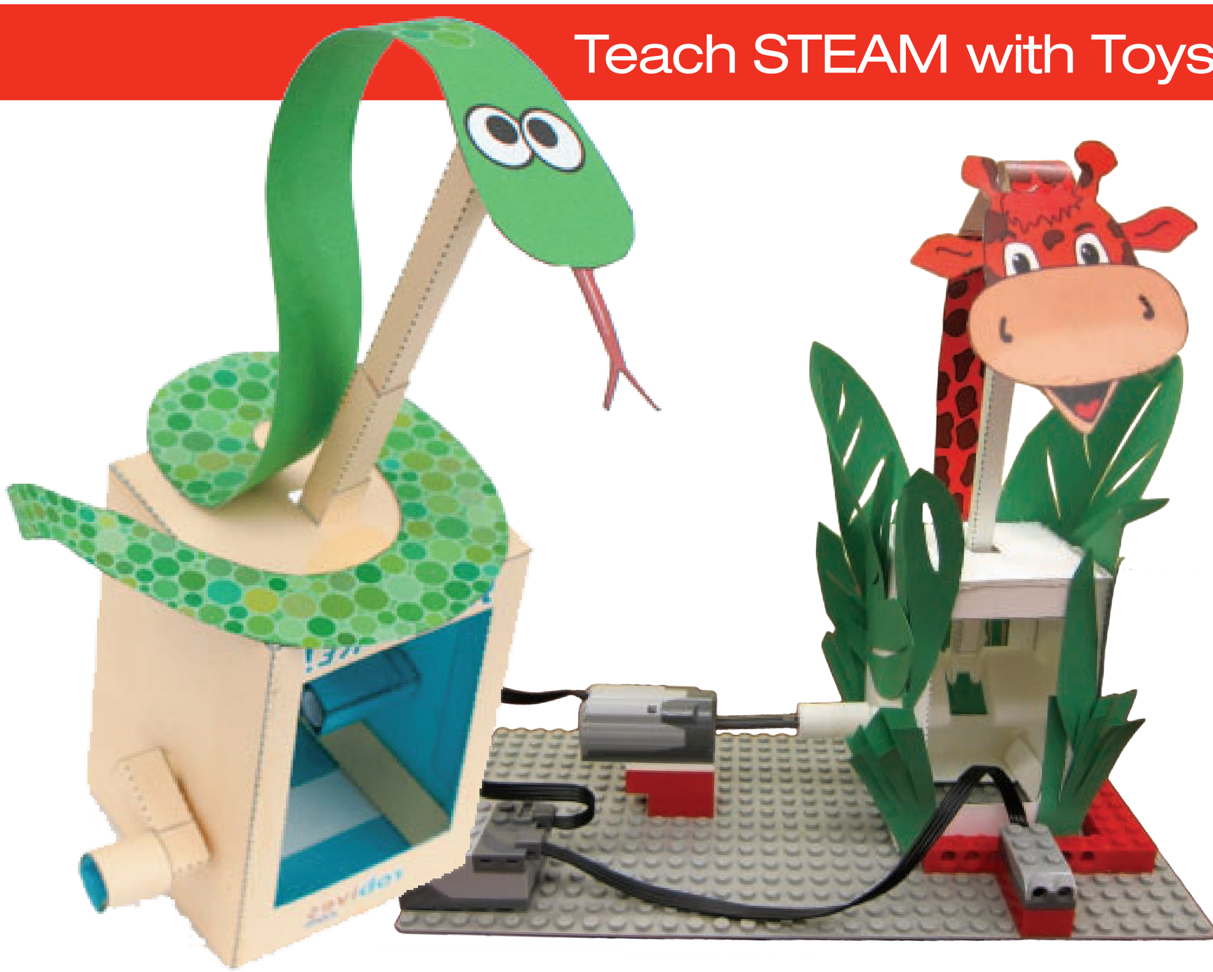
Teach STEAM with Toys



Students can learn how a crank mechanism works while building a fun toy using nothing but paper and scissors. Add technology to the lesson by enhancing a cardstock toy with a Lego motor and motion sensor.

People used mechanical models extensively for both play and scientific exploration from the time of the ancient Greeks through the Renaissance. And now the trend has returned.

The European Union established the Automata Toy Construction project (www.clohe-movingtoys.eu) to explore educational uses for mechanical toys, based on the premise that mechanical moving toys—sometimes known as "automata"—can combine play and technology to introduce the arts, engineering, and science to students of all ages.

The National Science Foundation's Albert Einstein Fellows (science.energy.gov/wdts/einstein)—teachers who develop educational programs in collaboration with federal agencies—are exploring these possibilities in the United States as well. They are collaborating with educators and engineers at the University of Virginia to explore how we can use digital fabrication technologies, such as 3D printers and computer-controlled die cutters, to create educational toys.

One advantage of using a digital design process is that it allows teachers to easily share and replicate mechanisms. These emerging technologies, combined with inexpensive educational computers such as Raspberry Pi (raspberrypi.org), which is about $40, have fueled the rapid growth of the maker movement among children and adults who are designing and constructing their own physical inventions. The movement's popularity is creating opportunities for educational innovation through the development of inexpensive tools and related communities whose members are often willing to volunteer their expertise to support schools.

Want to get involved in the maker movement? You can get started by designing, building, and automating mechanical toys like these with your students.

Creating Cardstock Mechanisms

The essence of engineering is designing, building, and testing prototypes while optimizing solutions. Inspiring iterative thinking and decreasing the costs of failure are key to forming the habits of mind we hope to cultivate in our students.

