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Charlotte Corbett, MA, earned her master's degree in educational technology and leadership from George Washington University. She has taught technology-based classes with deaf and hard of hearing students for nine years at HMS. A child of deaf parents, she loves exploring the integration of language and technology.

Building Bridges, Robots, and High Expectations

By Fiona Bennie, Charlotte Corbett, and Angela Palo

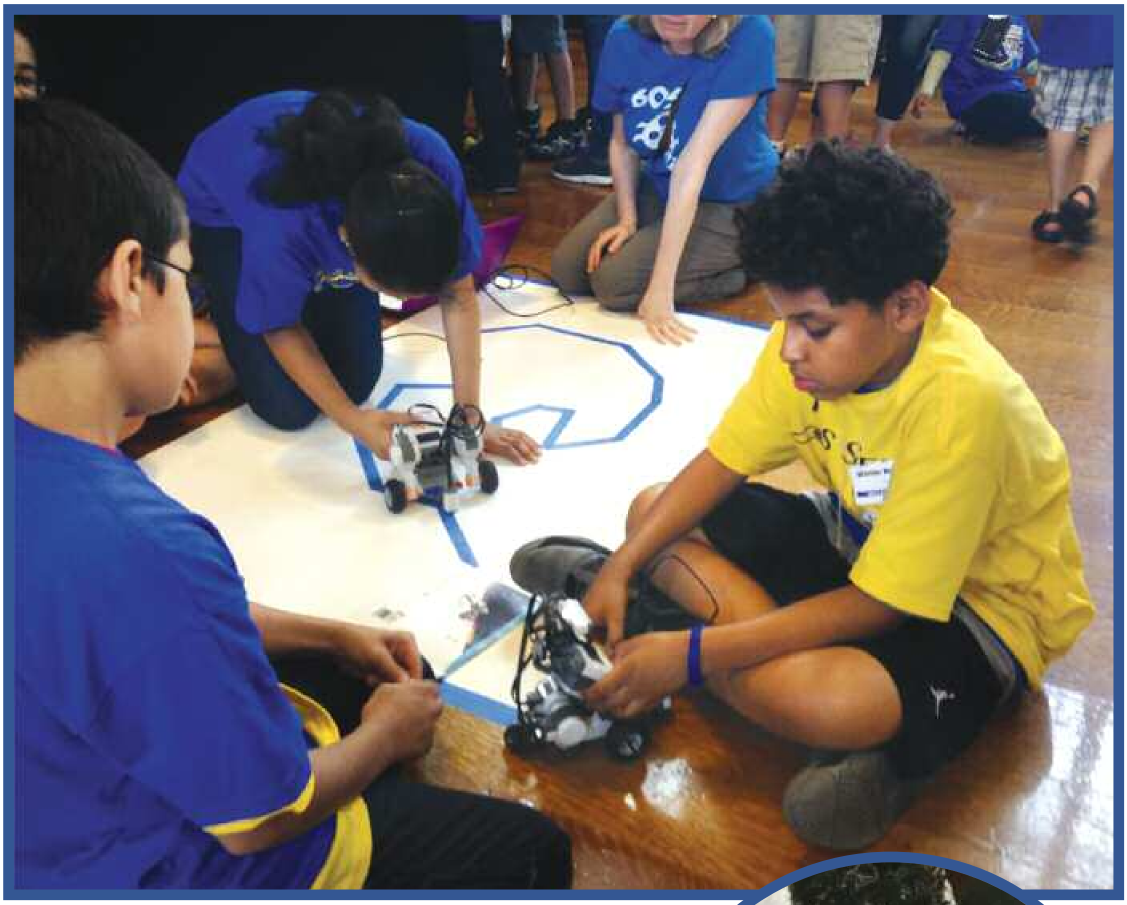
Robots! They bring to mind the world of the future, in which the landscape is populated with autonomous walking, talking machines—machines known to our students as "transformers." At the Horace Mann School for the Deaf (HMS), the oldest public day school for deaf students in the United States, 40 of our students, almost half of the student body, participated in an after-school program where they not only imagined these machines but created them.

