

A Soft Circuit Curriculum to Promote Technological Self-Efficacy

by
Emily Marie Lovell

Bachelor of Arts in Computer Science
University of California at Santa Cruz, 2008

Submitted to the Program in Media Arts and Sciences,
School of Architecture and Planning,
in partial fulfillment of the requirements of the degree of
Master of Science in Media Arts and Sciences
at the Massachusetts Institute of Technology

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Signature of Author

Program in Media Arts and Sciences
May 6, 2011

Certified by

Leah Buechley
AT&T Career Development Assistant Professor of Media Arts and Sciences
Thesis Supervisor
Program in Media Arts and Sciences

Accepted by

Mitchel Resnick
LEGO Papert Professor of Learning Research
Academic Head
Program in Media Arts and Sciences

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ABSTRACT

The development of technological self-efficacy in young people can have a dramatic impact on diversity in the field of computing. Students' self-efficacy and scientific understanding can benefit from engaging in hands-on activities, such as creating soft, electronic textile (e-textile) circuits. There is, however, a notable lack of instructional materials to support such learning experiences. I have developed a workshop facilitation guide which outlines five e-textile activities, accompanied by a collection of low-cost craft and electronic components. The instructional materials target educators, who may facilitate e-textile activities in settings such as science museums, after-school programs, or summer camps. I have assessed the effectiveness and usability of the materials through a short series of workshops, during which I also evaluated their impact on students' technological self-efficacy.

Thesis supervisor: Leah Buechley
Title: AT&T Career Development Assistant Professor of Media Arts and Sciences

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Emily Marie Lovell

Advisor

Leah Buechley
AT&T Career Development Assistant Professor of Media Arts and Sciences
Program in Media Arts and Sciences, MIT Media Lab

Reader

Mitchel Resnick
LEGO Papert Professor of Learning Research
Program in Media Arts and Sciences, MIT Media Lab

Reader

Chris Randall
Senior Editorial Project Director
Educational Outreach, WGBH Boston

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1

Introduction

1.1 To What End?

Self-efficacy has been established as an important factor in the retention of women and underrepresented minorities in computing [23]. Consequently, a body of literature has emerged which documents efforts to promote technological self-efficacy at the university level (for example, mentoring programs and pair programming practices [24, 26]). However, I believe that students can benefit even earlier from hands-on experiences of technological mastery — and that soft circuits are a relevant and accessible medium for this.

Soft circuits, also known as electronic textiles (e-textiles), are electrical circuits created using flexible conductive materials (such as conductive threads and fabrics) in conjunction with discrete electronic components (such as lights, batteries, switches, and sensors). Previous research has shown e-textiles to be a rich and appealing context for promoting self-efficacy at the K-12 level [6, 7]. This may be due, in part, to students building new knowledge (of computing and electronics) atop experience in a domain which already interests them (sewing/crafts). For similar reasons, the domain of e-textiles may provide educators with an approachable context in which to teach with confidence; this is an important consideration, because educator self-efficacy has been shown to impact students' learning [3, 32].

There is, however, a notable lack of instructional materials to support soft circuit learning experiences. Many educators are interested in exposing their students to interactive e-textiles but are unsure of how to obtain affordable materials or efficiently prepare to lead activities. They may also be unaware of what is possible — for example, that switches may be constructed from everyday objects such as snaps, beads, and tin foil.

Although a variety of toolkits and instructional materials have been developed to ease the construction of e-textile artifacts, these have not been evaluated with regard to self-efficacy, nor formally evaluated with sizable user groups. Additionally, the lack of dissemination of research findings outside of academia have hindered the ability of such toolkits and instructional materials to impact learners and educators on a significant scale.

The focus of this thesis is to address the lack of e-textile instructional materials and evaluate their success in terms of how well they promote technological self-efficacy. By providing educators with the information and structure to efficiently direct and support e-textile learning activities, it is my hope that students will develop technological confidence and capability.

1.2 Overview

I have sought to design a particular kind of hands-on learning experience, scaffolded by instructional materials and resources. This process has included developing a curriculum (in the form of a workshop activity guide), curating a collection of useful tools and materials, and enacting a series of workshops in order to evaluate my efforts.

My intention is that the workshop activities be well-suited for informal learning environments, such as summer camps, science museums, and after-school programs — for example, the Computer Clubhouse Network, Digital Youth Network, and Short Circuit Afterschool Program [7, 9, 31]. In such settings, the focus is more on exploratory learning than following a set curriculum, and so there exists greater freedom to engage students by means of unconventional teaching practices.

Although my indirect audience is the students themselves, the workshop activities directly target those in teaching/facilitation roles. The instructional materials offer educators the practical/technical knowledge necessary to confidently direct an activity without much advance preparation. They also contain information to help anticipate (and be prepared to support) common pitfalls and trouble spots that students may encounter.

The guide opens with an overview of soft circuits as well as general notes on facilitation, activity structure, and audience. Each activity's overview provides educators with realistic expectations as to what students should learn during the session. Each activity also includes:

- photos of example projects
- a list of tools and materials necessary
- preparation instructions
- a walkthrough of how the activity might be facilitated

Appendices offer additional resources, troubleshooting tips, and information on materials. The guide is structured such that it may be used exactly as it was designed, yet it also allows educators the freedom to tailor certain aspects to their unique student community and learning environment.

The assortment of physical tools and materials referenced in the workshop guide includes everything needed to lead all of the included activities. Tools and materials were specifically selected on account of being affordable, accessible, and easy to use.

Finally, I organized a series of two workshops through which to evaluate the usability of the instructional materials, in addition to their potential impact on students' self-efficacy. I taught the first workshop myself, while the second was taught by an educator using the instructional materials I've developed.

1.3 Definitions

In the context of this thesis, *technological self-efficacy* refers to one's self-perception of proficiency across technological domains.

Although *educators* may generally be interpreted to mean classroom teachers, I also use the term as being inclusive of workshop facilitators and leaders of summer camps or outreach programs.

A *soft circuit* is defined here as a flexible electrical circuit constructed on the surface of (or embedded in) textiles. Such a circuit may be created using a variety of soft conductive materials (such as conductive threads and fabrics) in conjunction with discrete electronic components (such as lights, batteries, switches, and sensors).

2

Background & Related Work

My research builds upon an interdisciplinary foundation of related work across several domains, including: self-efficacy, diversity in STEM fields (science, technology, engineering, and math), instructional materials for craft and technology, and e-textile construction kits.

2.1 Self-Efficacy

Self-efficacy, as initially conceptualized by Bandura [1], has the potential to greatly influence success in learning. Through extensive research, Bandura found a high correlation between perceived self-efficacy and actual human performance; that is to say that a lack of belief in one's capability can be a greater limiting factor than one's actual capability [2].

Although a wide variety of factors can contribute to the development of self-efficacy, Bandura notes that there are four main sources from which it tends to grow [3]:

- *experiences of mastery*, in which an individual successfully overcome obstacles in pursuit of an objective
- *vicarious experiences* (or *social modeling*), in which individuals observe others to whom they relate succeeding as result of sustained effort
- *social persuasion*, which is when individuals are verbally persuaded that they have the capability to succeed at a given effort
- *somatic and emotional states*, which influence how individuals judge their own capabilities

I have considered each of these throughout my design process, paying particular attention to the first three (*experiences of mastery*, *vicarious experiences*, and *social persuasion*).

Evaluation of self-efficacy is itself a broad topic of research, although one common method of evaluation is to use Likert scales [25]. In assessing self-efficacy, such rating scales measure one's level of agreement with a set of hypothetical statements about domain-specific tasks or challenges — for example, *I can debug my circuit even without the use of a multimeter*.

I have chosen to develop my thesis with an emphasis on self-efficacy precisely because of its impact on persistence in learning [3]. If students are better scaffolded to overcome obstacles, they are more likely to continue to challenge themselves going forward – revising mental models and deepening their scientific understandings.

2.2 Diversity in STEM Fields

Technological self-efficacy has the potential to impact diversity in STEM fields, as it can bolster an individual to be more resilient in the face of adversity. Rising attrition rates have been well documented by many, including Margolis and Fisher, who reflect on their study of

female retention in computer science in *Unlocking the Clubhouse* [23]. In *Self-Theories*, Dweck also discusses developmental differences along gender lines, some of which might be better balanced if all children were encouraged to develop a strong sense of self-efficacy at an early age [11].

Buechley and Eisenberg have sought to broaden the appeal of engineering specifically through combining craft and computation [4, 5, 6, 7]. Their research has found that women are more drawn to engage with electronics in the context of textiles than other, more traditional means (robotics, for example). STEM fields have a lot to gain from attracting more women, as a more diverse workforce naturally yields a more diverse set of ideas, products, and solutions.

2.3 Instructional Materials for Craft and Technology

Instructional materials for blending craft and technology come in many forms, such as blogs, books, and websites. Blogs such as CRAFT and MAKE offer hobbyists pointers to a variety of online tutorials and resources, in addition to publishing their own [9, 22]. Fashioning Technology and Soft Circuit Saturdays are blogs specific to the field of e-textiles [15, 35]. Both websites showcase projects, highlight research developments, and offer information on selecting/purchasing materials.

While blogs fill the role of aggregating latest news and trends, static websites have also become a valuable resource for those interested in engaging with e-textiles. Buechley's LilyPad Arduino tutorials, along with my own introductory e-sewing tutorial, provide a structured path through the basics of sewing, circuits, and microcontroller programming [12, 20, 21]. Similarly, Lee's Tech DIY website offers tutorials for specific craft/technology projects with a focus on mother-daughter engagement [17, 38].

In recent years, e-textile project tutorials have also been published in a handful of books. Fashion Geek, Switch Craft, and Fashioning Technology provide readers with a basic understanding of circuits, followed by a selection of soft circuit project tutorials [14, 18, 31]. Open Softwear, while currently only available in digital format, provides a structured introduction to e-textile prototyping using the Arduino platform [30].

Effective instructional materials are essential to conducting and engaging in positive learning experiences. The development of my own instructional materials has been largely informed by the above-mentioned resources, although my materials differ in that they specifically address an audience of educators. While existing tutorials and books effectively guide individuals through e-textile projects, the needs of an educator are significantly different; an educator must gather the necessary knowledge and materials to support many learners in parallel.

2.4 E-Textile Construction Kits

A number of kits have been already developed for the construction of electronic textiles, some of which are commercially available. Both Hartman and Stern have used the Etsy website as a storefront for basic e-sewing kits, which include components such as lights, batteries, and conductive thread [16, 36]. Such kits allow the purchaser to freely create her own soft circuits from relatively low-cost materials. Pakhchyan's *Salt n' Peanut* and ZippyKit's *Loopin* (see Figure 1) are examples of more structured e-textile kits which guide the user through a pre-designed craft project [33, 39].



Figure 1: Examples of two e-textile construction kits: the *LilyPad Arduino* (left) and *Loopin* (right).

For more complex projects in which programmability is necessary, users can opt for Buechley's *LilyPad Arduino* (see Figure 1), a sewable microcontroller toolkit for use with conductive thread [18]. Ngai, et al. subsequently developed two modular platforms for wearable computing, *TeeBoard* and *i*CATch*, to bring Arduino into the classroom and teach basic programming [25, 26]. Elumeze and Eisenberg's *ButtonSchemer* and Aniomagic's *mimeelight* offer an alternative to other sewable interfaces, allowing a user to transmit programs to computational garments through patterned light [13, 27].

Falling somewhere in between the low-cost e-sewing kits and those which offer microcontroller programmability is *fabrickit* [37]. *fabrickit* combines the simplicity of Hartman and Stern's kits with the modularity of the *LilyPad Arduino*, *TeeBoard*, or *i*CATch*; it consists of elegantly designed battery, light, and connection "bricks" which may be connected using a three-wire conductive fabric ribbon.

