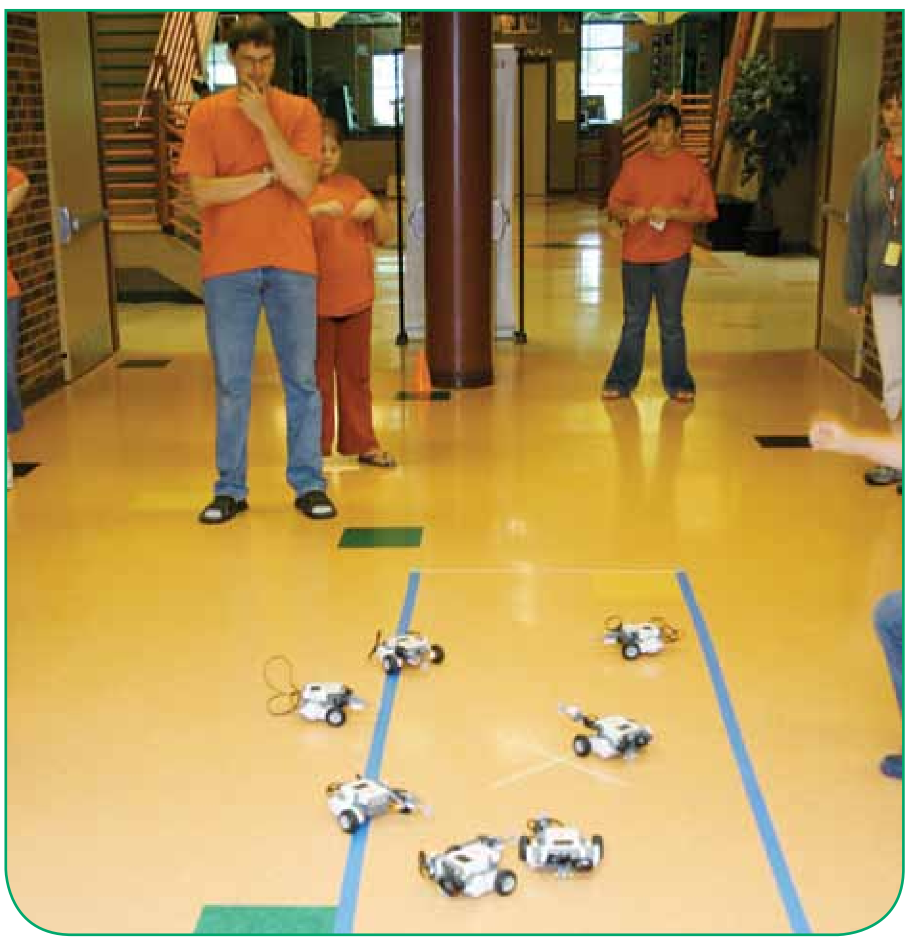
No Robotics in School? 4-H Can Help

By Bradley Barker and Richard Mahacek



There's no shortage of opportunities for young people to engage with robotics. They can participate in competitions, after-school clubs, summer camps, and even a few classes or mini-classes. But robotics activities can be expensive, often requiring pricey kits as well as computers to program the robots. That's why 4-H offers a way for students to learn about robotics and the connected science, technology, engineering, and mathematics (STEM) skills without a robot. We developed a program that allows students to learn about robotics in one of three ways:

- Participating in a virtual robotics environment
- Taking part in Junk Drawer Robotics activities using items found in a typical classroom
- Using off-the-shelf robotic kits

Our program, 4-H Robotics: Engineering for Today and Tomorrow, allows students to explore technology and engineering concepts using robotics and associated systems as an integrated theme. And they can do it with or without buying a robot.

Our goal in creating the 4-H robotics program was to give students and teachers flexibility in costs, materials, and subject areas by developing three diverse learning tracks. The program was developed by teachers, extension educators, engineers, and university researchers. It uses various technolo-

In the Robotics Platforms track, youth build and program their robots to complete a variety of tasks. In this image, the robots are navigating a maze.

Computer Science

A 4-H volunteer helps facilitate Junk Drawer Robotics activities as youth implement engineering designs they have created based on science concepts they have explored.

gies and delivery strategies to increase student understanding of basic physical-science concepts related to robotic systems, introduce the use of technology tools for learning and communications, and provide career exploration opportunities for students.