Originally a club, the Deaf Robotics Engineering And Math Team, or the DREAM Team, became an official school activity last year. All 20 of our HMS students in grades three through five participated as well as 20 more in grades six through eight. We met weekly for two hours after school for two months. During the first hour, we used a curriculum guide from Engineering is Elementary, an educational component of the Museum of Science, in Boston, to face the challenge of building bridge prototypes. During the second hour, students worked to develop their own LEGO robots with the goal of competing in the Boston Public Schools Robotic Olympics. During both hours, students explored activities related to science, technology, engineering, and math—the STEM areas that promise exciting possibilities for future careers.

One of the elementary students' tasks: to create and build a bridge prototype and, as a separate challenge, construct functioning robots. The bridge was built over the course of several weeks as students learned about and engaged in the engineering design process. For both the bridge and the robot design challenges, students identified the problem; brainstormed solutions; planned, created, and tested a prototype; and then improved their original designs.

The elementary students also used LEGO NXT and WeDo LEGO kits to build and program robots to perform simple actions with gears and levers. For example, young computer programmers set and modified the rate at which the seesaw they built would rise and fall; similarly, those who used LEGO to create monkeys could set up a drum for their monkey to bang and control how rapidly the monkey would bang it. The Mindstorms NXT kit allowed older students to build more complicated devices. For example, students built one device in

Photos courtesy of Fiona Bennie, Charlotte Corbett, and Angela Palo



which a sensor could distinguish colors.

Both challenges required students to follow and create diagrams and engage in the engineering design process. At the same time, as they worked together they developed skills in what we call the five C's:

- communication
- collaboration
- critical thinking
- cooperation
- creative problem solving

The program allowed students to put the five C's into practice.

Building Bridges

Learning Through Narrative, Teamwork, and Hands-on Creation

The elementary students engaged in engineering through *To Get to the Other Side: Designing Bridges*, from the curriculum developed by the Museum of Science. We selected this unit because of its use of personal narrative. Research indicates that personal narratives may help students who are from minority affiliations "to identify with or apply themselves to more technical studies or the physical sciences" (Cunningham & Lachapelle, 2014). In our narrative, the main character,

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Javier, builds a bridge to get to his island where he maintains a play fort. We saw Javier's blended family and Salvadoran culture as an added plus.

Using what they learned about bridges and the engineering design process in reading about Javier, students explored how forces act on different structures, including beams, arches, and suspension bridges. Students worked in teams to think critically, discuss their ideas, and design and construct their own bridge prototypes. When they were finished, HMS held an engineering expo. This allowed students to share their work with—and show it off to—the rest of the school.

Robotics

Competing Citywide

When the students began work on making robots, experimental play was part of the instructional design, and students freely explored their LEGO Mindstorms NXT kits and their programming potential. Once one student mastered a particular programming trick, he or she was quick to share the new skill with others.

We knew that we wanted the students to compete in the annual Boston Public Schools Robotic Olympics so we had them construct robots based on themes from the competition. Students picked their Olympic challenge and worked in teams on designs and prototypes.

Students found that most of the designs they developed initially would not quite work and required additional tinkering. For example, the line-following robot could turn left but not right. Students analyzed this. They figured out what worked, what didn't work, and how their robots could be better designed just like professional engineers would. We worked with the students to help them understand that valuing failure builds the determination, the "grit," that allows them to make the most of their education. We took heart from Cunningham and Lachapelle's (2014) statement that "A student doesn't fail; a particular design fails" (p. 125). Understanding that learning means taking risks empowers students to make changes, to keep thinking, and to keep trying. It fosters an attitude and a mindset that is valuable throughout life.

In the end, we were pleased and proud of our students, the robots they developed, and their performance in the citywide Olympics. In fact, several of our students won Olympic awards:

- **Muna Abanoor**, a third grader, and **Janelys Rodriquez**, a fifth grader, placed second in what turned out to be the most popular event of the competition, the "Freedom Trail." In this category, students designed robots that advanced along a blue line, as do Boston visitors who follow the Freedom Trail, a path of bricks that winds through the historical sites of America's founding.

