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

The emerging field of e-textiles is exciting, fun, beautiful and overflowing with opportunities for innovation. You'll sew LEDS into fabric and build simple circuits sewing with conductive thread. You'll learn basic circuit design, explore the aesthetics of circuits, and be introduced to the possibilities of embedding computational and electronic elements into wearables, architecture, and home furnishings.

Workshop Objectives

During the course of this workshop, participants will:

- Learn about circuits by experimenting with sewn components.
- Design a microcontroller circuit with up to 4 LEDs and a switched battery pack.
- Sew a strong conductive circuit.
- Embellish or plan to embellish the circuit with non-conductive decorative materials.

Suggested Ages

10 and older is optimal. Younger children need to already know how to sew to be successful.

Next Generation Science Standards Addressed

- 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
- MS-ETS1-4.A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.
- HS-PS3-1.The availability of energy limits what can occur in any system.

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

Safety

- Goggles are optional for this session. Take care when using needles and small parts.
- It sounds silly, but I always remind participants that the needles are sharp and to be mindful of where they place them when not in use.
- Do not sew the circuits with the battery in the battery pack. You can inadvertently close the circuit with a finger—it is not dangerous but the little shock can be surprising.
- Threading the needles can be difficult with the conductive thread. It IS non-toxic, so if a participant wants to lick the end as many do with regular thread, that is not dangerous. Tastes weird but is not dangerous.
- Some of the components might have rough edges where they have been snapped from the plastic frames they were made in. These can be filed down so they don't scratch people or cut the thread.

Materials

For each participant:

- Handout
- LilyTiny microcontroller
- Switched coin cell battery holder
- 3v coin cell battery Conductive thread
- 2 needles
- Fabric (cotton plainweave)
- Flat, sewable light emitting diodes (LEDs)
- Embroidery hoop

For the group:

- Embroidery thread or sewing thread
- Beads, buttons or other embellishments (non metallic)
- Rulers
- Scissors
- Thread rippers
- Pencils
- Paper
- Beeswax thread conditioner

What is conductive thread?

Conductive thread is spun from stainless steel fiber. There is no "filler" in it-- it is 100% steel although it feels like fabric. The steel fiber is "toothy" so it spins well, but can be a bit irregular. Examine your thread and if it has weak spots, don't use it! The toothiness can also cause it to stick to itself and tangle. Beeswax helps with this.

Prerequisite knowledge

This session can be a stand-alone workshop, but if time permits, it is helpful to have some preliminary sessions so that all participants can be successful. These are suggested sessions to have before this workshop:

Non-conductive sewing project: make sure kids can thread needles, tie knots and sew. One idea is to make felt bookmarks with running and backstitch designs.

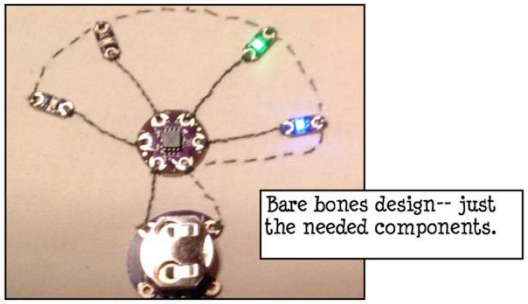
Meet the conductive thread: great project is sewing conductive pads into the fingertips of gloves to make eGloves which work with touch screens. Sew a small patch on each fingertip making sure there is good coverage inside and outside the glove-- use a marker with an indented cap to hold each finger for sewing. Instructions can be found at http://www.instructables.com/id/Making-A-Glove-Work-With-A-Touch-Screen/

Simple circuit: unswitched battery holder, one light- if battery is in, it lights up, if not, it doesn't. We made ornaments with cycling LEDS.

Switched parallel circuits: such as the bracelets from Getting Hands on with Soft Circuits: A Facilitator's Guide by Emily Lovell. http://alumni.media.mit.edu/~emme/guide.pdf

Preparation

- Cut the fabric into pieces that fit into the embroidery hoops.
- You may want to pre-thread a bunch of needles, especially if your participants are not used to sewing.
- Gather embroidery books from your collection to help with design and stitches.
- Make sure that there is good lighting in the work area for the session.
- It helps if you have a "bare bones" circuit to show as an example.



