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TEACHING STEM: inquiry

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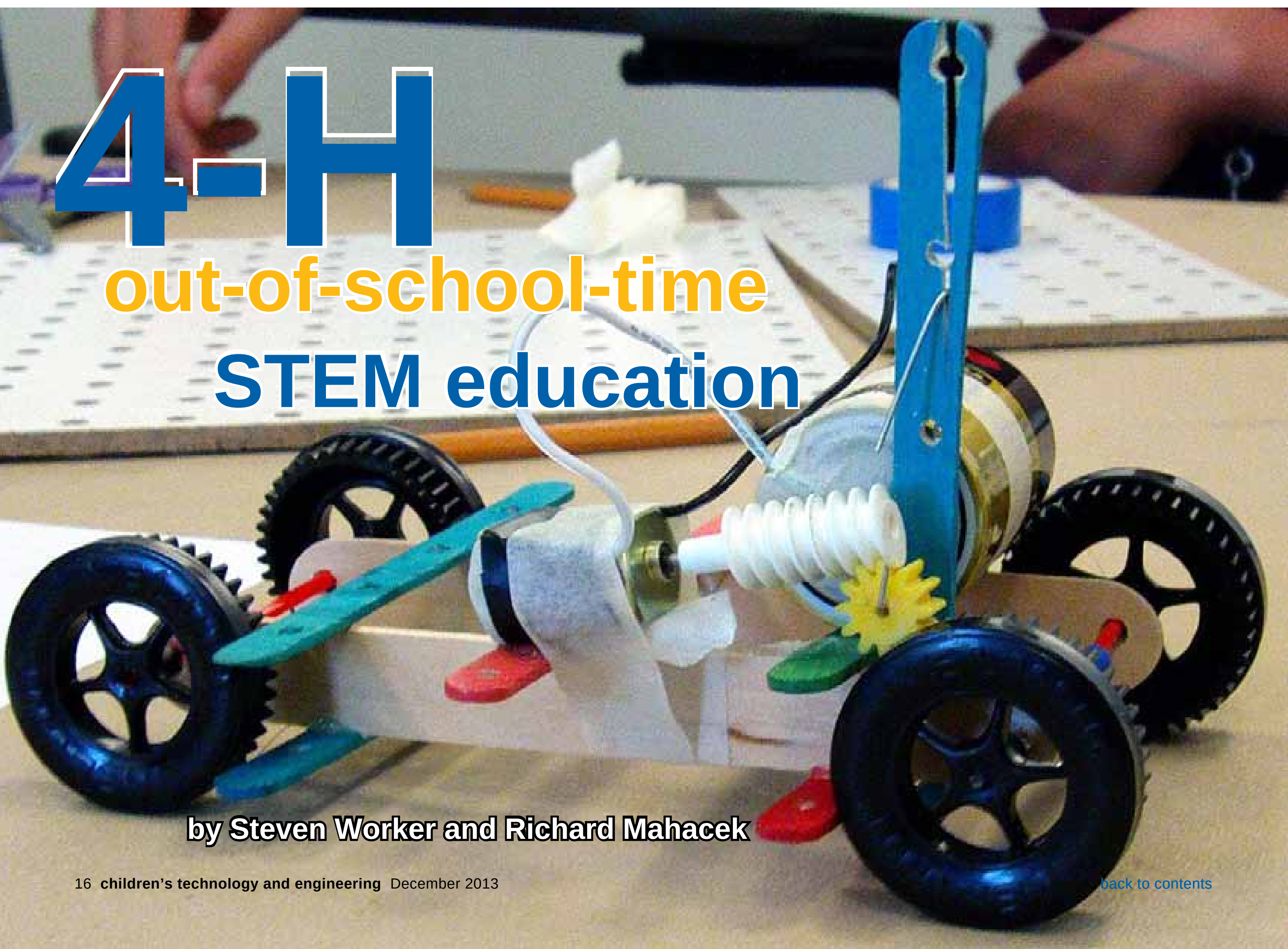
Significant learning takes place outside of formal classrooms. While school is recognized as the accepted method for instruction, out-of-school-time education can dramatically increase interest and motivation for learning while supplementing formal education. Only 5% of learning over a person's lifespan takes place inside of a classroom, leaving the other 95% to out-of-school settings such as museums, organized programs, hobbies, television, and other sources (Falk & Dierking, 2010). The educational approaches used in out-of-school settings allow for flexibility in meeting the needs of diverse youth. Numerous strengths make these learning environments ideal to spark curiosity for learning: options and choices for learners, potential for community involvement, and emphasis on youth development. Out-of-school-time environments tend to be fun, enjoyable, relevant, and engaging, leading to higher levels of intrinsic motivation.

