Maker Programs in Vermont Libraries: Spark a Culture of Innovation presents:

Toy Hacking is a fun and playful way to learn how circuits work. Starting with used electronic toys, toy hackers carefully examine then safely take the toys apart to learn how they work. Participants explore both the simplicity and complexity of these toys and their unique circuits and are shown how to identify inputs, outputs and power. We'll experiment with circuit bending and reverse engineering while we reimagine and reinvent the toys with materials on hand.

Workshop Objectives

During the course of this workshop, participants will:

- Examine toys and determine how the makers planned for the toys to be used.
- Identify and draw **inputs**, **outputs** and decorative features of the toys.
- Learn and follow safety procedures for toy hacking.
- Safely examine **circuit boards** and **components** inside their toys.
- Use provided materials to "reinvent" their toys.

Suggested Ages

9-14 if students are working independently. Younger children (6-9) have been successful with an adult supervisor.

Next Generation Science Standards Addressed

- K-2-ETS1-2. Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.
- 3-PS2-3. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.
- 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

For more information on NGSS, please visit http://www.nextgenscience.org

Materials

For each participant:

- At least one working, battery-operated toy
- Batteries
- Safety glasses
- Mini screw driver
- A few alligator test leads
- A few jumper wires
- Graph paper and pencils

For group:

- Hand cleaning wipes
- Extra alligator leads and jumper wires
- Extra buttons and switches
- Extra toy parts
- Wire cutters
- Wire strippers
- A tool box with pliers, hammers, saws, stronger screw drivers and other tools for hacking

Preparation

Collecting toys: Choose only ***battery-operated*** toys. Try to find toys that have both sounds and lights. Toys that move are also fun to hack.

Extra toys: Invariably, there is a toy that will not open. Screws get stripped, some toys seem sealed with extra strength glue or parts are welded. Having extra toys for frustrated participants can be helpful.

Demo toy: It is a good idea to have two identical toys, one hacked and one still assembled, to assist in conversation. It helps some participants to see how toys work if you have a model they can refer back to.

Set up

Set up in an area which allows sound—there will be electronic noises and banging.
Make sure participants have ample table space for working.
You may wish to designate a space for real toy bashing—some are tricky to open! Don't hammer on a table you don't want marred.
Access to a sink at the end of the session is essential for hand washing.
Make certain no food or drink is in the same area as this activity.

Safety Considerations

Never hack a toy that has a wall plug. Only hack battery operated toys.
Always wear goggles while opening toys or experimenting with the insides.
You may want to remove batteries while you are opening the toys then replace them when you have the toy taken apart.
Watch out for sharp edges and metal pieces in the toys.
If you see or smell smoke, sparks or flames, STOP! Remove the battery.
Be aware that the inside of a toy can contain toxic substances, especially lead. The solder used in most toys is lead based. Therefore:

- Avoid touching your eyes, mouth or nose while you are hacking.
- Do not allow food or drink near the toy hacking.
- Use wipes as needed during the hacking activity.
- Wash hands thoroughly after hacking.
- If you get cut, immediately clean and bandage the wound before you continue hacking.

Running a Toy Hacking Session

Getting Started:
Explain that in this session, participants will take toys apart to see what makes them work. Emphasize that the group won't necessarily find all the answers or be able to rebuild the toys—this is a session for exploration and play.
Explain that the session will have activities with group discussions between the activities. Establish how the group will reconvene between the activities.

Examination:
Explain that we cannot understand how a toy works without examining it first. In this activity, participants will sketch and describe their toys.
As they sketch, ask them to explore and document the following:

- Who buys this toy and who plays with the toy?
- What does the toy do?
- Does the toy switch on and off? What causes the toy to switch on and off?
- What triggers sound, light and motion?
- What inputs does the toy have? (Buttons, keys, spinners, etc.)
- What outputs does the toy have? (Lights, sounds, movement, etc.)
- Is the toy fun for you? How about for the intended audience?

Discussion: Have the group gather to introduce their toys. Try to find common features.

Discovery and Interpretation:
Go over the Safety Concerns and the Laws of Toy Hacking.
Have participants open toys gently and safely. (Once open, replace any removed batteries.)
Have them sketch the open toy, documenting what they see inside. Have them locate:

- The **battery** or battery pack
- The **leads** coming out of the battery
- The **printed circuit board** (PCB)
- Where the battery connects to the PCB
- The **microprocessor chip** (generally under a spot of black goo on the PCB—it is unlikely you can remove it)
- The speaker (may be loose or part of the circuit board)
- Lights (may be loose or part of the circuit board)
- Switches, buttons and other connections
- Any other working parts
- Any purely decorative parts
- Anything surprising

Use alligator clips and lead wires as needed to follow connections and map out the interiors of the toys.

