Alpha-Robotics: A Multi-Disciplinary Approach to Teaching Engineering Concepts to K-2 Students

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Abstract

Boston Public Schools are piloting an innovative engineering curriculum called Alpha-Robotics. Alpha-Robotics was developed by Judy Robinson, a former Boston teacher with over 30 years of teaching experience. Ms. Robinson's unique background enabled her to develop a pre-engineering curriculum for K-2 students that integrates engineering, science, literacy, math, and 21st Century Skills.

By designing Alpha-Robotics to integrate multiple subject areas, the curriculum is proving to be attractive to teachers and administrators who are often pressed with the decision of fitting numerous lessons and activities into the tight school schedule.

The Alpha-Robotics curriculum consists of 17 hands-on lessons where students design and build original ideas using LEGOs and other materials while exploring math concepts such as number recognition, circumference and diameter, fractions, measurement, graphing and variables. Science concepts integrated in the curriculum include wheels and axles, friction, data collection and analysis. Reading skills are incorporated using LEGO vocabulary. Students also get an overview of engineering disciplines such as mechanical and civil engineering. In the final lessons, students program their LEGO robot to do simple tasks, getting a glimpse into computer science concepts. Students work in teams throughout the curriculum, fostering their 21st Century Skills. Teachers involved in the pilot have reported improvement in students' communication, teamwork, and problem solving skills.

Two Boston schools have adopted the Alpha-Robotics curriculum by having at least 50% of their K-2 teachers trained and teaching the curriculum. Four other Boston schools are offering the curriculum to at least one class. In this paper, we will introduce the Alpha-Robotics curriculum, provide an overview the professional development program for teachers and illustrate how the curriculum ties to Boston and Massachusetts standards.

Background

TechBoston is a department within Boston Public Schools whose mission is to provide advanced technology opportunities for students. As such, we have been instrumental in bringing LEGO robotics to Boston Public Schools over a decade ago and have continued to support teachers and students through professional development, competition opportunities, and robotics kit loans programs.

Several years ago, we received a request from a teacher who was participating in our robotics workshop that she wanted to teach engineering and robotics to her kindergarten students. Until then, robotics had been primarily taught in middle schools, with some elementary schools introducing it in upper grades (grades 3-5). At the time, TechBoston did not have a curriculum unit that was appropriate for kindergarten students. Judy Robinson, a retired Boston Public Schools teacher was working with TechBoston as a consultant to help new robotics

teachers. Ms. Robinson took on the task of writing a curriculum that was appropriate for K-2 students.

Alpha-Robotics was developed with a several goals in mind. First of all, we wanted the curriculum to be aligned with BPS's K-2 curriculum, particularly in science and math. We envisioned employed a multidisciplinary approach that would also address 21st Century skills such as teamwork and creativity. The Engineering Design Process, part of Massachusetts Science and Technology/Engineering Frameworks, will be used throughout the curriculum. LEGO robotics system was chosen as the main tool because these materials were already in used by schools was readily accepted by young students.

The curriculum was first piloted at the John P. Holland Elementary School in Dorchester in a kindergarten class with English language learners and at the Dennis Haley Elementary School in Roslindale in a computer class. In the second year, the program was expanded to the Sarah Greenwood K-8 School in Dorchester. This year, the program has expanded further to a K2 classroom at the Maurice J. Tobin K-8 School in Roxbury and a computer class at the James Otis Elementary School in East Boston. Two schools – the Sarah Greenwood K-8 and the Holland Elementary – have shown school-wide commitment by opting to have the majority of their K-2 teachers trained in Alpha-Robotics.

The following sections describe the curriculum in greater detail, including overview of the lessons and the rationale behind the curriculum design.

Alpha-Robotics Curriculum

The Alpha-Robotics curriculum consists of 17 lessons, each about 60 minutes long. The original set of lessons is designed for students in kindergarten and first grade, and an advanced set of lessons are being developed for second graders. A typical implementation involves an Alpha-Robotics lesson once a week, with the whole curriculum lasting about a half year.