Below: A version of a completed vehicle from the activity, Es-Car-Go, where youth built a vehicle that (a) is battery-powered; (b) uses a drive train of gears; (c) moves slowly; and (d) climbs a cardboard ramp.



4-H out-of-school-time STEM education

by Steven Worker and Richard Mahacek

Youth work on completing a drive train that (a) uses at least three gears; (b) has a driven gear that turns at least three times faster than the first driver gear; and (c) has a driven gear that turns in the opposite direction of the first driver gear.

Along with the growing recognition of the role of out-of-school-time programs in educating young people, there is increasing national attention on the need for science, technology, engineering, and mathematics (STEM) education. Our young people need to be equipped to live in a 21st century democratic society. Preparation involves engaging youth in meaningful opportunities that promote active, collaborative, meaningful learning that supports mastery and expands horizons (described as the five Learning in Afterschool and Summer Principles). Educators promote out-of-school-time programs as vital links in addressing science, technology, engineering, and math education (National Research Council [NRC], 2009a). But these programs also have a unique niche: helping generate interest and excitement around STEM that encourages exploration and interactions among learners and provides opportunities for youth to think of themselves as people who can use scientific concepts and engineering in everyday life.

The strengths of out-of-school-time programs are especially evident in technology and engineering education, where youth are challenged to use their hands and minds to solve engineering design challenges (NRC, 2009b). Learning to use an engineering design process can help youth reinforce science and mathematics concepts. Youth learn about science, engineering, and technology through active collaboration, problem solving, and practice in these domains. In addition, many programs, embracing experiential learning or service learning, promote real-world connections that allow youth participants to directly apply their learning to authentic community issues.

4-H Youth Development Program

The 4-H Youth Development Program exemplifies the role of out-of-school-time programs in engaging youth to reach their fullest potential. As the youth component of the nation's cooperative extension system, administered by the USDA and land-grant university system, 4-H programs have been present across America since 1902. The 4-H Youth Development Program has a long and proud history of helping youth develop into capable and successful adults by engaging them in science, engineering, technology, nutrition, leadership, and citizenship education. Every year across the United States, 4-H programs reach over six million young people between the ages of 5-19, mentored by adult volunteers, in rural, suburban, and urban areas.

In 2007, 4-H made a commitment to help address youth STEM literacy needs in the U.S. through the formation of its 4-H Science

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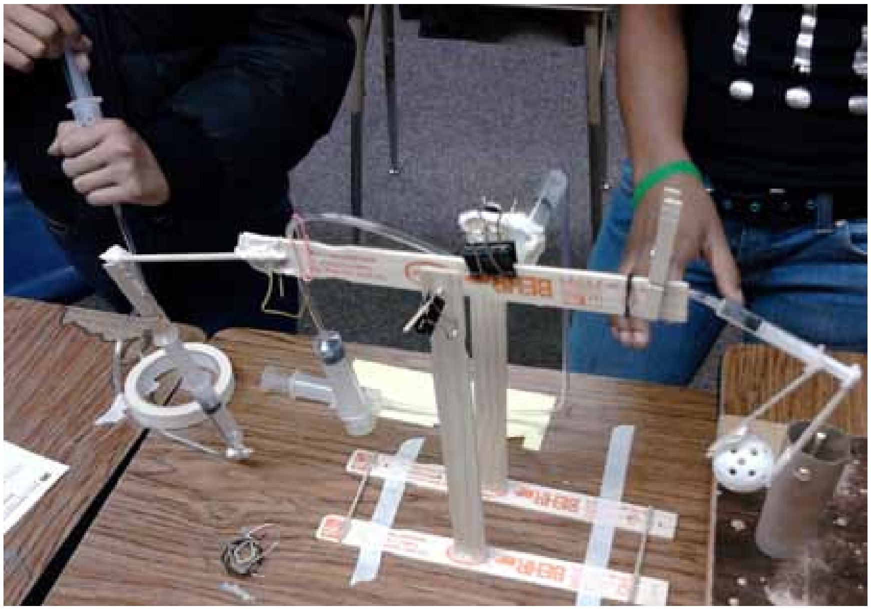