After-School Engineering and Robotics Support Students' Learning

Here are just a few of the standards that we address in our after-school program.

NGSS: Engineering and Design Standards

Elementary School Level

3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Middle School Level

MS-ETS1-1	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-2	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
MS-ETS1-3	Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
MS-ETS1-4	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

CCSS
RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

RST.6-8.3
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

- **Mohamed Abanoor** and **Andy Chow**, seventh graders, placed third. Everyone enjoyed their entry in the "Boston Tea Party" event, in which student-designed robots pushed miniature boxes of tea over the edge of a 15" boat without allowing the robot to fall over the edge, too.
- **Shawne Johnson**, a third grader, won first place in the "Fenway Park Challenge." He designed a robot that swung and hit a miniature baseball, and it rose the highest of all up the Green Monster, the famous wall in Fenway Park.

Seeing their work, Jeremiah Ford, our principal/headmaster, was impressed. "I just hope that they don't replace me with a computer," he chuckled. Ford noted that education in STEM at HMS allows our students to look at engineering as a solution-based tool; further, it brings equality and opportunity to our deaf and hard of hearing students.

The STEM Future

On Our Screen

The STEM program is underway this year and will continue at HMS. Each year the theme will be different and the program will focus on a different engineering challenge. This year students are working as ocean engineers, designing underwater submersibles. In upcoming years, the program will include engineering challenges in the environmental and biomedical fields. Students who attend HMS will have three years of experience in STEM studies.

Our goal is that they gain knowledge and skills in STEM fields, develop skills in communication and teamwork, and develop a broader understanding of engineering careers. Participation in this program allows students to excel at academically rigorous

tasks, feel a sense of accomplishment, and experience the camaraderie that comes with being part of a team. We hope these experiences will ignite a passion and confidence in more of our students to pursue a profession in STEM. We expect to see them thrive.

For more information, visit *www.eie.org/eie-curricul um/engineering-design-process*.

The teachers and staff at HMS extend their deepest thanks to the following organizations and individuals without which/whom our program would not have been possible: Amelia Peabody Foundation, Boston Public Schools, Machine Science, Raytheon, TechBoston, Randee Pascall-Speights, Elsa Herrera, Kristin Osborne, Jeremiah Ford, Jeremy Ford, Melissa Chiet, Violeta Calderon, and Maximo Moya.

Reference

Cunningham, C. M., & Lachapelle, C. P. (2014). Designing engineering experiences to engage all students. In S. Purzer, J. Strobel, & M. Cardella (Eds.), *Engineering in pre-college settings: Synthesizing research, policy, and practices* (pp. 117-142). Lafayette, IN: Purdue University Press.

Doing Engineering—

A BLUEPRINT FOR THE CLASSROOM

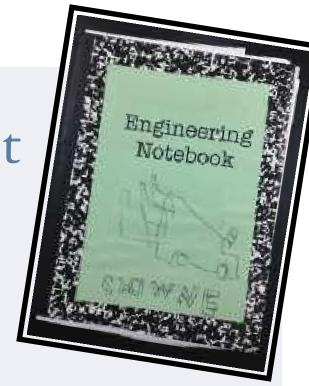
While every design process is different, our students followed the steps developed by the Engineering is Elementary Project of the National Center for Technological Literacy at the Museum of Science in Boston. Using their engineering design process, we challenged students to:

- **Ask:** First, the students defined the problem. They discussed how others had approached it. They discussed the constraints of their solution. They brainstormed and researched, working together as a team.
- **Imagine:** Once they realized that there were multiple ways to solve a problem, the students shared their ideas with each other, explored the ramifications of each possibility, and selected the best one.
- **Plan:** After selecting their design, the students, like their professional counterparts, developed diagrams, made a list of materials, and planned their prototypes (i.e., robots and bridges).
- **Create:** As their projects moved from conception, to design, to reality, the students put together their robots and their bridge prototypes.
- **Improve:** The students were encouraged to critique their final products. What worked? What didn't? How could their designs be improved?

