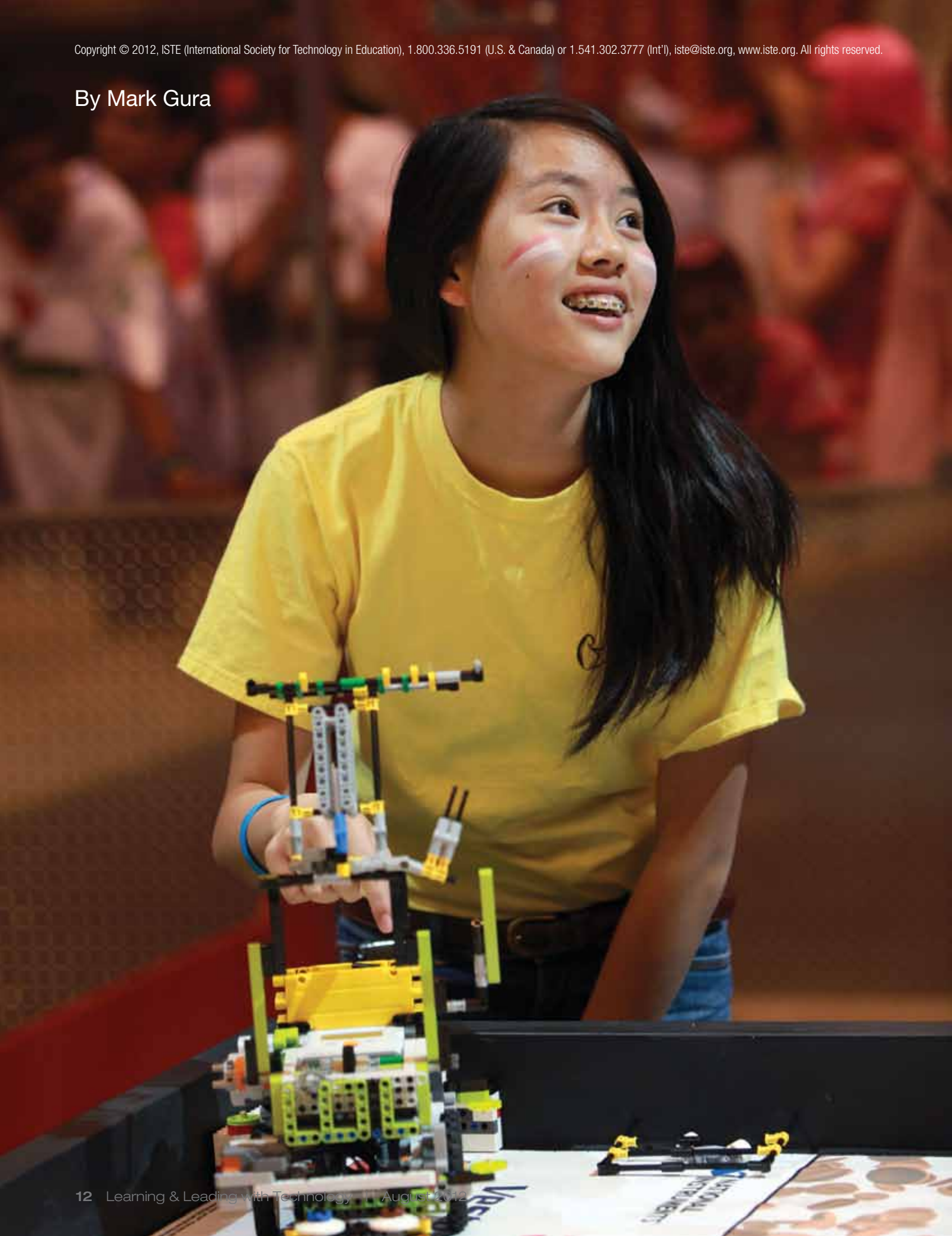


By Mark Gura



# Lego Robotics: STEM Sport of the Mind

Lego Robotics is not just for after-school clubs anymore. It's engaging and hands on, aligns with the NETS, and teaches students how to use digital age skills in the real world. In short, it's just what they need in the classroom.