I considered the strengths of each pre-existing e-textile construction kit as I selected materials for my workshop activities. In particular, I chose to focus on materials which are inexpensive and accessible (as in Hartman and Stern's kits), yet durable and versatile (as in the *LilyPad Arduino* toolkit). I also opted to index an assortment of recommended materials, rather than assemble a kit. In doing so, I hope that educators will take the liberty of selecting materials (and quantities) best suited to their teaching style, students, and environment, rather than adjusting to constraints that a kit might impose.

Unlike previous work, which has focused solely on either standalone instructional materials/construction kits or technological self-efficacy (in adults alone), my research has sought to bring together all of these areas; I have developed instructional materials with particular focus on promoting technological self-efficacy in youth.

3

Design & Development

In developing the workshop guide, collection of tools and materials, and the learning experiences, Bandura's sources of self-efficacy provided a framework to guide my design decisions. In this section, I will detail the work that I have produced, with particular attention to specific design choices that I made along the way.

3.1 Workshop Guide

Bandura notes that successful efficacy builders structure situations which invite success; similarly, they avoid placing people in situations in which they are likely to fail [3]. With this in mind, I developed a set of five workshop activities that use e-textiles as a vehicle for hands-on, exploratory learning about computing and electronics. Together, these activities appear in a workshop facilitation guide, entitled *Getting Hands-On with Soft Circuits* (which is included in its entirety in Appendix A). I intended that the activities be interesting and fun for students, but constrained enough that educators could ensure their success.

The guide opens with an overview of soft circuits and notes on facilitation, intended audience, pre-requisites, and the organization of the guide. In this section, I wanted educators to begin to feel comfortable and supported in exploring a new domain with their students. If an educator is comfortable with approaching the material, then he or she will be well-poised to infuse *social persuasion* and encouragement into the learning environment.



Figure 2: An example activity with accompanying circuit schematic handout.

Following the educator overview, the guide contains a series of activities designed in sequence, such that each activity builds on the concepts of those preceding it. Each activity includes a photo of an example project, a list of tools and materials, a summary, a list of learning goals, and directions on how to prepare and lead the activity (see Figure 2). Activities also include support materials, when necessary, such as project templates or circuit schematic handouts that can be given to students (also shown in Figure 2). Each activity is designed to be completed in a two or three hour session, with the exception of the final activity which is better suited to a half-day workshop. Photos of each activity may be seen below, in Figure 3.



Figure 3: The five workshop activities included in the guide.

Activity #1: A Simple Circuit

In the first activity of the guide, students are introduced to circuits and sewing with electrically conductive thread. Each student can create a simple soft circuit, connecting a light and battery, either on a piece of scrap felt or by embedding the components into a soft object brought from home.

Activity #2: Switches

Next, students become familiar with switches and how they affect electrical flow through a circuit. Each student can construct a brooch which flickers as it moves, using a dangling metal bead to close a circuit.

Activity #3: Parallel Circuits

In the third activity, students learn how to sew a circuit with more than one light, upon understanding the concept of parallel circuits. Using this knowledge, each student can fabricate a bracelet or cuff which incorporates multiple lights into its design. Building upon the previous activity's introduction to switches, students can use a metal snap as the means to secure the bracelet/cuff around their wrists – dually functioning as a switch. Because of this, the bracelet or cuff will turn on only when it is worn (or otherwise secured in a loop).

Activity #4: Microcontrollers

The fourth activity exposes students to microcontrollers and the concept of programmability. Each student can make a light-up patch, using a sewable pre-programmed microcontroller to control the behavior of an LED (flashing, fading, or steadily on). Three different patch templates/designs are provided, and these could be modified by an educator (or the students themselves) to make them more personal.

Activity #5: Connecting Back

In the final activity, students draw upon their experiences in previous activities as they make their own electronic quilt squares. The quilt squares can then be pieced together to create an electronic patchwork quilt. The activity encourages students to design and create a few different squares so that some can remain part of a collective project, while others may be

taken home to share with family – or even begin one's own quilt. The physical structure of the squares allows them to be rearranged repeatedly, encouraging the exploration and development of a group narrative and/or artwork. The goal of this activity is not to introduce any new concepts, but rather to reinforces students' sense of mastery over those taught in earlier activities.

Following the five activities, the guide contains a section on troubleshooting, which could even be photocopied and posted at a "debugging station" in the workshop space. Through including the troubleshooting section, I hope to provide educators with a sense of support, even when unanticipated obstacles arise. I also hope to communicate to students that debugging is a valuable part of the process, rather than something to be discouraged by.

A list of tools and materials, which can be cross-referenced from each activity, is included near the end of the guide. Each entry includes a photo as well as suggestions about where to purchase the item – and, in some cases, more specific ordering information (such as product numbers or purchasing tips).

Finally, the guide concludes with a section on related resources (both in print and online) for those interested in learning more about soft circuits. Each of these supplementary sections can be seen below, in Figure 4.



Figure 4: Workshop guide sections on Troubleshooting, Tools & Materials, and Further Resources.

3.2 Tools & Materials

The tools and materials listed in the workshop guide were selected with two main qualities in mind: affordability and accessibility (see Figure 5 for a sampling of the materials). With very few exceptions (such as the conductive thread), all of the materials are relatively low-cost and easily obtainable. Included are a selection of craft notions (such as fabric, beads, and needles) as well as electronics components (such as battery holders, LEDs, and microcontrollers). The complementary assortment of tools includes items such as needle nose pliers, fabric scissors, and hot glue guns.



Figure 5: Some of the affordable, accessible materials listed in the workshop guide.
Left to right: beads, a coin cell battery, LEDs, felt squares, magnetic snaps – each of which costs under 50¢.

For anyone learning to sew, fabric choice is very important; I specifically chose felt and coated canvas as the substrates for the workshop activities because they are inelastic and easy to sew through. Additionally, these fabrics tend not to fray at the edges, meaning they can be freely trimmed into a variety of shapes.

One challenge that I encountered was balancing a desire to realize creative projects (which promote *experiences of mastery*) within time and logistical constraints that educators typically face. Curling the legs of LEDs in order to make them sewable is a useful skill to learn, but also takes time and requires many pairs of needle nose pliers in one classroom. Although student engagement with the construction process is incredibly important, I decided to curl the legs of the LEDs that students would be using in advance of each workshop (see Figure 6). In order to minimize frustration decoding component polarity, I also color coded the legs of each LED and the backsides of each battery holder with permanent marker (black for *negative*, red for *positive*, shown also in Figure 6). This way, students could spend their time and energy focusing on arranging the components, sewing connections between them, and embellishing their projects to make them personal.



Figure 6: An LED, made sewable by curling its legs and also color coded with permanent marker (top).
A battery holder, also color coded with permanent marker (bottom).

Preparing for the workshops in this way also made the activities more accessible to the lower end of my target age range. Further preparation (such as hot gluing battery holders to project templates in advance) might allow for even younger students to engage with the activities – or for activities to be completed in a shorter amount of time. Similarly, older students necessitate less preparation and are apt to modify design templates to their liking.

I also set out hoping to expand the creative potential of introductory activities without prematurely overwhelming students with programming. To this end, I designed a small sewable breakout board for ATtiny45 and ATtiny85 microcontrollers — devices which may be integrated into circuits to enable pre-determined interactions such as lights that flash or areas that can sense touch. I based my circuit board layout on the *LilyPad Arduino* accelerometer board layout, which is open source and available under the Creative Commons License.

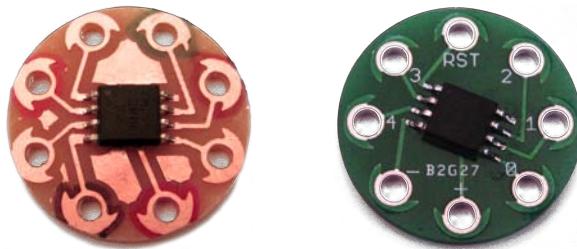


Figure 7: Sewable breakout board milled prototype (left) and custom-ordered prototype (right).

I used a milling machine to make the initial prototype of the breakout board (see Figure 7). I then used permanent marker to color code the pins that would be used for the fourth activity in the workshop guide. After testing the boards and successfully using them in a workshop (discussed in Chapter 4), I ordered a second revision from a circuit board manufacturer (also shown in Figure 7). As I expected, the second version of the breakout board proved to be noticeably more robust and reliable than the first.

After soldering the chips onto the boards, I programmed the microcontrollers using a physical programming device which connects a computer to each board via six alligator clips (shown in Figure 8). I wrote the program in the Arduino programming language and used the Arduino interface to upload the program to each microcontroller. It is my hope that, in the future, students and/or educators will be able to use a simplified version of this process to program their own microcontrollers.

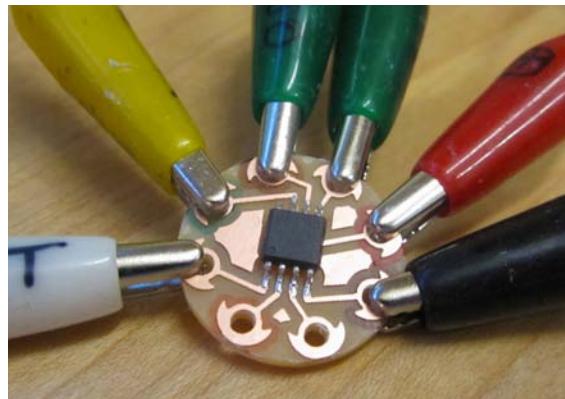


Figure 8: Alligator clips attached to a breakout board for programming.

3.3 Design Principles for Learning Experiences

In addition to designing a workshop guide and curating a selection of tangible tools and materials, I put significant thought into the design of the learning experience itself – in this case, a workshop.

My decision to design for group settings (rather than individual ones) was largely motivated by Bandura's discussion of *vicarious experiences*. In a workshop setting, students are surrounded by peers, hopefully to many of whom they relate (see Figure 9). Such a setting provides ample opportunity for students to watch their peers overcome obstacles, especially as a facilitator's role is to support students in doing so – in effect, providing *social persuasion* (see Figure 9 also).



Figure 9: Students engaging with their peers (left) and with a workshop leader (right).

I also drew inspiration from Papert's study of constructionism, wherein learning-through-creating allows a student to construct (and revise) her own mental models [32]. One conscious decision that I made which affected the design of the activities (but reinforced a constructionist approach to learning) was to place all of the electronic components on the same side of the fabric. (The second activity in the workshop guide is the only exception to this principle.) I believe this to be an important aspect of introductory e-textile projects, as it allows for students to learn about circuits in a way that is very transparent. When a circuit's "wires" (in this case, conductive thread) are not insulated, then the flow of electricity becomes more apparent – and the concept of a *short circuit* much more concrete.

Additionally, completing (or *mastering*) an activity in a single session promotes a sense of capability and competency – so I prioritized the design of activities that students could complete in one session and take home the same day. By allowing students to keep the projects that they make, an educator gives students the opportunity to share their experience with others and feel reaffirmed in doing so.

{ 4 }

Evaluation

In assessing the effectiveness of my materials, I sought to evaluate both the usability of the workshop guide and the impact of its activities on student self-efficacy. I used workshops and questionnaires to aid in the evaluation process, supplemented by direct feedback from educators.

4.1 Workshops

I arranged two workshops in collaboration with the Edgerton Center Outreach Program, located on the campus of the Massachusetts Institute of Technology. The program offers hands-on science and engineering experiences to classroom groups and homeschool students in the Boston metropolitan area.

Both workshops piloted the fourth activity from the workshop guide, in which students create a light-up patch with a light whose behavior is controlled by a pre-programmed microcontroller (see Figure 10). Most of the workshop participants had participated in previous activities at the Edgerton Center and were familiar with basic circuits and electronic components – a similar level of understanding to that which is covered in the guide’s first three activities.



Figure 10: A light-up patch being sewn by a workshop participant.

Both workshops were comprised entirely of homeschool students, who were recruited through an e-mail announcement including the following description:

During this session, we'll learn about circuits by making some of our own. We'll start by talking about a few fundamental concepts (conductivity, polarity, series/parallel circuits) and then build upon this knowledge as we complete a hands-on project. Using materials like conductive thread, lights, batteries, and metal beads/snaps, each student can make a personalized light-up patch.