Running an e-Textiles Session

What are e-Textiles? Introduction

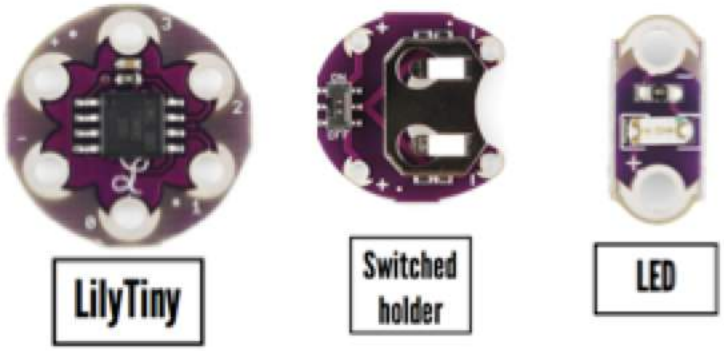
Start the workshop by explaining what e-textiles are:

"Electronic textiles (e-textiles) are electrical circuits created using flexible conductive materials (such as conductive threads and fabrics) in conjunction with discrete electronics components (such as lights, batteries, switches, and sensors)."

Emily Lovell, Getting Hands-on with Soft Circuits

Explain that participants will be designing circuits with special washable components that can be used on clothes.

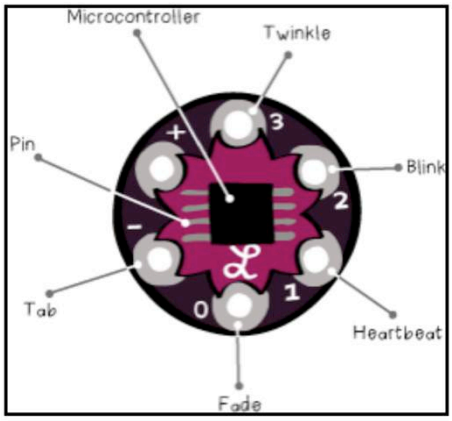
Identify the materials that will be used:



Explain that the LilyTiny is a **microcontroller**:

A microcontroller is a "compact microcomputer designed to govern the operation of embedded systems in common household items." They are used in many items that we use daily: electronic toys, sneakers that light up, small electronic devices, appliances, all the tech gadgets we carry around. There are many kinds.

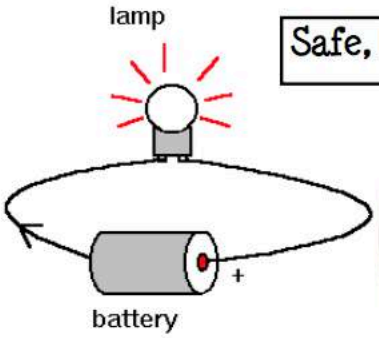
This is what Sparkfun has to say about the LilyTiny:

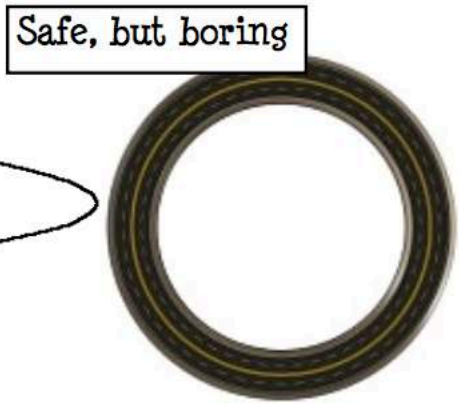


> "The LilyTiny is a tiny little LilyPad board designed to add flashy functionality to your project without taking up a lot of room. Even though it's as small as some of the LilyPad sensors, this board actually has an ATtiny microcontroller on it so it's actually pretty smart! Simply sew on 4 LEDs and connect a battery and the LEDs will each blink or fade differently. One will blink on and off (2), another will flash a heartbeat pattern (1), another will do a "breathing" fade (0) and the other will do a random fade (3). LilyTiny is a quick and easy way to add twinkling lights to a project without any programming or a bulky Main Board. It's also a great educational tool for showing a range of functionality without having to get out the computers. LilyPad is a wearable e-textile technology developed by Leah Buechley and cooperatively designed by Leah and SparkFun. Each LilyPad was creatively designed to have large connecting pads to allow them to be sewn into clothing. Various input, output, power, and sensor boards are available."
>
> https://www.sparkfun.com/products/10899

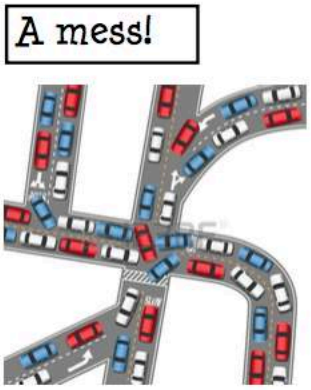
That is a description that confuses as much as it helps. Here is an English translation, stolen flagrantly from Jeff Branson at Sparkfun:

Let's start with a **circuit**. To create a circuit, you need a battery and a component like an LED. To connect these, you make **conductive traces**. Think of it as building a road for the electrons to travel.
The circuit is either on, so the electrons flow or off, so they don't. Traffic flows smoothly on your road.