I had come to the old stone building to observe a FIRST Lego League (FLL) qualifying competition. As I entered the public school that Saturday morning in New York City, I was expecting to witness a few dozen middle school robotics geeks putting their creations through paces that only fellow enthusiasts could appreciate. But nothing could have been further from the truth.

I was shocked when I opened the doors to find a huge, animated crowd. In addition to the members of the participating FLL teams that I expected to see, there was a roiling mass of enthused parents, classmates, and onlookers, all cheering wildly. Embedded STEM learning or not, this struck me as nothing less than a high-energy sporting event.

After thinking about it, that made sense. When Lego Robotics, with all its user-friendly technology resources and applications, is in its FLL role, it is very much a sport of the mind (see "A Day at FIRST Lego League," page 17). All the challenges, thrills, and satisfaction of traditional school sports are there. The kicker, though, is that the students involved are also experiencing some of the best

science, technology, engineering, and mathematics (STEM) learning opportunities available. And that's when it hit me: Why not harness this engagement and excitement in the classroom to get students excited about STEM?

## A Fun Way to Meet Standards

Schools often begin their involvement with Lego Robotics by establishing an after-school FLL club. FIRST, which stands for "For Inspiration and Recognition of Science and Technology," is an international not-for-profit organization that inventor Dean Kamen founded 20 years ago to engage students in hands-on, mentor-based robotics programs. FLL, one of four programs at FIRST (including Junior FLL for ages 6–9 and two high school programs), is for students ages 9–14. Once a group of students and a teacher or two have accrued some experience and confidence with Lego Robotics materials, they are ready to move on to the International FLL program.

Many would argue that FLL is the most popular and visible way that students participate in Lego Robotics. But often only a small number of a school's students participate in its robotics clubs and teams. That's why a crucial next step is implementing Lego Robotics in the classroom. This ensures that many more students reap the STEM learning benefits that Lego Robotics has to offer. Teachers around the world are beginning to implement Lego Robotics in a variety of ways in the classroom to provide rich, hands-on, standards-based STEM learning.



When students work on robotics projects, they learn important science and math concepts, including standards-based content and skills. Simple machines, for instance, is a core curriculum concept that is also an important part of many robotics activities.

But the great advantage of Lego Robotics is that it provides an alternative to learning from textbooks and teacher-driven, lecture-style lessons. Lego Robotics activities are hands on and experiential. In typical projects, such as constructing and programming a mobile robot to climb a ramp or lift a crane to move objects, students use wheels and axles, inclined planes, pulleys, levers, and screw gears. As students stretch their imaginations to come up with solutions to real-world problems, they are also learning the varieties of simple machines outlined in science standards.

In the classroom, these middle school students are learning standards-aligned science and math content while also building digital age skills such as collaboration, creativity, critical thinking, and problem solving.



### How Much Does It Cost?

Many experts agree that Lego Robotics projects work best when students work in pairs or groups of three to share materials (groups of four may also be functional but less ideal). Robotics kits come with enough parts and equipment for a single robot. These can be recycled for the next robot after completing a project. By multiplying the number of pairs or work groups by the price of a kit, you can approximate the cost for the class or group. See the Lego Education website (see Resources below) for the exact cost of kits, which currently are below \$300 apiece.

Students will also need access to computers or laptops to program their robots, and schools must purchase the programming software separately, although students can share.

To participate in FIRST Lego League, you'll also need to pay a registration fee (currently \$225 for each team) and purchase a Field Kit, which establishes the "field" or environment where the robots will perform their tasks, for under \$100. And you'll need an FLL Challenge table, which teams build themselves for \$75 or less. See your local FLL chapter website for up-to-date costs.

### Resources

Lego Education: [www.Legoeducation.us](http://www.Legoeducation.us)

Lego Mindstorms class package:

<http://tinyurl.com/6sepyko>

Lego Mindstorms Education NXT Base Set:

[www.Legoeducation.us/eng/product/Lego\\_mindstorms\\_education\\_nxt\\_base\\_set/2095](http://www.Legoeducation.us/eng/product/Lego_mindstorms_education_nxt_base_set/2095)

Lego Mindstorms Education NXT Software:

<http://tinyurl.com/89ptjhb>

In addition, few practices better embody the NETS than Lego Robotics, which give students opportunities to learn creativity and innovation, practice communication and collaboration, conduct research, use information, think critically, solve problems, make decisions, and use technology effectively and productively in ways that mirror the real-world work of scientists and engineers, for whom robotics is of increasing importance.