An example of a completed arm and gripper that uses pneumatic power to pick up a ping-pong ball.

The national 4-H robotics curriculum, titled *4-H Robotics: Engineering for Today and Tomorrow,* was published in 2011 (available at www.4-h.org/robotics/). Junk Drawer Robotics, one of the tracks in the curriculum, engages middle school youth in engineering design through the use of common household items. The curriculum was developed to focus on scientific and engineering practices, frame activities in the experiential learning cycle, and promote small-group collaborative learning (Mahacek & Worker, 2011). The 4-H Junk Drawer Robotics program offers a useful way of engaging youth in engineering design using robotics. In each module, youth learn about an underlying scientific or engineering concept related to robotics. As youth progress through the curriculum, their knowledge of the multidisciplinary nature of robotics grows. At the end of the three levels, youth design and build a robot using what they have learned.

mission mandate. This effort seeks to engage youth across the country in out-of-school-time science programming that is experientially based, uses inquiry methods, and promotes positive youth development. The goals of these programs are to address the critical need for more scientists and engineers in the workforce. The expected outcomes include: (a) knowledge gains among youth—increased awareness of science; improved science, engineering, and technology skills and knowledge; and increased life skills; (b) a change in youth behavior—youth apply science, engineering, and technology learning to contexts outside of 4-H; youth adopt and use new methods or improved technology; and youth express aspirations towards STEM careers; and (c) long-term societal impact—increased number and more diverse pool of youth pursuing education and careers in STEM fields; and increased scientific literacy in the general population.

4-H junk drawer robotics

A multifaceted approach is being employed by the 4-H program to reach these desired outcomes. One of the approaches is recruiting youth into robotics education projects. An emerging body of research is showing that robotics education generates excitement and interest in youth to learn about STEM (Barker et al., 2012).

Think about two situations:

> *An educator opens a box of parts preparing to lead youth in a robotics activity. The kit contains preselected pieces needed to construct a robot that meets a design specification. The pieces dictate certain ways of assembly, and while the possibilities are large, there are limits in how pieces may be connected. Losing a part might mean that the robot cannot be completed. Following the directions is common. There may be few opportunities for open-ended exploration.*

Contrast this example with an educational experience using a more open-ended approach found in Junk Drawer Robotics:

> *A facilitator challenges youth to build a pneumatic-powered robotic arm using assorted materials that might include paint sticks, brass brads, rubber bands, wooden skewers, and paper clips, along with plastic tubing and syringes for the pneumatics. Tools are provided so youth can cut, bend, and modify the parts. The possible designs are limitless. The open-ended nature of the activity is seen by the repurposing of common household items. Small groups of youth collaborate to meet the design challenge, often in vastly different ways. For example, if rubber bands are not available, how will youth work together to find an alternative?*

The open-ended approach promotes a materials-engineering perspective, which Bennett and Monahan (2013) describe as promoting materials literacy, helping children become comfortable with exploring object affordances, reusability, and repurposeability. This method is similar to tinkering approaches found in many science centers, and the curriculum strengthens this approach with engineering practices by integrating a curricular design cycle described below.

The Junk Drawer Robotics curriculum has three levels. In Level 1, Give Robots a Hand, youth explore the design and function of robotic arms, hands, and grippers, and build a robotic arm. In Level 2, Robots on the Move, youth design and build machines that roll, slide, draw, or move underwater, and explore robot mobility—movement, power transfer, and locomotion. Level 3, Mechatronics, is about the connection between the mechanical and electronic elements of robots. Youth explore sensors, write programs, build circuits, and design their own robot.