The Virtual Robotics track. We created this track using the Unity 3D game development tool, which allows students to build and test robots in a virtual robotics laboratory. The track contains 12 modules focused on physics, electricity and circuits, motors and gears, computer programming, sensors, and robot behavior. The learning experience includes videos, simulations, and animations. Students explore a virtual world representing an industrial environment and must employ robots to stop gas leaks and other disasters too dangerous, dirty, or dull for humans. While sensors on the virtual robots collect data about the environment, students maneuver their robots using keyboard controls and computer programming to deal with the industrial challenge.

The Junk Drawer Robotics track. This track guides students through the design, construction, and testing of robots using everyday objects. Students build working robots that lift, move, or float to explore topics such as robotics design and subsystems; mobile robotics, including constructing remotely operated underwater vehicles; and robot control and behavior, including basic programming and sensors. This track comes with a leader's guide, a student robotics notebook, and an optional supply kit of the basic components or everyday materials used to construct robots.

It focuses on three activity outcomes: learning (science), doing (engineering), and making (technology). These focus areas are not independent of one another. The structure of the track allows each focus area to be addressed separately yet highlights and reinforces the interconnections.

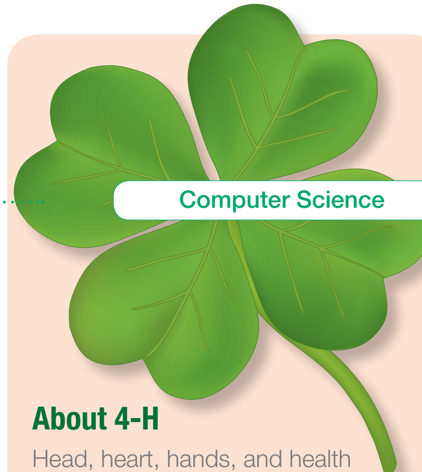
The lesson modules start with an exploration science learning activity. These activities allow students to build conceptual understanding by exploring scientific processes and information. Engineering design activities promote concept development of what students discovered in their exploration.

The design activities build on the knowledge students gained in the exploration by allowing them to solve a problem and overcome constraints.

The design phase promotes problem identification, framing, and solving as students work within the given constraints to engineer a solution to the challenge.

In the third phase, students apply these concepts using tools to construct a physical model. They strengthen their reasoning skills as they make and test their designs, observe solutions, find sources of failure, and consider redesigns. This iterative process of engineering and technology allows for deeper exploration into the concepts.

The three types of modules spotlight science, engineering, and technology while encouraging a scaffolding of learning as students work to understand the elements of robotics systems.



About 4-H

Head, heart, hands, and health comprise the four H's in 4-H, and they are the core values participants focus on while in the program. The U.S. Department of Agriculture, the National 4-H Council, and the 109 land-grant universities in the Cooperative Extension system provide leadership to the 4-H youth development network. 4-H engages kids ages 5–19 in a wide range of nonformal educational programming, including projects in the field of robotics. 4-H reaches more than 6 million youth annually in urban, suburban, and rural communities in every part of the country with out-of-school time science, engineering, technology, healthy living, and citizenship projects. Moreover, the 4-H learning environment emphasizes positive development and helps youth develop essential skills they will use throughout their lives, such as identifying interests, setting goals, communicating, leading, and giving back to their communities.

Engineering and technology play a vital role in the world economy, yet no U.S. engineering education standards exist to help guide program development, and scant research is available on existing levels of youth engineering proficiency. In 2008, the USDA 4-H National Headquarters responded to the lack of STEM literacy by establishing the 4-H Science, Engineering, and Technology Initiative. This initiative tasked a multistate collaborative with developing a 4-H robotics curriculum to engage the next generation of leaders in science, engineering, and technology.