Discussion: Ask each participant to choose an interesting

The Laws of Toy Hacking

- Fear not!
- Open the toy gently, you do not want to break the wires that connect to the batteries.
- It is easier to take something apart than to put something together.
- Make notes on what you are doing as you go along, not after.
- Avoid connecting the battery backwards.
- Many hacks are like butterflies: beautiful but short-lived: Many hacks you perform may destroy the circuit eventually. Accept this. If it sounds great, record it as soon as possible, and make note of what you've done to the circuit so you can try to recreate it later.
- In electronics some things are reversible with interesting results, but some things are reversible only with irreversible results
- If it sounds good and doesn't smoke, don't worry if you don't understand it.

Based on Collins, Nicolas. *Handmade Electronic Music: The Art of Hardware Hacking*. 2. London: Routledge, 2009.

finding about his or her toy to share. It may be easier to have the group move around to see the toys as each person presents.

Experimentation

In this activity, participants will try to make their toys do new things. This can be frustrating if a participant is hesitant—really; anything the group learns is exciting.

To start, encourage participants to use the alligator clips and lead wires to make new connections inside the toy. Good places to try are:

Battery to **contact points** on the PCB

Solder points to contact points

Lights and speakers to solder points on the PCB

Many connections won't do anything. That is okay. Some may destroy the entire circuit. That is okay too, though may be sad.

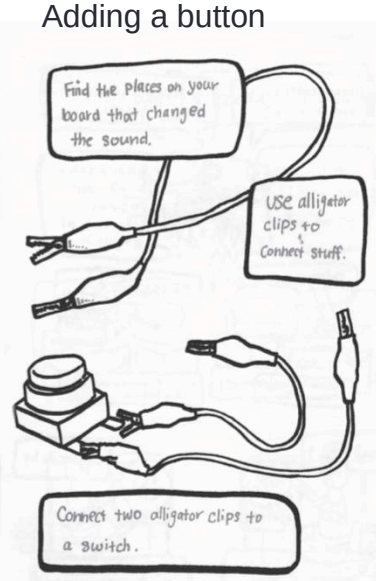
Try connecting parts of different toys together.

Can you make a toy stereo (run two speakers?)

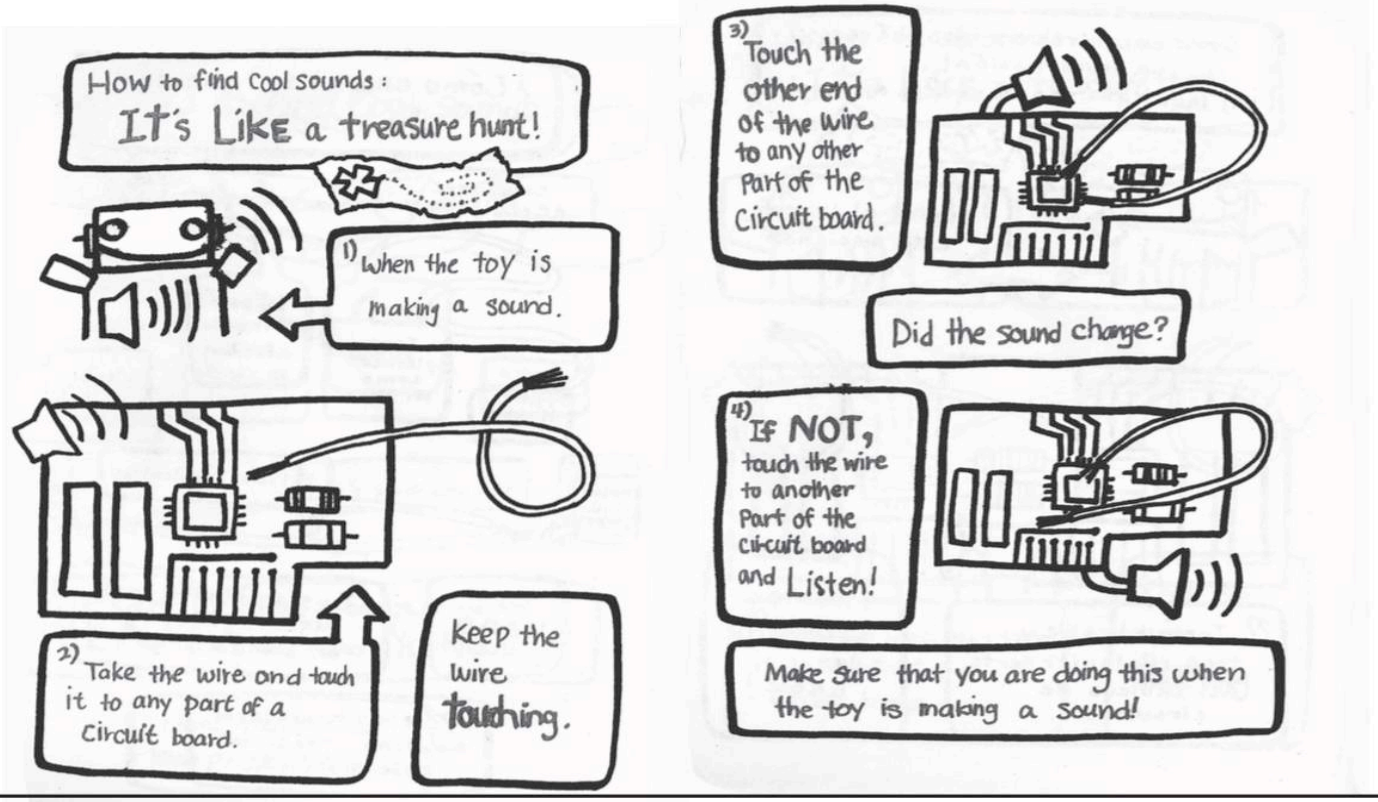
Can you use buttons from one toy on another?