### Robotics for Science

At El Camino Junior High School in Santa Maria, California, USA, science teacher Luke Laurie, with the enthusiastic approval of his administration, has reworked the school's eighth grade science curriculum to add a robotics course to the traditional physical science course. Students get to choose the version they prefer. Students in the robotics course learn the same required curriculum that those in the regular science class do, except they learn it through the hands-on experience of designing and building robots, and then by reflecting on the processes and the discoveries they make along the way. Robotics has proven extremely popular, and its students

have shown significant growth and high levels of proficiency on standardized tests.

In Laurie's class, students solve problems that involve designing, building, programming, and operating robots to move from location to location and to carry and deposit objects, all within specified parameters. This involves the same type of problem-solving and decision-making thinking and work processes that professional roboticists perform as they create bots to perform industrial, domestic, social, medical, and military and security tasks.

In Pearl City, Hawaii, USA, Highlands Middle School teacher and technology coordinator Dwayne Abuel has trained science teachers from a number of schools to teach with the Lego Robotics NXT Mindstorms system, highlighting its use of sensors for data collection as part of the state's Stewards of the Island program.

Part of the regular daytime instructional program at 16 schools, the Stewards program applies contemporary science to traditional Hawaiian cultural activities centered on sustainable agriculture and maintaining the land. The result is a highly relevant,

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highly engaging, STEM-rich body of student activities.

Students in Abuel's class use Lego equipment to record temperature, soil moisture, pH levels of liquids, and ultraviolet emissions readings. They make decisions about which environmental factors to measure, which probes to use, and which approach would be effective in programming the mobile robotic processor for the specific job at hand. Then they use the processor they build to collect, download, interpret, and report the data, just like a professional environmental engineer/scientist would.

### Robotics for Math

Designing and programming a robot also involves math skills, including counting, measuring, and estimating—all required learning in pre-algebra and beyond. A typical project might involve constructing a robot to travel a set distance down a hallway, stopping to take temperature readings at set intervals of distance, and recording these measurements. To accomplish this, students would need to measure a robot's wheel circumference, calculate the number of revolutions required to have the robot travel a given distance, and use the icon-based programming software to direct its movements accordingly. It's

Robotics activities provide both meaningful challenges and the means by which to solve them.

a scenario much like what they would face if they worked for a real mining company that wanted to send a robot through a horizontal shaft to test the safety of the environment before following it with human workers.

### Robotics for Engineering

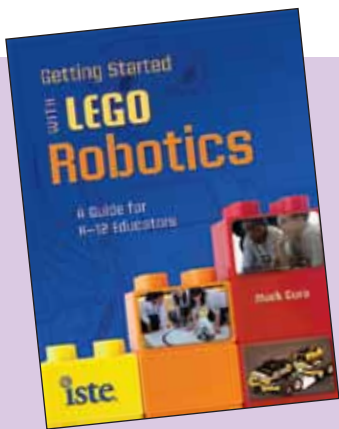
Lego Robotics weaves together subjects that would otherwise be taught in isolation. Bringing together science, math, and technology gives students exposure to engineering, which is the practical application of these subjects to solve problems. Robotics activities provide both meaningful challenges and the means by which to solve them, and they align easily with the Engineering Design Process, a framework that NASA recommends for learning and doing engineering. This eight-step process begins with identifying the problem and works its way through identifying criteria, brainstorming possible solutions, generating ideas, exploring possibilities, selecting an approach, building a prototype or model, and refining the design for a final solution.

Evan Weinberg taught high school physics, engineering, and math for

nine years at Lehman High School in the Bronx, New York City, New York, USA, and currently teaches at Hangzhou International School in Hangzhou, China. He's made extensive use of Lego Robotics in his engineering classes, an approach he finds to be highly effective for teaching engineering concepts, programming, and the design process.

He has also employed Lego Robotics as a demonstration tool in his AP Physics class to collect data from a rotation sensor as a Lego car accelerates from rest, which is an easy way to generate graphs of position and velocity versus time. In another activity, a Lego car moves according to a preprogrammed pattern, and students sketch their predictions for the graphs. The final part of this series involves students trying to move a car with a rotation sensor so that its position versus time matches a provided graph. Relating these graphs to the movement of an actual object is a fundamental concept emphasized in the AP Physics B curriculum.