The first lesson lets students simply explore several LEGO pieces to familiarize themselves with the pieces. They also begin to build their LEGO vocabulary using a song. Three commonly used LEGO pieces -- bricks, beams, and plate -- share the letters "b" and "p" which are often confused by young students due to similarity in shape. By stressing these vocabularies, students also learn to differentiate between these often-confused letters.

In the second and third lesson, students continue to explore LEGO pieces. They are introduced to the profession of Engineering through a PowerPoint presentation. Students work in teams of two to use the LEGO pieces to create their own invention. The Engineering Design Process, part of the Massachusetts Science and Technology/Engineering Frameworks, is introduced and is used throughout the curriculum.

The first three lessons focused on getting familiar with the pieces and vocabulary and making stationary objects. Throughout these lessons, tools such as puzzles and visual aids are used to assist teaching and learning. Continued emphasis is placed on using correct LEGO vocabulary. In these lessons, they also learn to distinguish the different LEGO sizes by counting the "studs" on top of the pieces. This reinforces their counting and sorting skills.

In lessons 4 and 5, students are given additional parts (i.e., wheels and axles). They are introduced to the new vocabulary and spend time designing and building a simple car that rolls down a ramp. The students learn to measure the distance traveled by the car by using a measuring tape.

Students work in teams or pairs in all Alpha-Robotics lessons. For many kindergarteners, this may be their first experience working in teams, and many may encounter challenges in sharing materials and/or tasks. Lesson 6 addresses this issue. In Lesson 6, students work in teams to build a tall tower using materials such as paper plates and tape. This activity is designed so that one needs more than two hands to complete the task, thus requiring the students to help each other in order to successfully complete the challenge.

Lesson 7 introduces students to a new concept: circumference and diameter. They look for round objects in the classroom and help each other measure the diameter and circumference of various objects. In addition to being an early introduction to these mathematical concepts, this lesson is also a practice in measurement and number sense. Armed with this new knowledge of diameter and circumference, students revisit their car design in Lessons 8 and 9. In these lessons, students systematically change their car design by using wheels of different diameters. They let the car roll off a ramp and measure the distances traveled. By comparing the distances traveled by cars having different wheels, students come to a conclusion that cars with larger wheels travel further because they have a larger circumference. (There are, of course, other factors such as friction and moment of inertia, but we will not discuss that here.)

By now, students have gotten used to working in teams and have a basic understanding of designing and building moving objects with LEGOs. In Lesson 10, they are introduced to the electronic components of the LEGO robotics system -- the RCX or NXT, and the motors. RCX or NXT are the programmable "brain" of LEGO robotics system. Since building with motors can be tricky, students receive building instructions for making a simple car with two motors. Building a car by following instructions may seem like a trivial task, but for young students, it is an accomplishment nonetheless. In Lesson 11, touch sensors are attached to the car to allow students to navigate the car through a simple obstacle course.

In Lessons 12 through 15, the students learn how to program their cars using Robolab. Robolab is a simple graphical programming language that allows users to program their LEGO RCX and NXT. In Robolab, each command is represented by a corresponding icon, which are placed in sequence to create a program. In Alpha-Robotics, Robolab Pilot is used, which is the simpler of the two Robolab interfaces.

Programming is first introduced as a simple game with students, themselves, reacting to icons (commands) put up by the teacher. In this way, students get accustomed to a very important programming concept that actions (i.e., move forward or stop) happen in response to specific commands. The students also learn the specific visual icons that represent commands. The actual programming begins with a very simple task of programming their car to move forward for certain amount of time, then stop. This one-step program is simple but the activity is very rich. Students compare how far the car travels when they vary the time, which reinforces their number sense and measurement skills, as well as teaches them the use of "variables." Students also represent their results using a simple bar graph, which introduces them to graphing. In addition to varying the time that the car travels, the students also learn to vary the power setting of the motors (while keeping time constant). This allows the students to control a second variable.

As a final programming challenge, students move on to a two-step program and are asked to make the cars do whatever they want -- go forward, backward, stop, etc. The two-step program can also be looped so that it repeats itself indefinitely. During this exploration, many students discover that they can make the car turn by turning on just one motor or by making the two motors turn in opposite directions.