The e-mail solicitation traveled through a network of homeschool parents, who expressed great interest in the opportunity for their children to participate – so much so, that both workshops were oversubscribed and we had to cap enrollment.

The workshops were both conducted within a three-hour time period, as is typical of activities offered through the Edgerton Center Outreach Program. That block of time included a 30-minute student lunch break, and roughly another 30 minutes were spent on survey completion. This left about two hours for the activity itself.

Workshop #1

I taught the first workshop myself, after completing an initial draft of the print instructional materials. My goal in doing so was to become aware of preliminary issues related to activity structure and logistics. I also hoped to identify any knowledge gaps which needed to be better addressed in the support materials. Three undergraduate volunteers were also present to assist in facilitating the workshop, although none of them had any prior experience with electronic textiles or advance familiarity with the activity being taught.

A total of sixteen students participated in this workshop, of which ten were female and six were male. The students' ages ranged from 11 to 16 years old.

After a brief introduction to the activity (including demonstration of an example), students collected the materials necessary to complete their projects. I spent a few minutes explaining the function of each material to the students as a group. Next, I presented an overview of the project in the context of circuits – and gave a broad summary of how students would progress towards completing their patches.



Figure 11: Demonstrating a running stitch (left) and students practicing sewing on their own (right).

Moving into the longer, hands-on portion of the workshop, I demonstrated how to sew with conductive thread. I began by showing students how to thread a needle and tie a knot at one end. Then, using a piece of scrap felt, I demonstrated how to sew a running stitch – a basic stitch that students could use to complete their projects (see Figure 11). Students spent some time (about ten minutes) practicing on their own, also using some scrap felt and conductive thread (also seen in Figure 11).

Following a lunch break, students had about one hour to sew their light-up patches. I began this period of time by explaining the first couple of steps and then let students get to work. As students began to finish one part of the project, I would ask for the group's attention long enough to explain the next part. Although students worked at different paces, most were willing to relay instructions to neighbors who were on different steps. Additionally, each student had a handout with a diagram of the microcontroller pin functions and a list of each electronic component and its function. During this time, the undergraduate volunteers and I were also circulating to help students with any difficulties they encountered and to remind them what to tackle next (see Figure 12). The first breakout board prototype (made on a milling machine, then color coded by hand) was used for this workshop.



Figure 12: Guiding students through working on their projects.

The end of the workshop felt slightly rushed, with students trying to debug their patches up until the last minute, but most students (12 in total) were successful in getting their microcontroller to control an LED. Two of these students “finished” early and so I challenged them to add an additional light to their circuits. After a brief explanation (and a quick sketch) of a parallel circuit, both students were successful in adding a second light. In addition to the 12 students whose projects functioned by the workshop’s end, there were also two students whose projects were carefully constructed and merely one connection shy of being complete. All of the students were offered the option of taking conductive thread and/or additional LEDs home to complete or augment their projects. Figure 13 shows a few of the students with their finished projects.

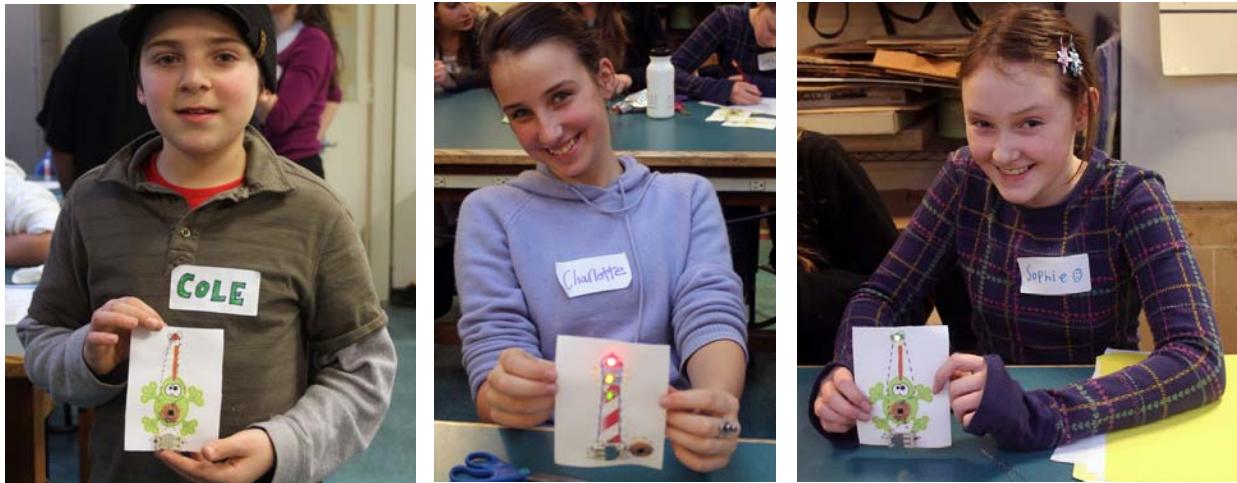


Figure 13: Students and their finished projects, at the end of the first workshop.
The center participant has sewn three lights into her circuit, in parallel.

Workshop #2

There were a few issues in particular that I sought to address prior to the second workshop. For example, many students from the first workshop had a difficult time sewing through the canvas that the patches were printed on – and their needles were prone to snapping in half. Both of these problems were remedied by sourcing different materials prior to the second workshop. Students from the first workshop also became frequently frustrated over threading their needles, as the conductive thread frays easily. However, we discovered that rubbing the thread over a glue stick makes it much easier to thread a needle, and so students were shown how to do this for the second workshop. (To save time, I also threaded several needles in advance of the second workshop.) We also found that hot glue was useful for isolating electrical traces, in addition to sealing knots. In areas where two clumps of knotted thread were competing for space, students were able to hold them apart while depositing a mound of hot glue to separate them permanently. This, too, was a technique that informed the second iteration of the workshop activity.

Having learned a great deal from the first workshop, I incorporated both student feedback and personal observations into a revision of the workshop guide. I then asked an Edgerton Center educator to teach one of the activities, so that I could assess the usability of the workshop guide. In order to determine whether the materials offered an accessible and scalable set of informal learning experiences, I observed this workshop and acted in a similar manner to the undergraduate volunteers who were present. For this workshop, there were again three undergraduate students assisting the session leader – although one of these students had previous exposure to the activity, having been present during the first workshop. I provided all of the physical materials necessary on the day of the workshop.

A total of ten students participated in this workshop, of which four were female and six were male. The students' ages ranged from 11 to 14 years old.

Before the students began to arrive, the leader spent a few minutes reviewing the activity instructions and debriefing undergraduate volunteers, so that they would better be able to anticipate and answer student questions.

After students filled the classroom, the leader began by asking students to briefly introduce themselves, since they would spend the entire morning working together. She then gave an overview of the activity, showing an example, and breaking it down into two components: first, practicing sewing, and second, integrating a microcontroller into a soft circuit project. Students collected the necessary materials from a central location and the leader began to walk through the list of materials (and their functions) with the group. During this time, she encouraged students to physically touch and hold each component as it was discussed (see Figure 14).

She began by introducing the conductive thread, explaining that it is electrically conductive because it is made from tiny metal fibers. She described it as being similar to electrical wire, except not insulated. To expand on this, she said that the “good news” was that students wouldn’t have to strip any wire, but the “bad news” was that they needed to keep their stitches neat in order to prevent electricity from jumping to other threads. She introduced the coin cell battery next, pointing out that while it wouldn’t ordinarily be a good idea to connect an LED directly to three volts of electricity (without resistors – which she calls “bodyguards”), it wouldn’t be a problem in this case because conductive thread itself is resistive and keeps too much electricity from flowing to the light. When talking about the light next, she engaged students in understanding polarity by asking them what would happen if she were to sew a light backwards into a circuit. Finally, when explaining the microcontroller, she clearly distinguished between the microcontroller itself and the circuit board to which it was soldered (allowing for it to be sewn into fabric).



Figure 14: Talking through the materials list as a group.

Next, the leader demonstrated how to sew a running stitch (just as I did in the first workshop), although she approached this by breaking the process down into smaller steps, namely: *how to start sewing*, *how to sew*, and *how to stop sewing*.

Following the introduction to sewing, she gave instructions for getting started on the light-up patch itself. As clusters of students would finish steps, she would explain the next part of the project – similar to how I’d taught the activity in the first workshop. The second breakout board prototype (ordered from a circuit board manufacturer) was used for this workshop.

In this workshop, *all* of the participants were successful in sewing a circuit containing a microcontroller-controlled LED. Additionally, several students went beyond connecting one light (exhibiting one behavior) to their microcontroller. Two students added an additional light to their circuits, creatively placing them in different locations on their patches. Another participant discovered that, by pushing a loose piece of thread into contact with another electrical trace, he could cause his LED to alternate between two behaviors. A third student added a second light to her project, but chose to connect it directly to the battery – this way, she could have one light blinking and another that shined steadily. Figure 15 shows a couple of student projects from this workshop.



Figure 15: A participant with her completed project (left) and another project, whose creator is beginning to sew in a second light (right).

This workshop felt significantly less rushed at the end, and there were even a few minutes left for students to reflect on the experience. The leader asked each one of them to share a thought or two about the session. A few students expressed that they liked when “it worked” – and a handful more commented that they either loved or hated the sewing.

4.2 Questionnaires

For each of the two workshops, I evaluated students’ self-efficacy through pre- and post-workshop questionnaires, which can be found in Appendix B. These questionnaires probed students’ perception of their own abilities, previous experience with sewing and/or technology, and interest in pursuing computational activities beyond the scope of the workshop. The questionnaires used Likert scales to evaluate items related specifically to self-efficacy.

As reflected also in verbal feedback at the end of the second workshop, many students commented that they either *loved* or *hated* that sewing was central to completion of the activity. Almost all of the students who enjoyed the sewing aspect expressed an increased comfort with basic circuit diagrams and debugging – although, the reverse does not seem to be true; those who disliked sewing did not express decreased comfort in these areas. This

suggests that e-textile activities might serve as an unintimidating way of introducing electronics to young adults.

When students were asked, "Did you learn anything new today? If so, what?", the most common response (reported by almost half of the total participants) was "How a circuit works," or "How to build/make a circuit." Roughly one quarter of the total participants responded to the same question with "How to sew."

Comparing the pre- and post-workshop responses from both workshops offers supporting evidence that students learned something about circuits from the activity. Students, on average, reported an increased comfort with drawing a diagram of a simple circuit (made from a light and a battery) following the first workshop. At the conclusion of the second workshop, students, on average, reported increased comfort with both making and debugging a simple circuit. In cases where the average response to these prompts did not increase, it also did not decrease – it merely remained the same.

It is also worth considering that in post-workshop questionnaires for both workshops, students reported the same average level of comfort with explaining the circuit that they made to a friend. This consistency may suggest that students were able to develop a similar level of understanding of their project, regardless of who was teaching.

4.3 Educator Feedback

In addition to the two workshops mentioned above, I also solicited feedback on the workshop guide from a couple of educators.

At the conclusion of the second workshop, I reconnected with the workshop leader to discuss both the teaching experience and how well the materials supported it. Overall, she seemed very pleased with how the activity had gone, remarking specifically about how happy and engaged the students seemed to be throughout the workshop. She offered some specific suggestions for the activity instructions, such as including better introductions to technical terminology and dividing the physical materials into those which are shared by the group and those which are needed for each individual. From a broader perspective, she also offered her thoughts on the role of pre-programmed microcontrollers in introductory e-textile activities; she believed that they might serve as a valuable entry point to students understanding programmability. She speculated as to how she might pursue the topic further, by showing students the code running on their microcontrollers and asking them to pick out key words that seem to be causing particular behavior (words like *on*, *off*, or *loop*).

Another experienced educator offered in-depth feedback on the workshop guide as a standalone resource. His feedback included suggestions on organization and accessibility, but also on an overall framework in which to consider the activities. For example, he suggested drawing educators into the guide with an expanded table of contents and more specific activity titles. However, he also shared his thoughts on the pedagogical implications of introducing microcontrollers during the light-up patch activity – and we discussed how future work in this space might make it easier for students to upload programs to their own microcontrollers.

