMENTS IN SUPPORT OF MIDDLE SCHOOL

1) *Programming is an Important Skill for Middle School Students to Learn.*

As pointed out earlier, programming jobs are growing and there are many opportunities for students in the future. Thus, we believe that programming is an important skill for middle school students to learn. Further, by creating 'applications' for programing, students are exposed to other STEM skills such as math (algebra, geometry) and physics.

2) *Middle School Students are Developing Interests.*

Middle school students start developing hobbies before high school, therefore it is important to expose students to programming earlier. STEM research points out that one of the keys to successful education programs for students is to spark the interest of students in earlier grades. (Koerner, 2013)

Children are exposed to technology as early as age two. Toddlers play games and watch videos of themselves on iPads. Through these experiences, children are taught how to use them, but not how to program them. Not knowing how digital environments are constructed leads children to accept them at face value. Facebook is an example where kids think the function of Facebook is to help them keep in touch with friends. In actuality, Facebook users are now actually the product, the target of ads and marketing. Students should learn how to make tomorrow's software, not just about how to use today's software. (Rushkoff, 2012)

3) *Afterschool Programming Offers Opportunities for Middle School Students.*

Programming seems daunting to many students. It is often perceived as a hobby that only 'geeks' and 'nerds' pursue. Generally, students don't realize they are capable of learning to program themselves and shun away from it. Only a small percentage of students are exposed to computer science, and only 23% of those are minority. (http://code.org/stats)

STEM Afterschool Programs focus on providing services to underrepresented populations in STEM

fields, and many also focus on providing girls with exposure to science and female role models. (Afterschool Alliance, 2011)

Feedback from participating teachers reflects these statistics: "there is clearly a gender gap in these activities. That said, I believe that the more competitions/games that encompass STEM activities students are exposed to at an early age will tend to reduce the gap."

Therefore Zero Robotics aims to make the competition as accessible to as much of the population as possible. The competition has no entry free, requires no setup, and is free in the sense that all you need is a computer that has a web browser to compete. The rare opportunity for students to have their code run by astronauts in space is geared specifically to minority and underrepresented students at the middle school level. The program attempts to show that anyone can learn to code by providing a rich set of free step-by-step tutorials on our website.

6 CONCLUSIONS

Through review of current events, literature research, analysis of ZR program growth and participation, and substantial feedback from participants, it is possible to conclude that:

- Space and astronauts provide a clear incentive for middle-school students to participate in a programing competition, even if they had never thought of programing as something they could or wanted to do.
- Using a competition format encourages not only participation but also collaboration.
- Students learn to relate to each other in new ways, by working together in a common goal using their minds.
- A curriculum with clearly prescribed activities allows middle-school teachers to guide their students in learning programing

Based on the success, the Zero Robotics Middle School Summer Program will continue to expand.

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