Every level contains multiple modules focusing on specific scientific and engineering concepts. Within a module there is a sequencing of activities in three stages. This process allows exploration of new knowledge using science inquiry, then takes those budding concepts and applies them in engineering design and technology-creation activities. The curriculum captures the synergy between science, engineering, and technology (see Figure 1). The curriculum is structured in such a way to allow each focus area to be addressed separately, yet highlights and reinforces the interconnections.

To Learn (Guided Science Inquiry) – Several activities emphasize exploration and form the foundation upon which youth build conceptual understanding. Youth learn the underlying scientific concept through activities that contain minimal guidance or expectations of accomplishments. Through intentional debriefing, educators pose open-ended questions to help youth reflect individually and in groups.

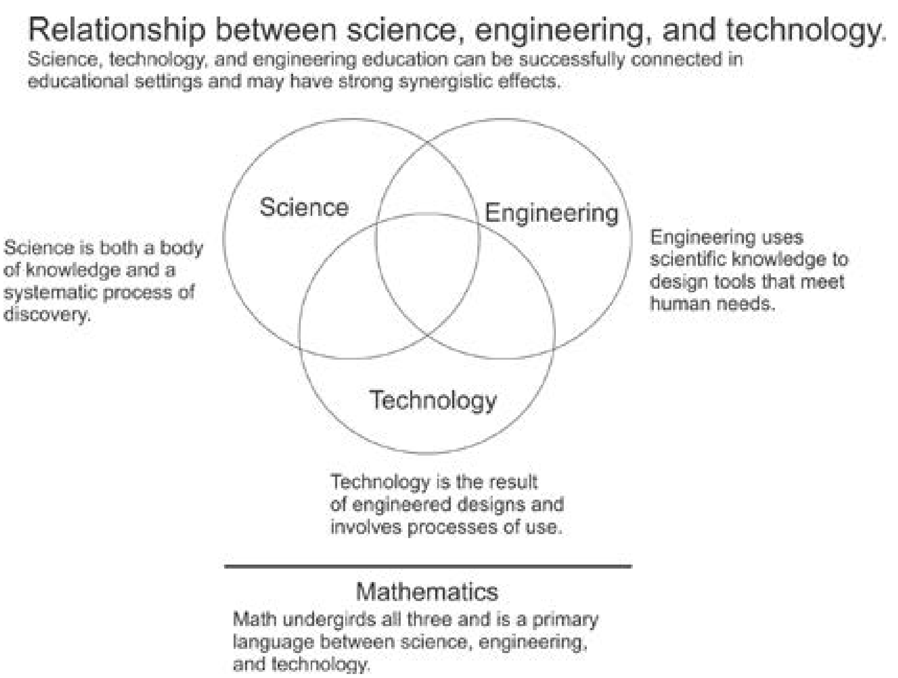
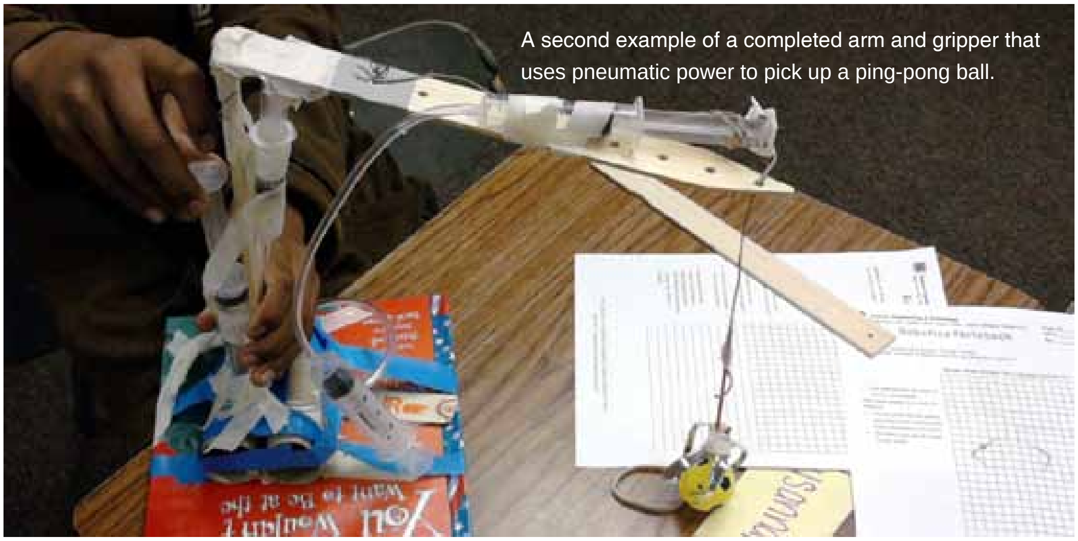