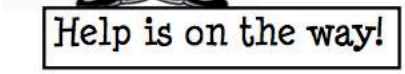


But a road going in a circle doesn't get you anywhere. You want to build lots of roads that carry different information.



So you need an intersection. But the circuit can only understand on or off. So either all the electrons go or they all stop. Oh my, the intersection is a nightmare!

You need a traffic controller, a nice policeman with a sign to tell the electrons here to go and those over there to stop.



The **microcontroller** is the nice policeman. It tells the electrons on the different roads when to be on and when to be off. And the circuit functions as it is programmed.

You have a preprogrammed microcontroller that is running an Arduino program. To the right is an example of an Arduino program. Inside your microcontroller, this is what your policeman is saying. Each LED has its own pinMode number. Basically, digitalWrite HIGH is "turn on" and LOW is "turn off". For each blink pattern, the "delay" number is slightly different. Loop just means do it again, and again, and again forever. It isn't important to understand this, but this is how the program works. There are sewable Arduino microcontrollers that you can program yourself, like the LilyPad.

```
Blink
/*
  Blink
  Turns on an LED on for one second, then off for one secor

  This example code is in the public domain.
 */

void setup() {
  // initialize the digital pin as an output.
  // Pin 13 has an LED connected on most Arduino boards:
  pinMode(13, OUTPUT);
}

void loop() {
  digitalWrite(13, HIGH);   // set the LED on
  delay(1000);              // wait for a second
  digitalWrite(13, LOW);    // set the LED off
  delay(1000);              // wait for a second
}
```

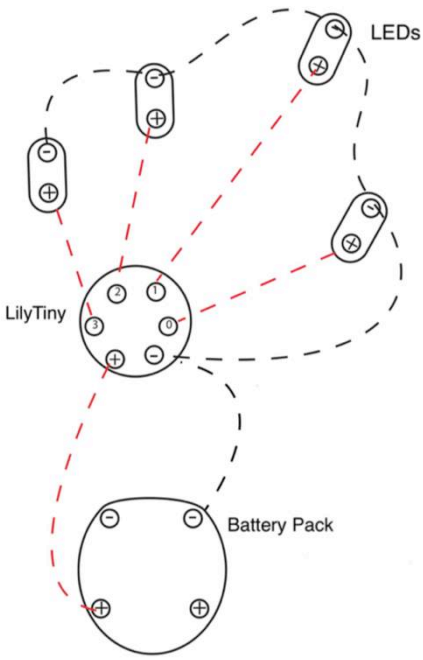
You have a ready and willing traffic controller. Now it is time to build some roads!

Designing and Sewing the Circuits

Some participants will want to draw their circuits and embroidery in detail; others will want to just start sewing the components together. Either approach works but make certain that participants are following "The Rules" on the handout. Circuits don't work if these rules aren't followed!

The Rules:

- Participants will be using conductive traces made of conductive thread to connect the sewable points on your components.
- The battery pack needs to connect to the LilyTiny: positive point to a positive point, and a negative to a negative point. (Note: there are two positives and negatives on the battery pack. You only need to use one of each.) This is a short trace, which terminates after connecting the battery pack and the Tiny.
- The positive point of each one of your LEDs needs to connect to ONE of the numeric points (0-3) on the LilyTiny. These are short traces, which go from numbered point to LED, then terminate.
- All the negative points on the LEDs need to connect and link back to the negative on the LilyTiny. This can be a long trace and you can simply sew through the negative points on the components three times then keep on sewing.
- A single 3v battery can run 1-5 LEDs. The more LEDs the shorter the battery life. I have eked out 6, but the current weakens fast!
- Positive and negative traces must not cross or touch. Thread is fibrous and tends to cross small gaps between traces.
- The shorter the trace, the better the connectivity.



Sewing the circuit

A tip: Sew the circuit and make sure it works before adding embellishments like embroidery.
After the circuit is designed, tuck the fabric firmly into the embroidery hoop. Thread a needle with about two feet of thread. Do not double it (that causes it to knot more easily.) Tie a knot in the end.
While sewing:

- Sew using tight, small stitches.
- Either running or back stitch will work-back stitching is more conductive.
- Do not allow positive and negative traces to cross or touch. Be careful of where you make knots.
- Only sew traces with conductive thread. Use sewing thread for other attachments. (Especially important on the battery pack!)
- Sew at least three tight loops through each hole of your components. More is fine. Make sure that the loops sit side by side to maximize contact with the metal legs.