5

Reflection

Students who participated in the two workshops do seem to have gained a deeper understanding of how a basic circuit works. While I had hoped that this would be the case, many students also learned how to sew – something which I had not anticipated. I also hypothesized that once students had a positive and successful initial experience, they would be intrinsically motivated to learn programming for the purpose of enhancing their projects. When asked what they would like to pursue in a similar future workshop, two students indicated specifically that they would like to learn how to program the microcontrollers themselves. A few more students suggested project ideas that would likely require some level of programming (such as “voice-activated light”).

Student responses also indicated consistency across the two workshops in terms of workshop length, difficulty, and pace; that is to say that students had a relatively similar experience in each workshop, despite having been taught by different educators. This is, perhaps, preliminarily indicative that the instructional materials are both usable and transferrable.

More generally speaking, developing and piloting the materials described in this thesis has been a very rewarding journey. The process of developing an activity, teaching the activity, and then watching someone else teach the same activity offered an incredible amount of insight into what makes an enriching educational experience. In particular, observing an experienced educator’s interpretation of my instructional materials allowed me to note alternative ways of explaining concepts or scaffolding students through moments of discovery.

The workshop guide and accompanying materials seem as though they might offer a set of accessible learning experiences (as I’d hoped they would), although they are fairly structured in order to facilitate this. While this may provide an approachable entry point for educators new to soft circuits, it is unclear whether or not educators will find this to be a constraint – or, perhaps, discouraging of open-ended exploration.

A future longitudinal study would offer more thorough analysis of the impact of a soft circuit curriculum on student self-efficacy. As the pre- and post-workshop questionnaires were administered within only a few hours of one another, I had not expected to see dramatic shifts in student self-efficacy. I also acknowledge that teaching home-schooled students is not necessarily predictive of how students in other settings would respond to the same workshop experience. However, although very preliminary, the results of my research are suggestive.

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Future Directions

I hope to continue to refine the materials developed as part of my thesis, including the workshop guide, the sewable microcontroller breakout board, and the process by which the breakout board can be programmed. The workshop guide could easily grow to include additional activities on topics such as sensors, actuators (such as motors), or even introductory microcontroller programming. Likewise, future revisions of the breakout board could promote re-programmability in a way which the current version does not. Above all, I hope that this iterative process will continue to include involvement with experienced educators such as those who have already offered feedback.

Thinking further into the future, I also hope to reach for bigger research questions which I've only begun to uncover through working on my master's thesis; I am especially interested in building bridges between introductory craft/technology experiences and those of mastery which result from constructive educational experiences. My research so far has primarily focused on introducing people to computational craft activities – attracting new audiences, while studying topics of motivation and self-efficacy.

As I've gained insight into broadening the appeal of technology, I've also become invested in developing and sustaining interest over time. Upon mastery, individuals have acquired enough knowledge and experience to tackle new projects and continue to deepen their own understandings – all of which enables them to push materials to the limit as they construct beautiful, computationally enriched artifacts. Yet, in order for individuals to progress from novice to a state of mastery, they need underlying intellectual scaffolding to ease the shifting balance between motivation and deep conceptual understanding. It is important that individuals feel challenged, but not overwhelmed, during this time.

Research in this transitional space between novelty and mastery would build nicely upon the foundation laid by my master's thesis. As a starting point, I hope to give greater consideration to the role of microcontrollers and computation in craft projects. Individuals might initially work with preprogrammed microcontrollers (as in this thesis), to which they can connect other electronic components and achieve predetermined behaviors/outcomes (such as lights that fade or switches that turn a circuit on or off). They could then transition to working with microcontrollers to which they can upload pre-written programs, offered as part of a library. A next step after that might be allowing individuals to tinker with variables in those same programs, via constrained interface elements (such as sliders). Subsequent intervals of increased complexity could continue to support individuals all of the way along the road to learning Arduino, or even more advanced programming languages like C or Java.

7

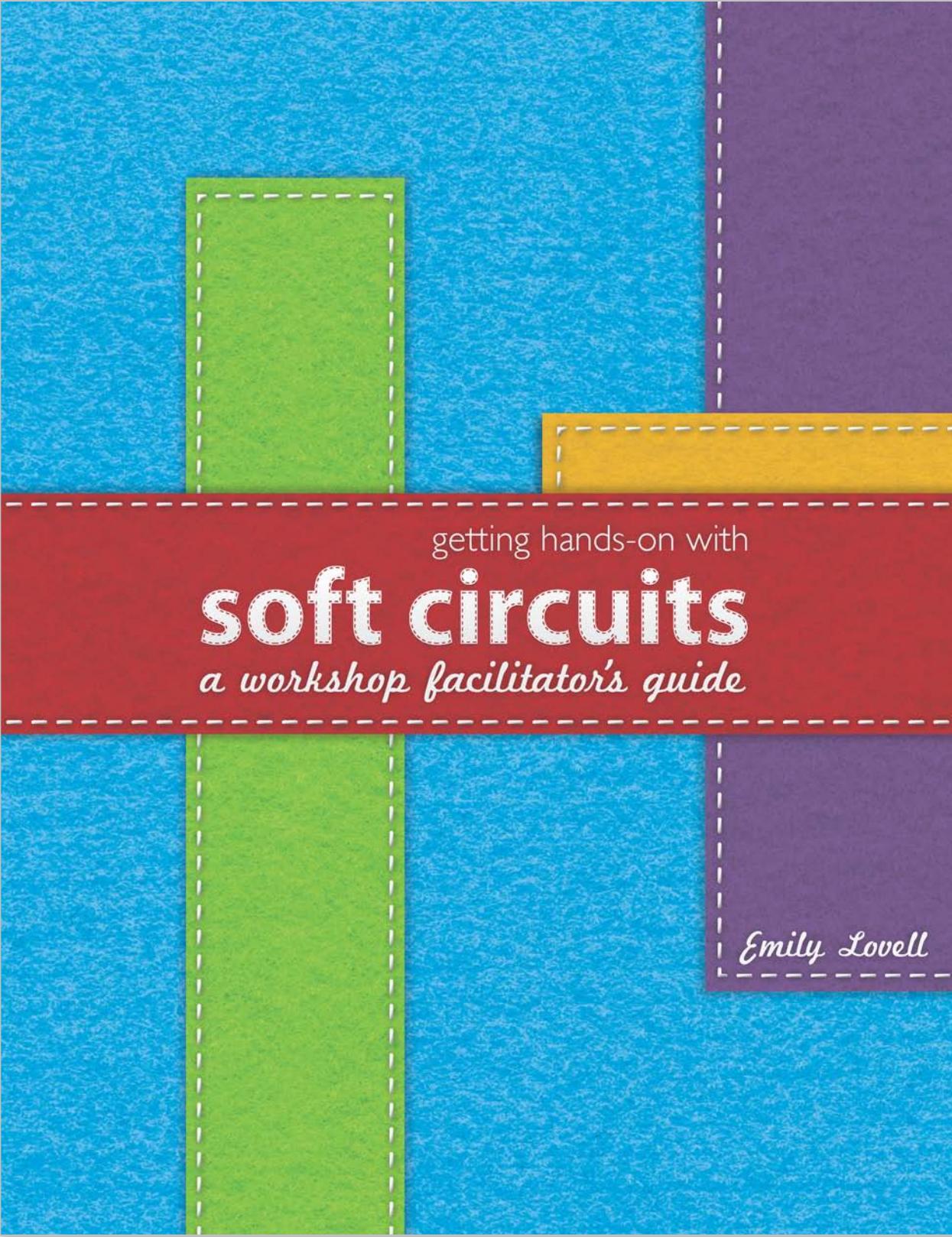
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{ A }

Workshop Guide



getting hands-on with

soft circuits

a workshop facilitator's guide

Emily Lovell

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The activities in this guide assume no prior knowledge of circuits, sewing, or design – so there are no prerequisite requirements aside from an interest in trying something new!

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OVERVIEW

What Are Soft Circuits?

Soft circuits, also known as 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).

Why Soft Circuits?

Learning to design and create soft circuits of increasing complexity has the potential to be an empowering and formative experience for young adults. Such activities invite students to consider technology in a more creative context - and, likewise, to consider creativity in a more technical context.

By integrating electronic and craft materials, soft circuit activities can appeal to a wider variety of students than traditional science or art activities. Furthermore, students should develop a sense of confidence when working with science and technology, as they will be supported throughout the process of successfully debugging unexpected behavior in their projects.

As outlined in the following workshop activities, students will learn about electricity in the context of hands-on design. Because students are making creative decisions about appearance and functionality, their projects will reflect characteristics of personal identity. They may find the activities to be a welcome outlet for self-expression. Whether students are motivated by the technical or creative aspects of each activity, they will learn by *doing*, instead of just by listening, reading, or watching others.

Notes on Facilitation

As a facilitator, your role will be to guide students through the activities. This will include providing students with the technical understanding necessary to complete each project, while also promoting the development of creative problem-solving and design skills. If something isn't functioning as expected, refer to the *Troubleshooting* section of the guide for some helpful tips. But be sure to challenge students to question, reason about, and revise their mental models as well. In these activities, the process of discovery is just as important as the outcome.

You should also encourage students to help one another. Those who already know how to sew can assist peers who lack sewing experience; likewise, students with knowledge of electronics can aid those who lack this familiarity.

You may find it useful to begin the first session with brief introductions and an icebreaker exercise. This will allow students to begin to build social relationships, which they will draw on as they experiment with (and troubleshoot) their soft circuits.

Consider starting each session by connecting back to the previous session. For example, summarize what students learned (and created) last time, or ask a rotating student volunteer to do so. After you've done this, introduce students to what they'll be learning in the current

session by framing it in the context of the session's tangible project. If you have time to try the activities ahead of time, bring your example(s) to share with students. Students may also find it helpful to walk through each activity's materials list as a group, visually identifying each component and reviewing its function or purpose.

Conclude each activity by asking students to take turns presenting their work to one another. Encourage them to share thoughts or the motivation behind the aesthetic design of their project, in addition to an explanation of how their circuit functions. This is a great time for students to share any difficulties that they encountered and how they managed to overcome them.

Additionally, invite students to take what they've learned in each session and relate it back to their daily lives. For example, at the end of the activity on switches, encourage students to think carefully throughout the coming week about which objects in their bedrooms or school classrooms would conduct electricity.

Structure

This guide has been developed for use in informal learning environments, such as after school programs, community technology centers, and art/science museums. With the exception of the final activity, each activity takes about two hours. A full morning or afternoon (4-5 hours) should be dedicated to the final activity. Ideally, the activities should be offered in close succession - for example, one session each week over the course of five weeks.

If necessary or desired, the activities may be compressed into a one or two-day weekend workshop. Alternatively, intermediate activities may be skipped if you wish to pursue a simplified version of the final activity.

If a student's circuit isn't working - or is functional, but not behaving as expected - see the *Troubleshooting* section at the end of this guide.

Additional information on the materials and tools listed for each activity may be found in the *Tools & Materials* section, also at the end of this guide. Pencils and paper should be available during each session, and you may choose to also offer conductive household items (paper clips, staples, safety pins, aluminum foil) from the second activity on.

The *Further Resources* section also includes suggestions for print literature and web sites related to these activities.

Intended Audience

Although the activities in this guide may be adapted for other age groups, they were designed with middle and high school students (ages 11-17) in mind. Each activity builds on those preceding it; ideally, participants should be able to commit to attending all workshop sessions.

activity #1

A SIMPLE CIRCUIT

connecting a light and a battery



alternatively, students can sew a simple circuit into something brought from home – such as a shirt, bag, hat, or hair tie (seen here)



Tools & Materials

For each student:

- battery
- battery holder
- piece of felt
- LED (light)

For the group to share:

- needle threaders or beeswax
- conductive thread
- fabric scissors
- hot glue gun and glue sticks
- needle nose pliers
- sewing chalk
- sewing needles

Summary

Students are introduced to circuits and sewing with electrically conductive thread. Each student will create his/her first soft circuit, connecting a light and battery.