Try **Circuit Bending** or Adding Buttons:

Adding a button



Circuit Bending



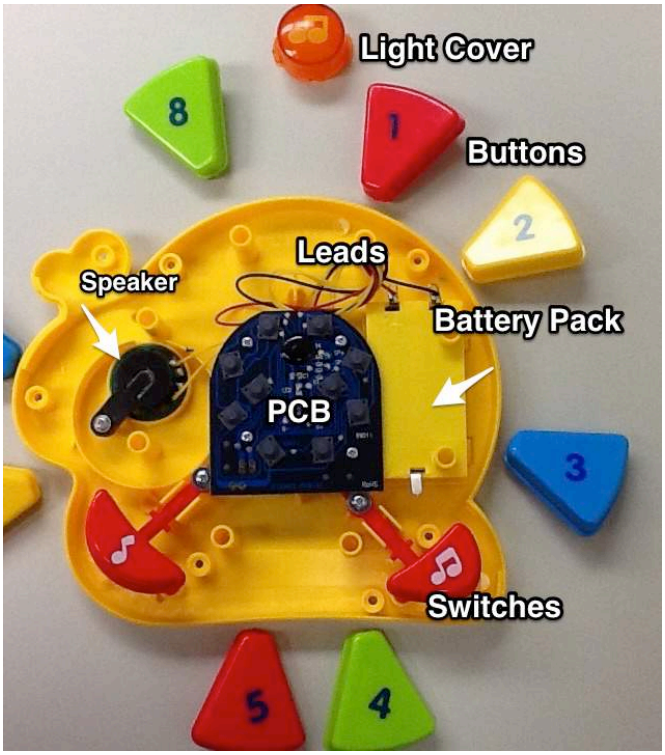
Closing Discussion:

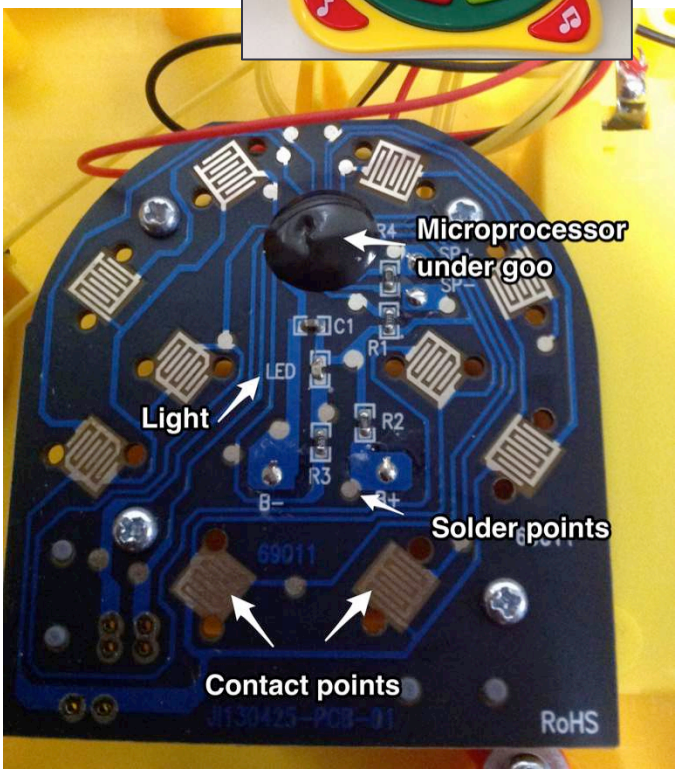
Have participants share new things they have made their toys do! Discuss what they have learned taking these toys apart. You may want to remind them to get permission before taking THEIR toys apart at home.