This model—really a listing of the philosophical underpinnings of the work we do in the classroom—is critical because the cycle is followed not only by students in classrooms but by scientists and engineers every day on the job throughout the world. Experience with this process provides students not only with a blueprint for their work in the classroom but for their professional lives as well.

More information about the Engineering is Elementary Project can be found at *http://eie.org/overview/engineering-design-process*.

A Closer Look: Measuring Program Impact



By Fiona Bennie, Charlotte Corbett, and Angela Palo

In order to measure the impact of our after-school engineering experiences, we tested our elementary students before and after they participated in the program—and testing revealed that our students improved their attitudes about engineering and understanding of what it meant to be an engineer. Further, the girls changed their attitudes most dramatically, from a negative perception to a positive perception. Classroom observations and students' engineering notebooks showed that students also improved their engineering vocabularies in both English and American Sign Language (ASL).

ENGINEERING CONCEPTS

Our elementary students demonstrated a stronger understanding of engineering; they showed increased knowledge that creativity and math are important aspects of an engineer's work. Replying positively to phrases such as "writing reports for other engineers is important," students showed an improved understanding that communication is critical. Having used engineering notebooks throughout the project, students recognized that writing, organizing, and communicating ideas were highly important to the engineering design process.

GENDER DIFFERENCES

Remarkably, prior to entering the program, gender differences in attitudes toward technology and engineering between male and female students were significant. The pre-test showed girls' interest in professions in science, technology, engineering, and math—the STEM professions—began decreasing as early as second grade. By third grade, a significant gap had developed as girls showed far less interest in engineering than boys.

After their experience with the DREAM Team, the girls who took the post-test showed that this gap was reduced; there was significant improvement in girls' attitudes toward engineering as a field of study. On 14 of the 15 attitudinal measures, girls showed increased interest in and appreciation for engineering. After participating on the DREAM Team, ratings for girls shot up on statements such as:

"I would enjoy being an engineer when I grow up."

"I would like a job where I could invent things."

"Engineers help make people's lives better as part of their job."

INCLUSION OF DEAF ROLE MODELS

A critical benefit of the program was the inclusion of deaf adult role models and partners. These role models—Randee Pascall-Speights, Elsa Herrera, and Kristin Osborne—explained many of the concepts, including those implicit in the engineering design process, in clear academic ASL. A deaf high school student, Maximo Moya, served as a mentor for our middle school DREAM Team and also provided an ASL role model. This created a collaboration of teachers with expertise in content and deaf role models with expertise in ASL that supported student learning. The adults benefitted, too, as hearing teachers learned conceptually correct ASL and deaf mentors learned engineering principles.

By having sophisticated language users on staff, students became conversant in the vocabulary of engineering. Since students were introduced to appropriate vocabulary, they were able to clearly communicate. The sign vocabulary enabled them to better interpret both the two-dimensional diagrammatic representations and the three-dimensional LEGO parts of the robots they would build.

The modeling of academic ASL also increased students' understanding of the engineering storybook *To Get to the Other Side: Designing Bridges*, which students frequently referenced both while collaborating with each other and while recording ideas in their engineering design notebooks. Team leader Pascall-Speights read the text aloud in ASL to the elementary students. She used technical vocabulary, appropriate grammar, handshapes, and directionality to help students develop a deeper understanding of engineering concepts.

In summary, objective measures administered before and after the students participated in the program showed the following positive impacts:

- the experience helped all students better understand the field of engineering,
- participation enabled female students to feel more positive about engineering, and
- the deaf adult volunteers helped students develop academic vocabulary in ASL and English.

Subjective observations merit consideration as well. Teachers observed students working together, maintaining attention, and accepting suggestions from each other to develop new ways of looking at a problem.

Perhaps Maximo summarized best what the students learned, remarking, "There's never just one right answer or way of thinking about things. Being creative means thinking with an open mind. Looking at the world and imagining different possibilities is how to be a creative person."