Learning Goals

Students will...

- understand that power flows from the positive terminal of the battery, through components of a circuit (such as lights), and back to the negative terminal of the battery.
- recognize *positive* (+) and the color red as representative of power.
- recognize *negative* (-) and the color black as representative of ground.
- understand that LEDs have electrical *polarity*.
- understand that a short circuit occurs when positive and negative connections cross and that a short circuit is not functional.

Preparation

- Gather the materials.
- Cut felt into squares around 8" x 8" in size.
- If you plan to give students handouts of the simple circuit schematic, print copies in advance.

Activity

1. If examples are available, begin by sharing those with the students.
2. Review the simple circuit schematic and polarity diagrams (on page 6) with the students. This can be done by distributing copies, projecting, or redrawing the diagram on a chalkboard or whiteboard.

3. Explain that a circuit is a continuous loop through which electricity can travel. Our circuits all have a power source, and for our purposes this will be a coin cell battery. Additionally, circuits can have outputs, such as lights and motors. As we design a circuit, our goal is to guide the electricity out of the battery, through any output components (like lights), and then back to the battery.
4. Point out that batteries and LEDs have a "positive" and a "negative" side. This is called **polarity**.
 - Positive is also referred to as +, *power*, or by using the color red. The positive side of an LED is known as an *anode* and corresponds to the longer metal leg.
 - Negative is also referred to as -, *ground*, or by using the color black. The negative side of an LED is known as a *cathode* and corresponds to the shorter metal leg.
5. Explain that connections should be made from positive-to-positive and negative-to-negative. Positive and negative connections should never touch or cross - this will cause a *short circuit* (which won't be functional).
6. Ask students to sketch the electrical connections and placement of components for their first project. This may look similar to the example schematic, or it can vary (for example, the electrical connections might zigzag or follow a decorative path).
7. Distribute one of the following to each student: battery, battery holder, LED (light), felt piece. Make the rest of the materials available on a common table.
8. Ask students to pair up and compare LEDs, identifying the *anode* and *cathode*.
9. Instruct students to curl the legs of their LEDs using the needle nose pliers so that the LEDs can be sewn to fabric. (See photo at right for an example.)
10. Have students transfer their sketched circuit design onto their piece of felt by using chalk. (The chalk will wash or rub off after the project is complete.)
11. Suggest that students attach the components to their fabric with a dab of hot glue, being careful leave the conductive parts of the components exposed.
12. Students can follow the chalk pattern to sew the connections between components and sew the components to the fabric. Make sure they sew each component securely to the fabric (similar to sewing on a button) before sewing between components. After sewing each connection, students should tie a knot on the fabric's backside and cut the thread.
13. After students have finished sewing, show them how to insert the battery into the battery holder (with the "+" side facing up).

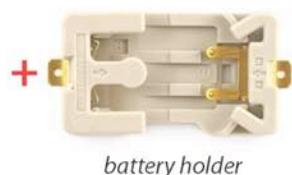
Tips for Working with Conductive Thread

- Try to keep your stitches as close together as possible - this will keep them in place whenever you bend or pull on your fabric.
- Conductive thread tends to fray, so if a circuit is not functioning, check for spots where the thread has frayed to the point of making contact with another electrical connection of opposite polarity.
- Because the thread frays easily, it may be difficult to thread your sewing needle. Run thread through beeswax or use needle threaders to help with this.
- Knots that are tied with conductive thread may not stay in place permanently on their own. Secure each of your knots by dabbing them with hot glue. This will also help insulate any loose thread ends.
- The soft circuits created in these activities are washable! Just remove the battery and hand-wash with gentle detergent.

a sewable LED whose legs have been curled with needle nose pliers



Identifying Polarity

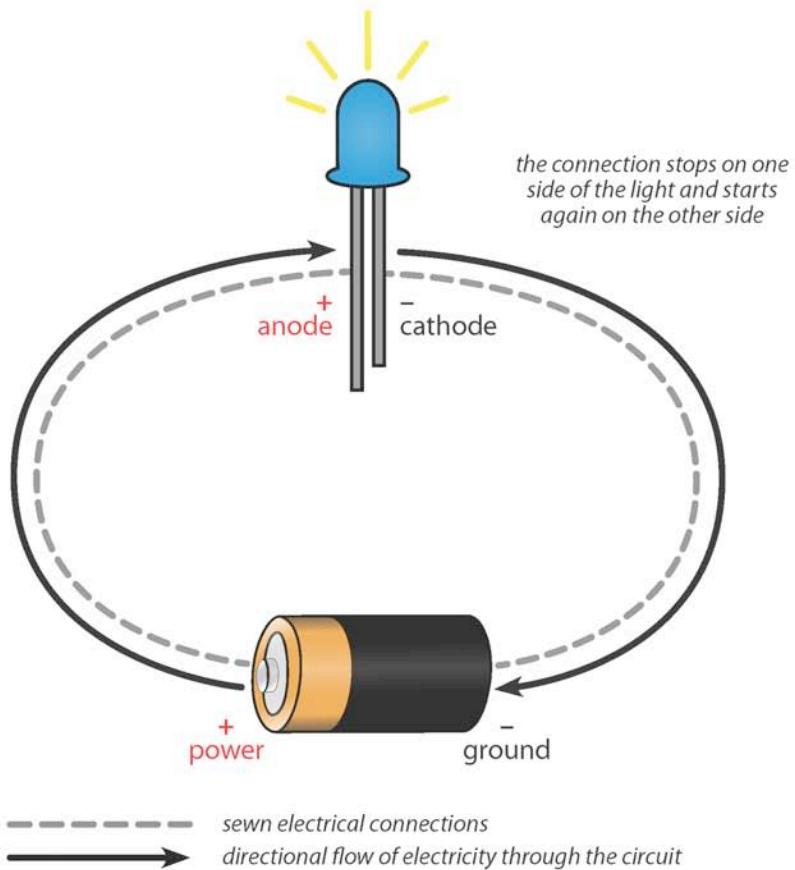


battery holder



LED

A Simple Circuit Schematic



activity #2

SWITCHES

a flickering brooch



Tools & Materials

For each student:

- battery
- battery holder
- LED (light)
- safety pin

For the group to share:

- needle threaders or beeswax
- conductive thread
- fabric scissors
- hot glue gun and glue sticks
- needle nose pliers
- sewing chalk
- sewing needles
- felt scraps
- metal (conductive) beads
- glass or plastic beads
- sewing thread (any color)

Summary

Students become familiar with switches and how they affect electrical flow through a circuit. Each student will construct a brooch which flickers as it moves, using a dangling metal bead to close a circuit.

Learning Goals

Students will...

- understand that a switch interrupts the flow of electricity through a circuit.
- understand that, unlike LEDs, switches are not polarized.
- become familiar with *conductivity* as a material's ability to conduct electrical current.

Preparation

- Gather the materials.
- If you plan to give students handouts of the simple circuit schematic for *switches*, print copies in advance.

Activity

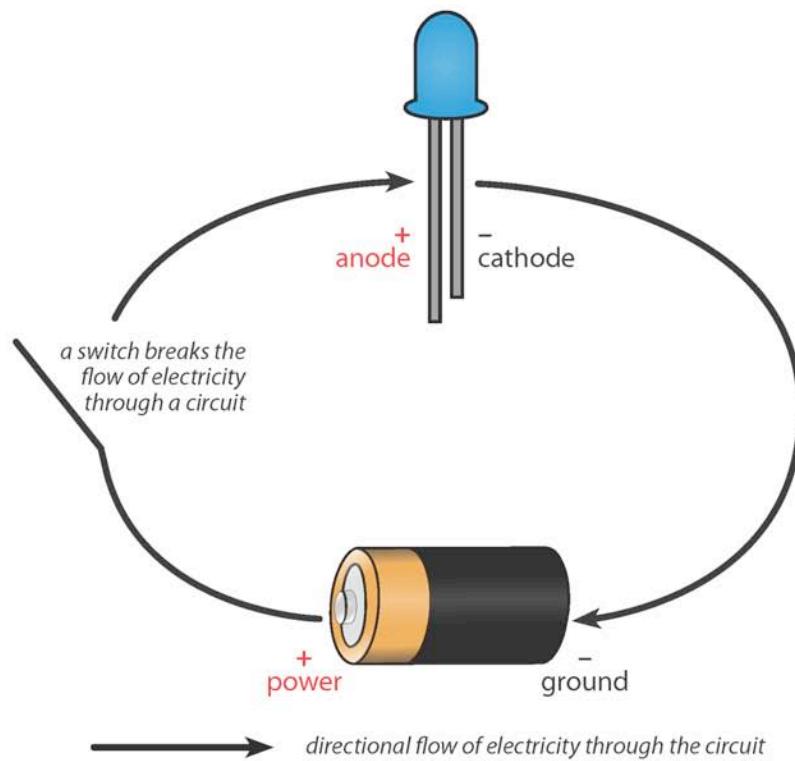
1. If examples are available, begin by sharing those with the students.
2. Share the simple circuit schematic for *switches* (on page 9) with the students. This can be done by distributing copies, projecting, or redrawing the diagram on a chalkboard or whiteboard.
3. Explain that a switch interrupts the flow of electricity through a circuit. An *open* switch stops the flow of power through a circuit, while a *closed* switch allows power to flow continuously through it. In this activity, we'll use a switch to control the flow of power to an LED.

4. Additionally, explain that switches do not have polarity in the way that LEDs do – that is to say, they do not have a positive (+) side and a negative (-) side. Consequently, it doesn't matter which way they are oriented within a circuit.
5. Explain that a material which is *conductive* allows electricity to pass through it. Ask students to give examples of materials that are conductive (such as water, paper clips, and tin foil) and non-conductive (like wood, fabric, and paper).
6. Instruct students to curl the legs of their LEDs using needle nose pliers so that the LEDs can be sewn to fabric (see photo on page 5).
7. Review the circuit template (on page 9) with students and ask them to use chalk to draw the connections on their felt scrap(s). Explain that they will each make a switch using a metal bead which closes a circuit whenever it touches areas of conductive thread. Students can create the body of the brooch however they like, although its surface should be big enough to sew between the battery holder, LED, and switch.
8. Suggest that students attach the components to their fabric with a dab of hot glue, being careful leave the conductive parts of the components exposed.
9. Direct students to sew their components to their fabric, following the design pattern which they sketched in chalk.
10. Show students how to use regular thread to sew a safety pin to the backside of their brooches (see photo below). If the safety pin makes contact with any conductive thread, it can cause a short circuit – so be careful to separate it with extra felt if necessary.
11. Direct students to insert the battery into the battery holder (with the "+" side facing up).