Figure 1. Relationship between science, engineering, and technology promoted in 4-H Junk Drawer Robotics. *Adapted from the Massachusetts Department of Education (2006).*

To Do (Engineering Design) – The design activity takes place after the "To Learn" activities. Youth are presented with a design problem and must work together to design and plan a solution. This phrase promotes the engineering design concepts of problem identification, framing, and solving. This step poses challenges to the facilitator, as youth often want to dive right in and start building. Deeper learning happens because youth are forced to build upon the knowledge gained in the exploration phase and intellectually create a design without using the physical objects.

To Make (Technology Creation) – Finally, youth build, construct, and test their solution to the previous design activity. This stage often involves modifications to the original design. During this time, youth solidify their understanding of the concepts as they enact a solution, build a prototype, and test the design. Through facilitated debriefing by the educator, youth compare their products to those constructed by the other groups.

The 4-H Junk Drawer Robotics curriculum provides a salient example of out-of-school-time science, engineering, and technology education. By incorporating science into engineering/technology, the three disciplines achieve a synergistic effect. By engaging youth in fun learning activities, they explore, collaborate, and start to think of themselves as people who can "do" science and engineering. In this way, 4-H contributes to the array of out-of-school-time programs in helping spark curiosity for learning and development in STEM fields.


A second example of a completed arm and gripper that uses pneumatic power to pick up a ping-pong ball.

references

Barker, B. S., Nugent, G., Grandgenett, N., & Adamchuck, V. I. (Eds.). (n.d.). *Robots in K-12 education: A new technology for learning.* Hershey, PA: IGI Global.

Bennett, D. & Monahan, P. (2013). NYSCI design lab: No bored kids! In M. Honey & D. E. Kanter (Eds.), *Design. Make. Play. Growing the next generation of STEM innovators* (pp. 34-49). New York: Routledge.

Falk, J. & Dierking, L. (2010). The 95 percent solution: School is not where most Americans learn most of their science. *American Scientist, 98*(6), 486-493.

Mahacek, R. & Worker, S. (2011). Extending science education with engineering and technology: Junk drawer robotics curriculum. In A. Subramaniam, K. Heck, R. Carlos, & S. Junge (Eds.), *Advances in youth development: Research and evaluation from the University of California Cooperative Extension 2001-2010* (pp. 46-57). University of California Agriculture and Natural Resources. Retrieved from http://4h.ucanr.edu/Research/4HPublications/

Massachusetts Department of Education. (2006). *Massachusetts science and technology/engineering curriculum framework.* Malden, MA. Retrieved from www.doe.mass.edu/frameworks/scitech/1006.pdf

National Research Council. (2009a). *Learning science in informal environments: People, places, and pursuits.* Washington, DC: The National Academies Press.

National Research Council. (2009b). *Engineering in K-12 education: Understanding the status and improving the prospects.* Washington, DC: The National Academies Press.

Steven Worker *is a 4-H Science, Engineering, and Technology Coordinator. He can be contacted at smworker@ucanr.edu.*

Richard Mahacek *is 4-H Youth Development Advisor Emeritus. He can be contacted at rlmahacek@ucanr.edu.*