Recommended order (this is not necessary but it helps some participants keep their circuit straight):

1. Positive battery pack to positive Tiny.
2. O to LED positive.
3. 1 to LED positive.
4. 2 to LED positive.
5. 3 to LED positive.
6. Long trace that connects battery pack negative to Tiny negative to each LED negative.

If (when) a thread breaks or knots, thread your needle with new thread. Knot it to the old thread as close to the last stitch as you can. Cut the threads close to the knot and continue sewing.
As you finish each trace, tie a tight knot and clip the thread close to the knot.

Testing and refining

When the circuit is complete, put the battery in and switch on the circuit. Does it light up? If not, examine the traces. Do any touch? Are there any spare threads? Do the threads from the knots touch? Keep experimenting until your circuit works. Then decorate it with embroidery or whatever you wish! Look at the handout for ideas for finalizing your work.

Troubleshooting

- Over half of student problems are caused by lack of sewing ability. Prior to working on eTextiles, a crash course in sewing is a really good idea.
- Watch out for fuzzies and the thread you tied the knots with. Those things can cross and short out your circuit. If any are particularly annoying, use duct tape to hold them down!
- One of the most common short circuits with this particular battery pack happens when a participant sews the extra connectors on the battery pack with conductive thread. Use sewing thread for this.
- A short circuit can drain a battery quickly. If you have fixed a short circuit and your circuit still doesn't light, change the battery.
- If you are making a patch with the battery on the back, add a layer of felt between the front and back to act as an insulator.
- You can use duct tape to make "bridges" over traces when crossing is inevitable.
- Test component polarity with a multimeter (if you have one) or by using alligator clamps.
- Ripping out sewing is annoying but is often the only way to fix a problem.
- If participants want to add LEDs to other fabric items, make sure the items are not metallic. Working out circuits in clothing is a bit trickier but can be done.

Vocabulary

electricity: a form of energy that's produced by the flow of electrons
circuit: an electric device that provides a path for electric current to flow
current: the flow of electricity in an electric circuit
electrode: a conductor through which a current enters or leaves a circuit
anode: positively charged electrode, the sewable point on components marked +
cathode: negatively charged electrode, the sewable point on components marked =
power source: item which introduces energy into circuit (like a battery)
ground: a connection between an electric device and the earth
switch: a mechanical device used to turn a current on or off in an electric circuit
LED: light emitting diode
short circuit: an electrical circuit that allows a current to travel along an unintended path, often where essentially no resistance is encountered
conductive trace: a path for current to run through a circuit (thread, paint, tape, wire) •
conductive: a substance that allows electric current to pass through it
insulating: a material that does not allow the flow of electricity to pass through it

Most definitions are from What's the Word, Kids Save on Energy
http://kids.saveonenergy.ca/en/what-is-electricity/whats-the-word.html

To learn more:

An e-Textile inspiration video that I created (all images, many with project links are from my e-Textiles Pinterest page):

- video https://animoto.com/play/ONFG0jwLZVoJl0xbx3zfJQ
- Pinterest page: https://www.pinterest.com/DaylePayne/e-textiles/

The curriculum guide that started it all (for me, I should add-- it is a great place to start)
Getting Hands on with Soft Circuits: A Facilitator's Guide by Emily Lovell
http://alumni.media.mit.edu/~emme/guide.pdf

Sites with many resources

- Sparkfun (materials, inspiration, tutorials and everything else!) http://www.sparkfun.com
- Adafruit (materials, inspiration, tutorials and everything else!) http://www.adafruit.com
- SewElectric http://sewelectric.org/diy-projects/
- Instructables how tos (amazing resources) http://www.instructables.com/id/How-To-videos-for-eTextiles-soft-circuits-and-we/
- Make Geek Chic eTextiles Round up (classic projects, many very elaborate) http://makezine.com/2010/04/06/geek-chic-massive-e-textiles-roundu/
- etextile lounge (all kinds of info on materials) http://etextilelounge.com
- electrofashion (British and phenomenal!) https://www.kitronik.co.uk/blog/e-textiles-an-introduction-to-our-electro-fashion-range/

Books

- Sew Electric, Leah Buechley, 2013.
- Make: Wearable Electronics: Design, prototype, and wear your own interactive garments 1st Edition, Kate Hartman, 2013.

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