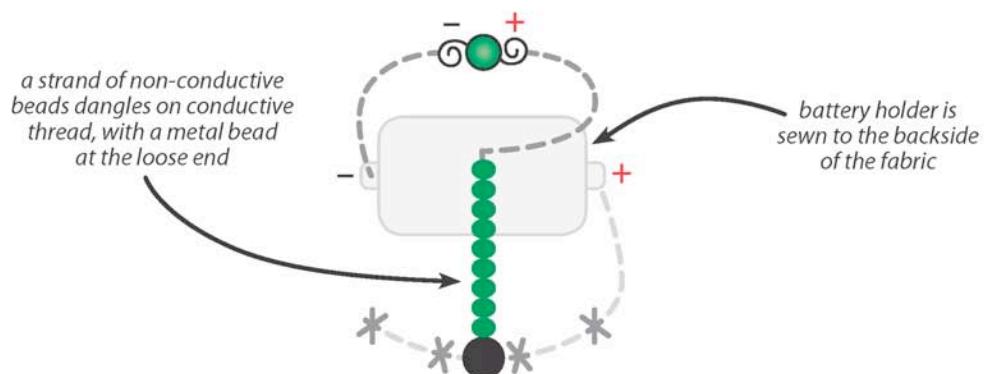


*a safety pin sewn onto the back of a felt brooch,
using regular sewing thread*

Simple Circuit Schematic for a Switch



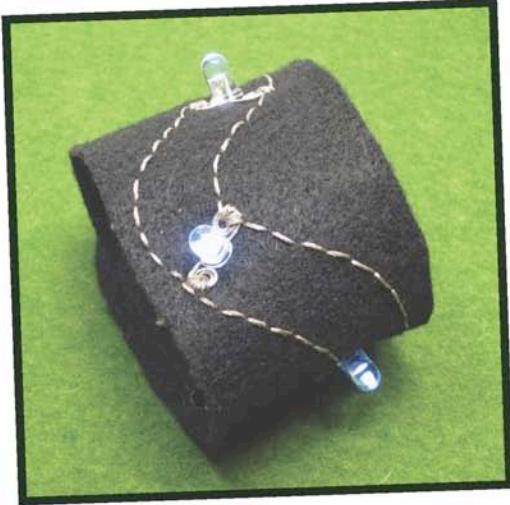
Example Beaded Switch Template



activity #3

PARALLEL CIRCUITS

an illuminated cuff/bracelet



Tools & Materials

For each student:

- battery
- battery holder
- felt strip
- 3 LEDs (lights)
- matched set of metal snaps

For the group to share:

- needle threaders or beeswax
- conductive thread
- fabric scissors
- hot glue gun and glue sticks
- needle nose pliers
- sewing chalk
- sewing needles

Summary

Students come to understand what constitutes a parallel circuit. Each student will leverage this knowledge as he/she fabricates a bracelet or cuff which incorporates multiple lights and turns on only when it is worn.

Learning Goals

Students will...

- understand that lights arranged in a *parallel* configuration each receive the same amount of voltage.
- understand that multiple lights within one circuit should be arranged in *parallel* to ensure that they all light up.

Preparation

- Gather the materials.
- Cut felt into strips, about 2" wide and 16" long.
- If you are plan to give students handouts of the simple circuit schematic for *lights in parallel*, print out copies in advance.

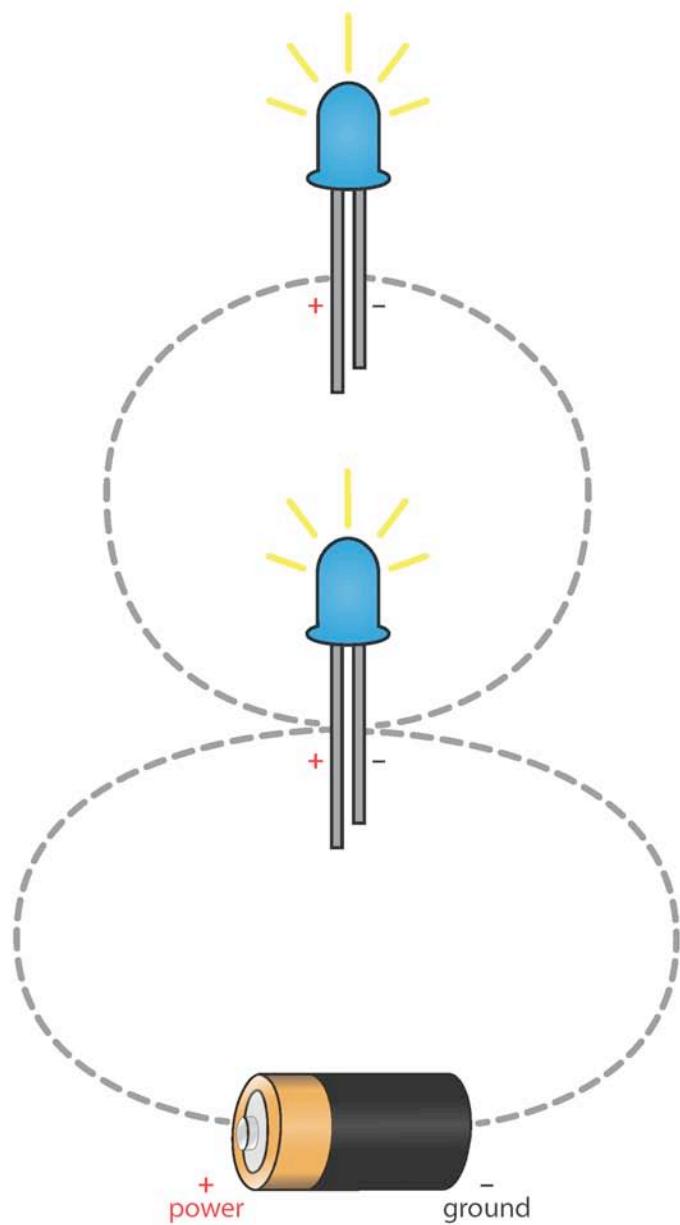
Activity

1. If examples are available, begin by sharing those with the students.
2. Share the simple circuit schematic for lights in *parallel* (on page 12). This can be done by printing copies, projecting, or redrawing the diagram on a chalkboard or whiteboard.
3. Explain that in order to add additional lights to a circuit, the lights must be arranged in *parallel*. This means that the first light's positive end is connected to the second light's positive end. Likewise, the first light's negative end should be connected to the second light's negative end.

- 4.** Ask students to draw or sketch the electrical connections and placement of components for their project which will incorporate three lights. This may look similar to the example pictured here (see right), or it can vary. The electrical traces may spiral and/or travel anywhere on the fabric, so long as positive and negative connections do not touch or intersect.
- 5.** Distribute one of the following to each student: battery, battery holder, felt piece. Distribute three lights to each student. Make the rest of the materials available on a common table.
- 6.** Instruct students to curl the legs of their LEDs using needle nose pliers so that the LEDs can be sewn to fabric (see page 5 for a photo of this).
- 7.** Ask students to wrap the felt strip around their wrist and trim it to the correct length – the felt should overlap by about 1" or 2" to leave enough room for the snaps and battery holder.
- 8.** Show students how to attach their snaps to each end of their felt strip (sewing, riveting, etc., depending on which type of snaps are used). Tell students to leave enough room to sew to the snaps later in the activity, since this is how the snaps will be electrically connected to the rest of the circuit.
- 9.** Have students transfer their sketched circuit design onto their piece of felt by using chalk.
- 10.** Suggest that students attach the components to their fabric with a dab of hot glue, being careful leave the conductive parts of the components exposed.
- 11.** Students can now follow the chalk pattern to sew the connections between snaps and components.
- 12.** Finally, show students how to insert the battery into the battery holder (with the "+" side facing up).



Simple Circuit Schematic for Lights in Parallel



----- *sewn electrical connections*

activity #4

MICROCONTROLLERS

an electronic patch



Summary

Students are exposed to microcontrollers and the concept of programmability. Each student will make a personalized light-up patch, using a sewable pre-programmed microcontroller to control the behavior of an LED.

Learning Goals

Students will...

- understand what a microcontroller is and how programming can add interactivity and dynamic behavior to an e-textile project.

Preparation

- Gather the materials.
- If you plan to give students the microcontroller diagram handout, print copies in advance.
- Print copies of the patch template(s) on an inkjet printer, using canvas paper. Make sure that the printer is adjusted to accept thicker print media (if available as an option). Cut out the individual patches.

Activity

1. Introduce the activity by sharing examples, if they are available.
2. Distribute the following materials to each student, or ask the students to collect them from a materials station:
 - one LED
 - one pre-printed canvas patch
 - one needle
 - 16" or so of thread
 - sewable microcontroller
 - battery holder
 - battery
 - microcontroller diagram handout

Tools & Materials

For preparing patches:

- canvas paper
- inkjet color printer

For each student:

- battery
- battery holder
- LED (light)
- sewable microcontroller

For the group to share:

- needle threaders or beeswax
- conductive thread
- fabric scissors
- hot glue gun and glue sticks
- needle nose pliers
- sewing needles

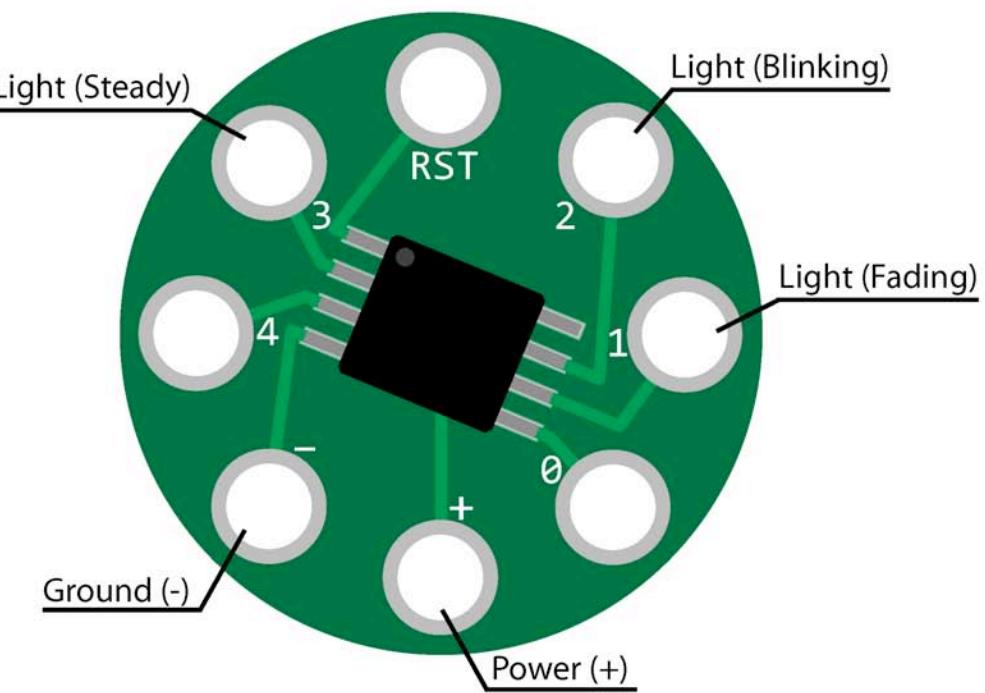
3. Spend a few minutes introducing the microcontroller as a miniature computer that can be programmed to control certain behaviors within a circuit. The microcontrollers in this activity have been pre-programmed to control the behavior of an LED.
4. Instruct students to curl the legs of their LEDs using needle nose pliers so that the LEDs can be sewn to fabric (see page 5 for a photo of this).
5. Guide students through creating their own patch. Begin by explaining the first step listed below, then allow students to spend the rest of the time working individually. As students begin to finish one step, pause to explain the next step in the process.