Although high-tech tools, such as 3D printers, can enhance the types of mechanical models you are able to develop for your classroom, you can also construct surprisingly sophisticated models with just a pair of scissors and cardstock.

Rob Ives, a Scottish math teacher who began constructing mechanical models for his classroom and now designs them full time, created a cardstock mechanical toy that illustrates how a crank mechanism works through the movement of a playful snake (see the photo on page 35). You can also build variations on this theme, such as a giraffe or dragon toy. For $15 a year, you can get a classroom license at RobIves.com that provides access to hundreds of models like this as well as suggestions for construction techniques.

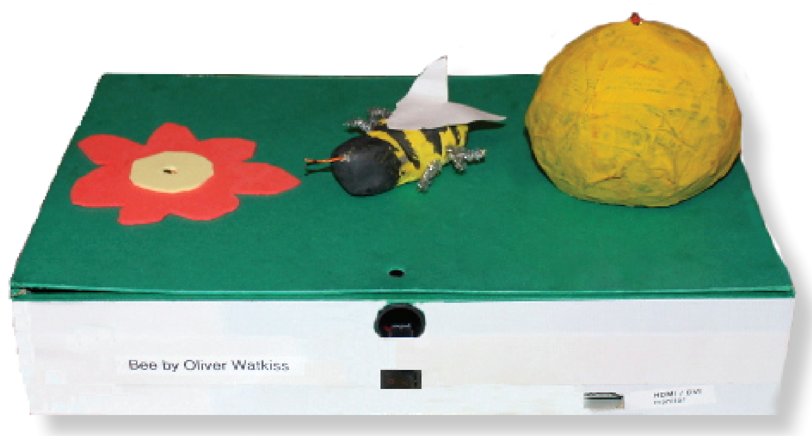
But mechanical models are just the beginning. With a little ingenuity and some inexpensive add-ons, your students can creatively enhance any basic mechanical toy.

Adding Electronic Extensions

These kinds of construction opportunities can give our students a feel for the movement and mechanics involved in machine processes. Automata also do a superior job of demonstrating systems thinking with input, process, output, and—with a little help from electronics—even feedback and control.

For example, the Albert Einstein Fellow James Town replaced the eyes in Ives' snake toy with LED lights. When you turn the crank, brush contacts light up the eyes alternately at different points in the cycle, which could illustrate parallel and serial circuits in a unit on electricity and magnetism.

A new field of engineering called mechatronics combines mechanical engineering, electronic engineering, and computer science and makes all three disciplines accessible to surprisingly young students.



When a user moves the bee across the top of this "bee box," created by 5-year-old Oliver Watkiss and his father, a hidden magnet and reed switches activate a Scratch script written by Oliver's 7-year-old sister to generate images of a flower and a hive on a computer screen.

You can also replace the hand crank with a computer-controlled motor. Just connect a simple Lego motor (about $8) to a computer through a USB port via a Lego hub ($45).

And by adding a Lego motion sensor ($20), you can make the snake move forward when a hand approaches it. Students can then use the free programming language Scratch (scratch.mit.edu) to program the motor and sensor using a prewritten script. The program waits until the gap between an approaching object and the sensor hits 15 cm, and then it rocks the snake forward and back again. Students can also use Scratch to program the computer to issue a hiss or another suitable sound for dramatic effect. The script, prerecorded sound effects, and directions for the automated snake toy are available at www.MakeToLearn.org/toys.

Have access to a 3D printer? You can use it to create a customized plastic version of the toy that is more durable and permanent.

Building Mechatronic Toys

A new field of engineering called mechatronics combines mechanical engineering, electronic engineering, and computer science and makes all three disciplines accessible to surprisingly young students.

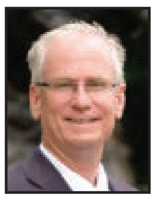
In one striking illustration of the possibilities, Stewart Watkiss collaborated with his 5-year-old son and 7-year-old daughter to create a "bee box" using the Raspberry Pi with Scratch. A magnet in an artificial bee closes reed switches beneath the lid of a shoebox as you move it across the top of the box to places of interest for the bee, like a blossom or its hive. A Scratch script running on the Raspberry Pi generates an image of a flower on the screen when the user moves the bee to the physical flower on the box, then displays an image of a hive when the bee returns to the beehive.

Watkiss's son constructed the physical box and wired it with some assistance from his father. Then his daughter created the simple Scratch script that brought the project to life. A complete description of the project and instructions for creating it (which are free under Creative Commons licensing) are on Watkiss's website (www.penguintutor.com/electronics/bee).

You can also make any toy mobile. If you contribute to a Kickstarter project called BrickPi (goo.gl/9ovIg), you will receive an adapter that lets you use a Raspberry Pi with three Lego motors and four Lego sensors. A 9-volt battery allows you to untether the motors, sensors, and Raspberry Pi from the wall so your project can go mobile.

Animating mechanical toys using these design ideas and resources provides a rich landscape for students to explore mechatronics, which makes complicated engineering concepts accessible to young learners. These activities also provide excellent scaffolding for the study of systems thinking and engineering design while encouraging student creativity and expression—both powerful motivators for all learners.

Glen Bull is co-director of the Center for Technology and Teacher Education at the University of Virginia and a volunteer columnist for L&L. *You can contact him at gbull@virginia.edu.*



Stephen Portz is an Albert Einstein Fellow at the National Science Foundation, on leave from Space Coast High School in Cocoa, Florida. You can contact him at sportz.einsteinfellow@gmail.com.