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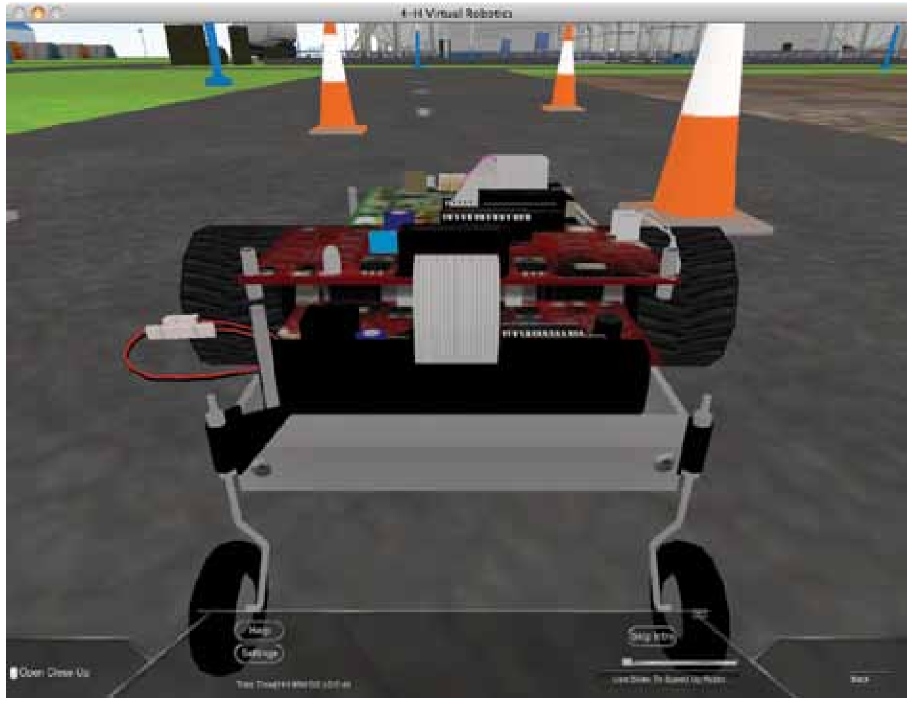
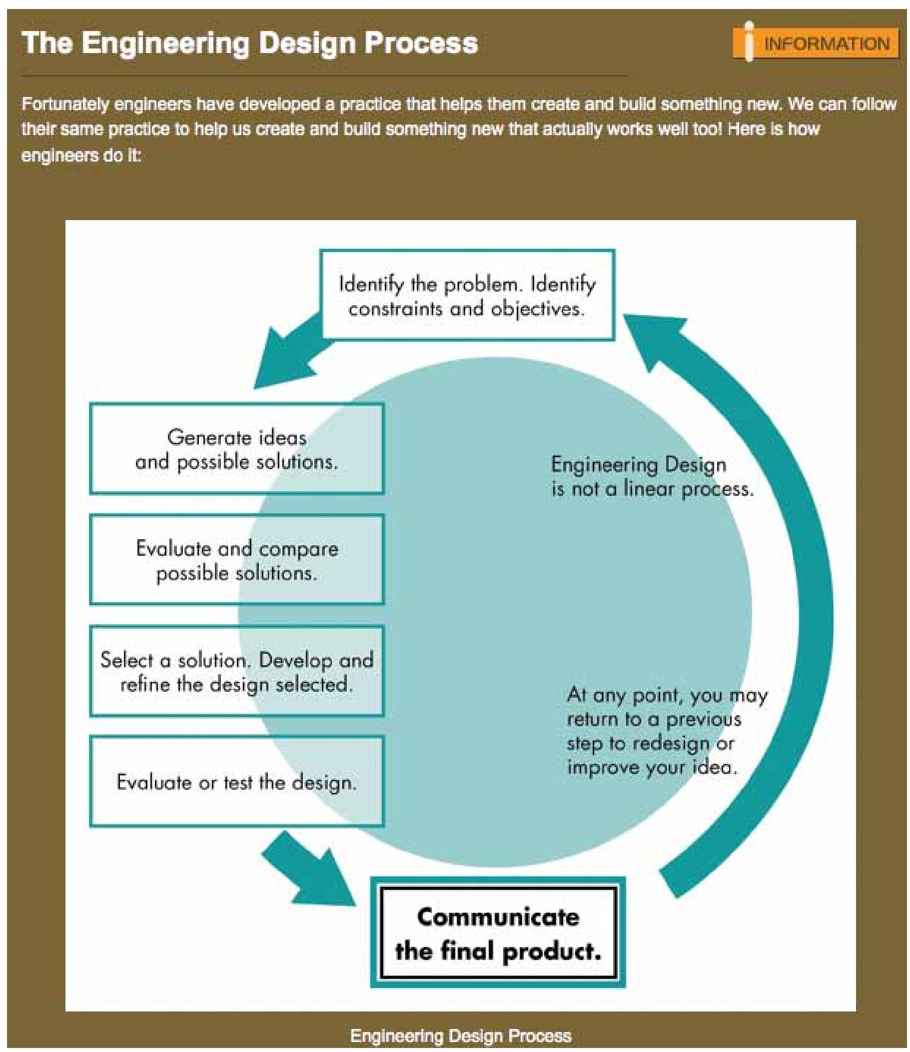
Right: This screen shot (right) shows the first-person perspective of driving the CEENBoT through a virtual industrial plant. Below: 4-H offers materials that teach kids about engineering design.