Weinberg also uses Lego constructions to teach the relationship between force and torque. He's found a number of ways to apply Lego motors to electric circuit problems and calculation



## Read More about Lego Robotics

If you're interested in learning more about using Lego Robotics in your classroom or starting a FIRST Lego League club, check out ISTE's book on the subject, *Getting Started with Lego Robotics: A Guide for K-12 Teachers* by Mark Gura. Written for beginners, this book explains Lego Robotics in detail—what it is, what student activities look like, how to begin, how to manage a class, how robotics relate to standards, and much more. It includes more than a dozen interviews with educators, trainers, and students and makes a case for using Lego Robotics in STEM education. Order it at [iste.org/robots](http://iste.org/robots).

of power, which are important parts of the curriculum. One of his favorite lessons involves demonstrating that rotating a DC motor turns it into a generator, enabling students to generate electric currents to light an LED. When they connect two motors together and rotate one, the other motor also rotates but in the opposite direction. This is an application of Lenz's Law, which can be a tricky concept for students to understand without a hands-on demonstration.

### Hard and Soft Skills

Ian Chow Miller, a teacher at Frontier Junior High School in Graham, Washington, USA, teaches an Introduction to Robotics course. Students take it as an elective in seventh or eighth grade and

use Lego Robotics materials to learn two separate sets of skills—hard and soft.

The “hard” skills include gearing and gear ratios in the course's drag race competitions; basic engineering concepts, such as torque and acceleration; programming concepts, such as loops, forks, subroutines, and logic; and the use of light, ultrasonic, and infrared sensors. These skills change depending on what project the students choose, but Chow Miller feels that they are actually secondary to the soft skills they learn.

“Soft curriculum” learning is closely associated with digital age learning and the NETS. A big part of soft skills are the opportunities they provide for process learning, which is so important to STEM education. The Conceptual Framework for New Science Education Standards (from the National Academies) speaks of “key scientific and engineering practices” that all students should learn, such as “asking questions and defining problems, planning and carrying out investigations, and engaging in argument from evidence.” While these are difficult to learn in textbook-centered, traditional classrooms, they are aspects of learning that are central to robotics projects.

For instance, Chow Miller describes an activity his students do called the “Wave” that engages both their hard and soft skills: “Each class programs their robots to do a coordinated dance. Each class designs their own dance, and individual groups are responsible for figuring out how to program their robot to do their part but also have to coordinate with all the other groups in the class to be successful. Groups use math to figure out the timing to get their robots to perform in a perfectly choreographed manner.” (See Resources for a URL to a video of this activity.)

Chow Miller reports that his robotics students learn problem solving,

teamwork, math sense (understanding distance, time, power, force, etc., as opposed to just paper-and-pen calculation), thinking skills, working like an engineer, and how to reflect on and develop their own learning.

Chow Miller says, “The students remain engaged and excited throughout the course, and this is one of the only classes I have taught where students want to continue working past the bell.”

The class is so popular that they have had to turn students away. To meet the demand, every middle school in the district will offer a robotics class as an elective beginning in the 2012–13 school year.

Sure, Lego Robotics is hyper-engaging for students, but equally important are the ways that it moves STEM education into new and important territory. It's an opportunity for teachers to finally realize many long-sought instructional goals and ideals: problem solving, authentic student research and information gathering, real-world application of basic skills, and practical student collaboration. Lego Robotics is an ideal way to teach these skills while integrating STEM elegantly and authentically in projects that give students hands-on experience with the things they will need to know as digital age learner/workers in the world beyond school.

### Resources

FIRST: [www.usfirst.org](http://www.usfirst.org)  
Ian Chow Miller's “Wave” activity video:  
<http://tinyurl.com/6q4lkct>  
Lego Robotics Mindstorms:  
<http://mindstorms.Lego.com>



*Mark Gura was a middle school teacher for 18 years before becoming director of instructional technology for New York City Public Schools in New York, USA. He has developed several programs to establish Lego Robotics and FIRST Lego League in NYC schools.*