Save pieces of toys for other projects if you wish—you can use them to make sculptures and for other electronic projects. They even make nice jewelry.

What's inside a toy?

"What am I looking at?" is one of the biggest questions toy hackers have. All toys are different, but here are a few brief diagrams of what you might see inside a simple toy like this one:





Troubleshooting

The biggest problem in this workshop is having a toy circuit break. When this happens, there is really nothing you can do.

Watch polarity as participants work—very often you can overload a circuit just by reversing the battery.

Some participants might become frustrated that they do not understand all the parts in a toy. The following books can be helpful to participants who want to go further with identification:

- Make: Encyclopedia of Electronic Components Volume 1: Resistors, Capacitors, Inductors, Switches, Encoders, Relays, Transistors 1st Edition by Charles Platt, 2012.
- Make: Encyclopedia of Electronic Components Volume 2: LEDs, LCDs, Audio, Thyristors, Digital Logic, and Amplification 1st Edition by Charles Platt (Author), Fredrik Jansson (Contributor), 2014.
- Make: Encyclopedia of Electronic Components Volume 3: Light, Sound, Heat, Motion, Ambient, and Electrical Sensors 1st Edition by Charles Platt (Author), will be published in Dec. 2015.

Talk Like a Maker Vocabulary

Toy hacking: "the act of modifying or customizing (electronic toys) to improve their functionality, repurpose them or just for fun" Designboom
Input: a device (button, switch, etc.) that feeds data to a microprocessor chip
Output: a device that sends data to a user (light, sound, movement, etc.)
Circuit: an electric device that provides a path for electric current to flow
Printed circuit board: a **non-conductive** material with **conductive** lines printed or etched. Electronic components are mounted on the board and the traces connect the components together to form a working circuit or assembly. The "nervous system" of a toy.
Conductive: a substance that allows electric current to pass through it
Non-conductive or insulating: a material that does not allow the flow of electricity to pass through
Microprocessor chip: a usually tiny integrated computer circuit that is programmed to specifically run a device. The "brain" of a toy.
Battery: a container that stores energy until it is needed
Leads and traces: wires and metallic etching that allows the flow of electricity
Components: all the parts of a toy—lights, speakers, buttons, etc.
Contact points: etching on the PCB that controls the components
Solder points: metallic points where components have been welded to the PCB
Circuit bending: "taking apart and creatively manipulating the circuits of children's toys to produce novel sound output" Garnet Hertz, Toy Hacking: Preliminary Results in Creative Electronic Workshops for Informal Science Education

To Learn More

- Much of this module has been designed using the work done by Garnet Hertz. Garnet Hertz's guide to Toy Hacking can be found at http://www.conceptlab.com/circuitbending/

- The MakerKids Toy Hacking curriculum module can be found here: https://docs.google.com/document/d/1JpgeqcvebXCr4bwHbgqEq5SNHg8x_z4qXA-qS1oI0dg/edit

- Two excellent books which help with understanding the circuits in toys and other small electronics:
    - Hacking Electronics: An Illustrated DIY Guide for Makers and Hobbyists 1st Edition by Simon Monk (Author), 2013.
    - Electronics from the Ground Up: Learn by Hacking, Designing, and Inventing 1st Edition by Ronald Quan (Author), 2014.

- Directions for a more complicated hack of a remote control car: http://www.instructables.com/files/orig/F9K/1POW/I66CY53Q/F9K1POWI66CY53Q.pdf

The Maker Programs in Vermont Libraries: Spark a Culture of Innovation grant was made possible by the following organizations:

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This work is based on the 2014 handout created by Vermont Makers. The original handout can be viewed at:
http://libraries.vermont.gov/sites/libraries/files/InitiativesProjects/ToyHackingActivitySheet.pdf