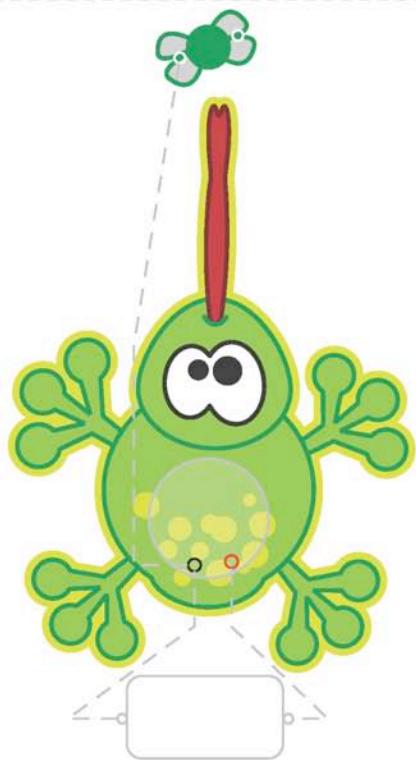
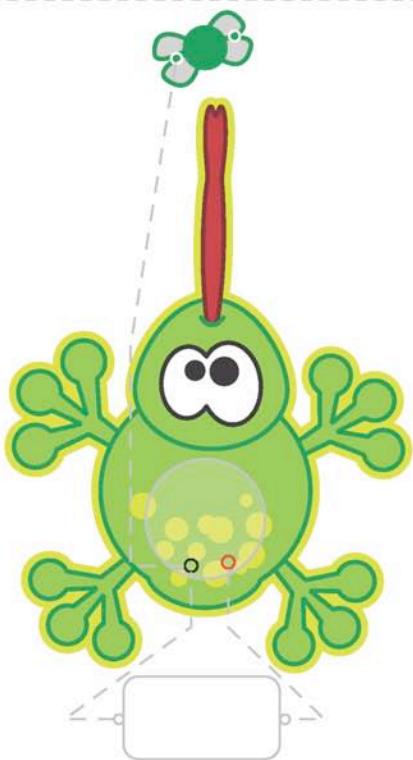
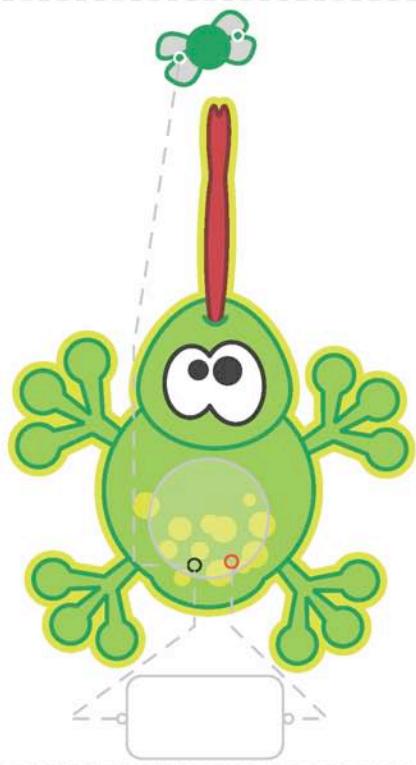
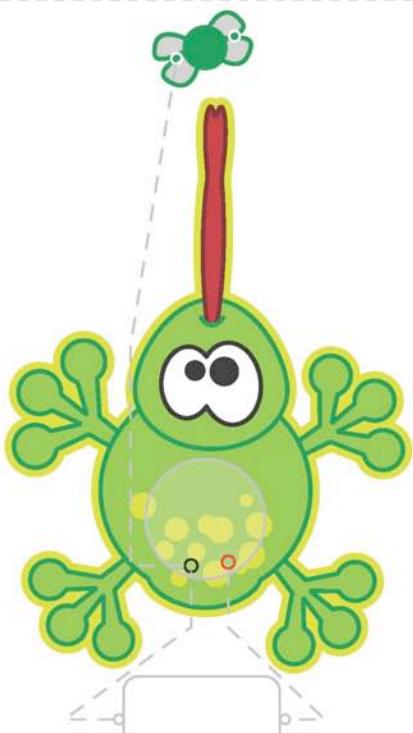
 - Follow the template on the patch to determine how to place the microcontroller. Orient the battery holder so that one dotted line connects its positive (+) hole to the positive (+) hole on the microcontroller. If the battery holder is placed correctly, another dotted line should connect its negative (-) hole with the negative (-) hole on the microcontroller.
 - Using a hot glue gun, glue the battery holder and sewable microcontroller to your patch. Use just enough glue to make the components stick; using too much glue will cover the metal contacts and prevent them from conducting electricity!
 - Sew from the positive (+) hole on the battery holder to the positive (+) hole on the microcontroller.
 - Sew from the negative (-) hole on the battery holder to the negative (-) hole on the microcontroller.
 - Decide which way you need to orient your LED so that the dotted line will connect the negative (-) side of your LED to the negative (-) hole on your microcontroller. Once you've figured it out, use a hot glue gun to glue the LED to your patch.
 - Sew from the negative (-) hole on your microcontroller to the negative (-) side of your LED.
 - Now, decide which behavior you would like your LED to have (steady, blinking, or fading). Look at the microcontroller diagram and figure out which microcontroller hole you'll have to connect the positive (+) side of the light to in order to produce this behavior. Once you've decided, sew from the positive (+) side of the light to that particular hole on the microcontroller.
 - Examine the backside of your patch and make sure that there are no loose pieces of thread that are accidentally touching one another. Trim any loose ends, if necessary. Using a hot glue gun, put a dab of hot glue over each of your knots. This will help protect them from unraveling and will also prevent the thread ends from shorting your circuit.
 - Insert the battery into the battery holder (with the "+" side facing up).

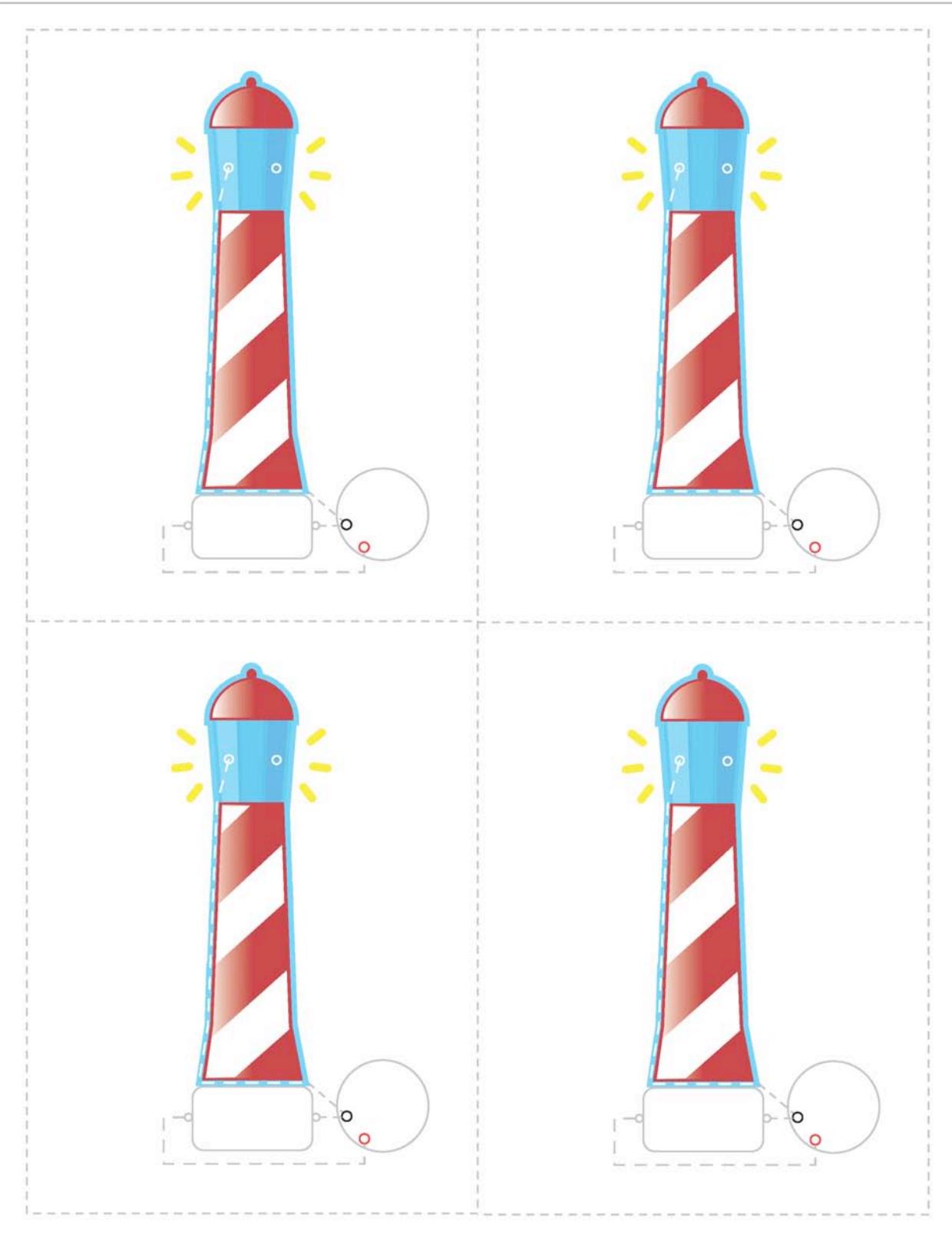
An Extra Challenge...

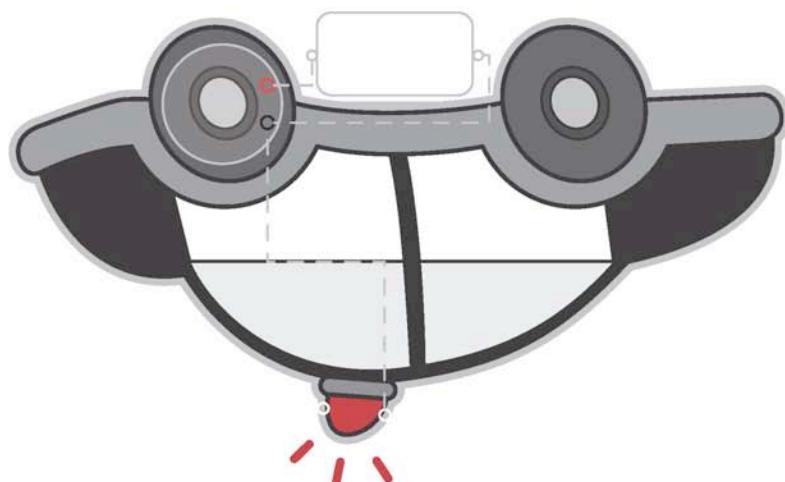
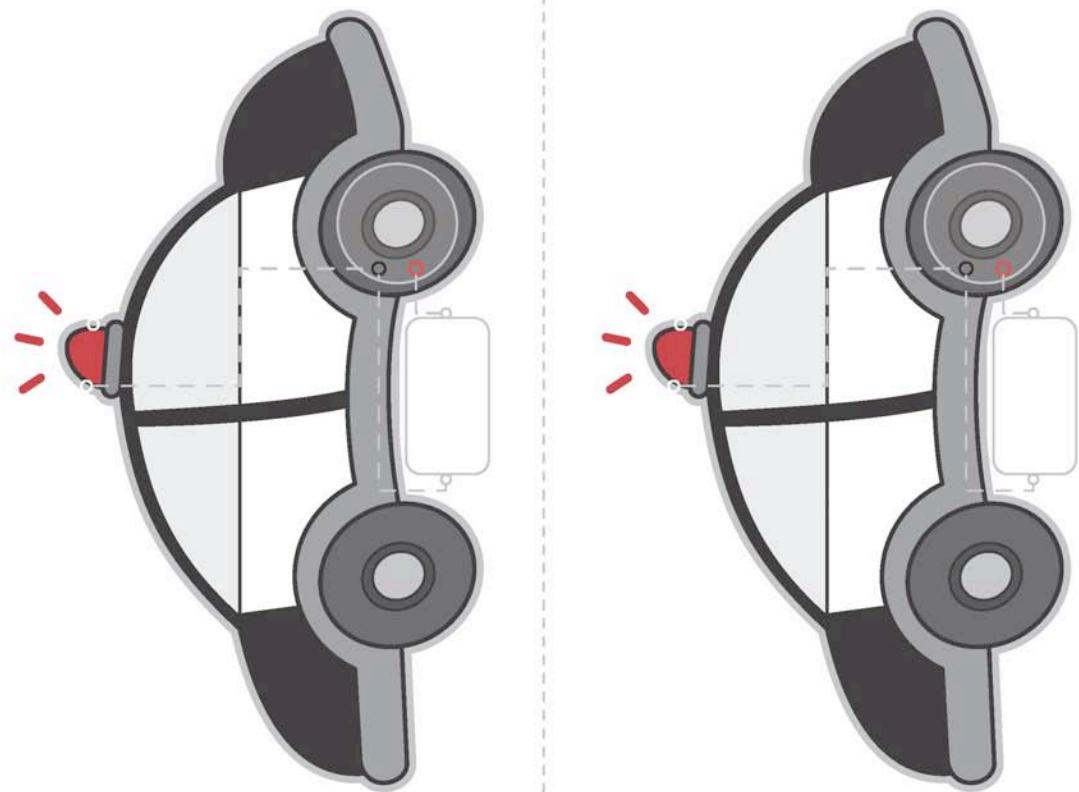
If students finish early, you can challenge them to add a second light to their circuit, in parallel.