For example, an important consideration in mobile robotics is the concept of friction. A properly designed robot will minimize friction to reduce energy consumption and extend the longevity of the robot's mechanical parts.

To teach this concept to students, we begin by sliding a box of paper clips down an angled cardboard ramp containing a number of surfaces with varying degrees of resistance. In the final challenge, student teams design and build a "clipmobile," a vehicle that can overcome friction and travel down the ramp and continue for a specified distance.

The challenge becomes even more interesting when students have a base kit of parts and $45 of pretend money that they use to purchase additional parts for their clipmobile. Student teams are evaluated based on outcomes related to their efforts, including: weight capacity of the vehicle, performance, complexity of parts used, efficiency in the number of parts used, and the cost effectiveness of their budget.

Teams are required to present their vehicle, an inventory sheet of parts, and budget sheets. Even with the best performance record, a team will not necessarily win the challenge if they buy and use a large number of parts. In the end, students learn that the engineering design process often includes real-life constraints that determine the engineering design process.

The Robotics Platforms track. This track uses LEGO NXT or the VEX robot kits. However, our goal in the Robotics Platforms track was to focus on learning important technology and engineering concepts and to help students develop important workforce skills. As students move through each module, they record their progress and keep records in a robotics notebook.

Results from the Classroom

Engineers piloted and field-tested all three tracks of the curriculum to ensure the lessons worked as intended and met the science, technology, and mathematics national standards.

The first phase of the piloting process was a formative review of the lessons by faculty curriculum specialists at the University of Nebraska. We revised the lessons and piloted them with 640 students and 62 facilitators (teachers, extension educators, and adult volunteers) at various locations across the country. Finally, the program was field-tested with 35 students and 13 teachers during the summer of 2010 in a meeting involving seven school districts in Nebraska.

Results of the field tests showed positive attitudes toward technology and engineering as well as increased conceptual learning related to big ideas, such as variables, engineering design, and robotics. In particular, students made good progress in their understanding of robotics and engineering design.

For example, when asked what a robot is prior to the program, one student in the Junk Drawer Robotics track answered "not sure." After the program, the same student answered, "A robot is a machine that can operate without a person."

When asked to define the engineering design process, one student in the Virtual Robotics track answered, "I have no clue." After the program, the same student answered, "The engineering design process is the process of designing something, revising the design, and testing it."

Robotics, in many ways, is an ideal field to engage youth in STEM education. Science, engineering, and technology are all connected and undergirded by mathematics. Each domain informs the other: Scientists inquire about the natural world, developing new theories. Engineers use scientific knowledge to design technological devices to meet the needs of human society. The field of robotics is multidisciplinary, involving concepts in physics (friction, electricity, and magnetism), computer engineering (programming and binary numbering), mechanical engineering (gears and sensors), and unifying science concepts (form and function as well as science inquiry) and engineering concepts (engineering design and flowcharts).

Discussion and Recommendations

It may well be that some of the benefits of engaging youth in educational robotics do not need to involve expensive robotics kits and computers. Our experience is that well-structured, creative, and engaging alternative activities using common materials found in a classroom may be able to achieve at least some of the STEM benefits sought in the context of using the more expensive technologies.

Acknowledgments

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Resources

National 4-H Council: www.4-h.org
Unity 3D: http://unity3d.com

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