While programming is not typically taught in K-2 and students are not expected to learn programming at such early age, we feel that including these final lessons have been very important for students. Knowing that they can make the robotic car do exactly what they told it to do is a thrilling and empowering experience for young students. They also learn to look at a complex sequence of events and break it down into step-by-step process. It also teaches them problem solving and troubleshooting, which is an important life skill. Furthermore, it introduces students to the field of computer science, which can be a successful career path for some of the students.

Second Grade Version

The original Alpha-Robotics curriculum was designed for students in kindergarten through second grade. However, as schools began adapting the curriculum, we were faced with the question of "what do we do when students who already learned Alpha-Robotics in kindergarten become 1st and 2nd graders?" The second grade version of the curriculum was developed in response to this question. (In 1st grade, students will re-learn the curriculum that was covered in kindergarten.)

The second grade version is not a completely new set of lessons; rather, it is based on the original curriculum with a few modifications. Some parts of the curriculum are identical to the original. For example, in the first lesson where students are given time to freely build using LEGO pieces, second graders are asked to build an insect. In the process, they discuss characteristics of insects such as symmetry. This topic was chosen for 2nd graders because it aligns well with what they are learning in science.

Also in second grade, students learn a little more about engineering disciplines, specifically civil and mechanical engineering. They learn about what civil engineers do, and spend a lesson building something that could have been created by a civil engineer. The following lesson introduces mechanical engineering in the same manner. Other changes include modifications to handouts and worksheets for the 2nd graders to include larger numbers and/or more graphing, and a lesson on fractions.

Feedback and Challenges

Feedback from teachers who have used the Alpha-Robotics curriculum (K-2 classroom teachers and computer teachers) has been very positive. Teachers have reported an increase in students' communication and teamwork skills, problem solving skills, and number sense. One teacher, who taught students with learning disabilities, commented how she was surprised to see her students able to focus and stay on task for 2 hours during an Alpha-Robotics lesson. One teacher said in a survey, "The area that I saw was the most beneficial was the idea that engineers have to try again and try again to make something work."

Despite the success, Alpha-Robotics also has challenges. The main challenge is materials. Classrooms need to be equipped with LEGO robotics kits and at least several computers in order to implement the curriculum. In schools with more than one classroom using Alpha-Robotics curriculum, we suggest that the kits be shared between the classrooms for improved cost performance. We also encourage and assist schools to seek grants to support the program.

Conclusion

Boston Public Schools is interested in creating K-12 engineering pathways by developing pre-engineering units for each grade level. Our goal is to enable students to develop an early awareness and interest in engineering and to structure opportunities for them to pursue this interest. Alpha-Robotics is an important first piece in this pathway.

While Alpha-Robotics has been received positively by schools, we need to measure students' math and science test scores, as well as track their interest in engineering, in order to fully study the impact of the program.

Author Biographies

Haruna Hosokawa is the Program Director for Middle School Initiatives at TechBoston, part of Boston Public Schools. Her prior experiences include working as a mechanical engineer and teaching engineering classes at a university. In BPS, her roles include curriculum development and professional development in engineering and robotics and organizing the annual Robotics Olympics for the Boston Public Schools. She has a Master's degree in Mechanical Engineering from Tufts University. Contact: TechBoston, Boston Public Schools. 55 Malcolm X. Blvd. Building 1, Roxbury, MA 02120. Phone: (617) 635-8801 E-mail: hhosokawa@techboston.org.

Judy Robinson is currently a robotics curriculum consultant to TechBoston. She has created a highly successful multi-disciplinary pre-engineering curriculum for kindergarten to second grades now being piloted in the Boston Public Schools. She taught in the Boston Public Schools for 33 years as a science teacher, reading specialist, special education teacher, and an elementary teacher. During her tenure there, she achieved Lead Teacher status, was awarded several Pioneer grants and gave several workshops on science and technology related curriculum. She has an undergraduate degree from American University, and two master's degrees in education from Boston Teacher's College and Antioch Putman. E-mail: judyrobinson@alpha-robotics.com.