Microcontroller Diagram









activity #5

CONNECTING BACK

a patchwork quilt



Summary

Students draw upon their understanding of circuits to make their own electronic quilt squares. The squares can then be pieced together to create an electronic patchwork quilt. Encourage participants to design and construct a few different squares; this way, some can remain part of a collective project, while others can be taken home.

The physical structure of the squares allows them to be rearranged repeatedly, encouraging the exploration and development of a group narrative and/or artwork.

Learning Goals

Students will...

- understand how to combine and apply all of the concepts covered in previous sessions.

Preparation

- Gather the materials.
- Cut out tabbed quilt squares (at least two per student), using the template on page 21. If using 9"x 12" pieces of felt, you should be able to fit two quilt squares on each piece. Cut along the template outline and cut slits along the short, straight lines.
- Decide how you would like students to attach embellishments to their quilt pieces:
 - Fabric glue is convenient, but takes a long time to dry.
 - Heat'n Bond Ultra Hold Iron-On Adhesive requires more preparation, but works almost instantly when ironed. (If using Heat'n Bond, it's best to use an iron to pre-fuse it to scrap felt. This way, students can cut out their desired shapes and iron them right onto their quilt squares.)

Tools & Materials

For preparing quilt squares

- 9"x 12" pieces of felt

For the group to share:

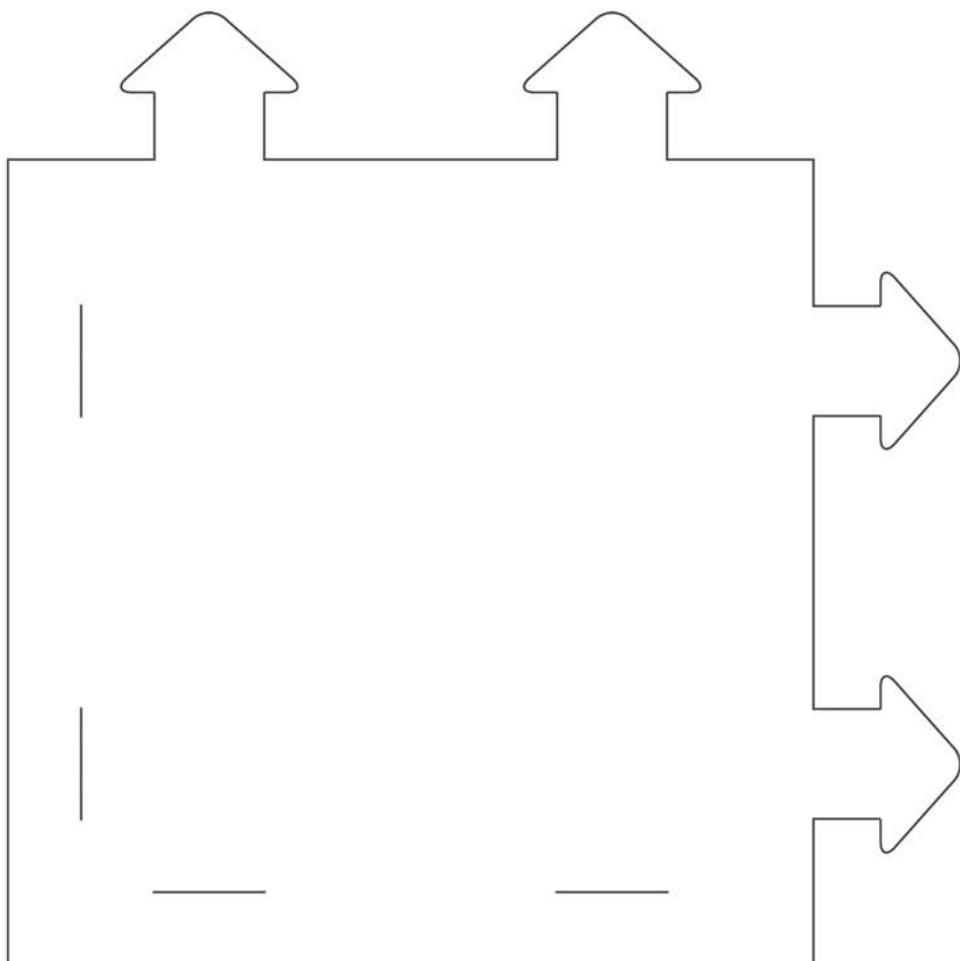
- needle threaders or beeswax
- conductive thread
- fabric scissors
- hot glue gun and glue sticks
- needle nose pliers
- sewing needles
- Heat'n Bond Ultra Hold Iron-On Adhesive* with mini iron* **or** fabric glue*
- puffy fabric paint*
- sewing chalk
- batteries
- battery holders
- LEDs (lights)
- sewable microcontrollers
- small felt scraps
- assorted beads
- metal snaps

- Print copies of the quilt square template for students to sketch their designs on.
- Decide upon a theme for the electronic patchwork quilt. It should be broad enough to allow for creative interpretation, but narrow enough to provide guidance to students who might otherwise feel lost. The theme may be concrete (calendar months, seasons of the year, animals, etc.) or abstract (civic issues, personal aspirations, etc.)

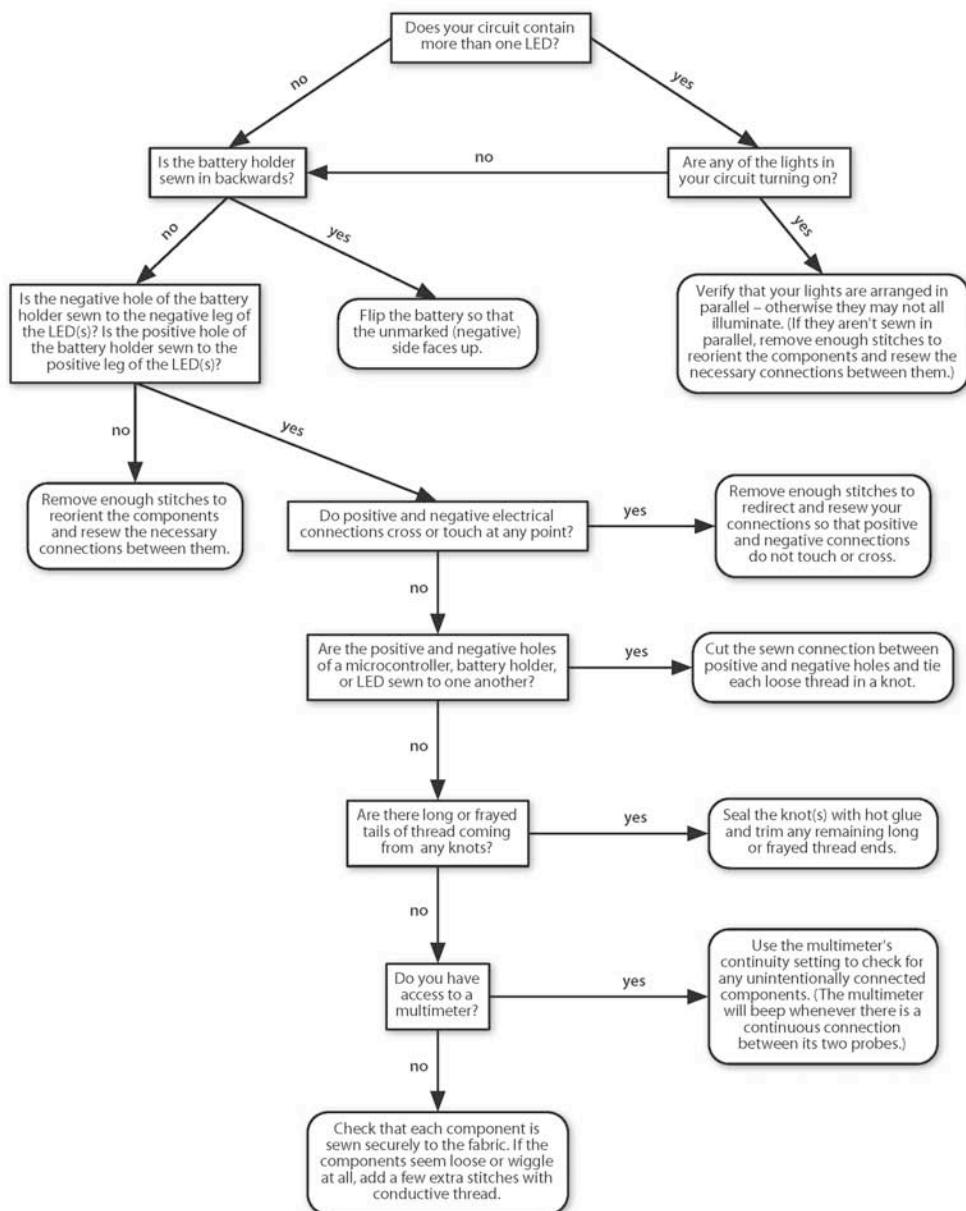
Activity

1. Introduce the activity by sharing examples, if they are available.
2. Explain that students will be making more than one quilt square during today's session; this way they can take one home to share with family and friends, while leaving others to remain part of the group quilt.
3. Ask students to draw or sketch the electrical connections and placement of components for each square onto the template provided. Their design may incorporate lights and/or switches along with decorative elements and a battery.
4. Distribute one of the following to each student (per square): battery, battery holder, quilt square. Make the rest of the materials (including a variety of lights) available on a common table.
5. Instruct students to curl the legs of their LEDs using needle nose pliers so that the LEDs can be sewn to fabric (see page 5 for a photo of this).
6. Have students use chalk to transfer their sketched circuit designs onto their quilt squares.
7. Suggest that students attach the components to their fabric with a dab of hot glue, being careful leave the conductive parts of the components exposed.
8. Direct students to sew their components to their fabric, following the design pattern which they sketched in chalk.
9. Encourage students to embellish their functional circuit with beads, additional fabric, and fabric paint. Feel free to provide additional craft supplies (such as feathers, sequins, and buttons) as well. You may even suggest that students sign their name in fabric paint somewhere on each square that they create.
10. As students begin to finish their patches, encourage them to arrange (and rearrange) how the pieces fit together.
11. At the end of the session, let students choose which square of theirs they would like to take home.

Quilt Square Template



TROUBLESHOOTING



TOOLS & MATERIALS

Item		Where to Purchase	Notes
alligator clips*		SparkFun ² RadioShack	<ul style="list-style-type: none"> • SparkFun SKU #: CAB-08927 (or search for "Alligator to Alligator Cables") • RadioShack catalog #: 278-1156 (or search for "Test/Jumper Leads")
assorted beads		fabric & craft stores	<ul style="list-style-type: none"> • provide a variety of metal (conductive) and non-metal (glass, wood, plastic) beads
batteries (CR2032)		Digi-Key ¹ SparkFun ² RadioShack electronics stores	<ul style="list-style-type: none"> • Digi-Key part #: N189-ND • SparkFun SKU #: PRT-00338 (or search for "Coin Cell Battery - 20mm")
battery holders		Digi-Key ¹ SparkFun ²	<ul style="list-style-type: none"> • Digi-Key part #: BA2032SM-ND • SparkFun SKU #: DEV-08822 (or search for "Coin Cell Holder - Sewable SMD")
beeswax		JoAnn Fabrics fabric & craft stores	
conductive thread		SparkFun ²	<ul style="list-style-type: none"> • SparkFun SKU #: DEV-08549 (or search for "Conductive Thread - 234/34 4ply")
fabric glue		fabric & craft stores	
fabric scissors		fabric & craft stores	
felt		JoAnn Fabrics A.C. Moore fabric & craft stores	<ul style="list-style-type: none"> • 9" x 12" size can fit two quilt square pieces • may also be purchased in large sheets/rolls

Item	Where to Purchase	Notes
Heat'n Bond Ultra Hold Iron-On Adhesive*	 JoAnn Fabrics A.C. Moore fabric & craft stores	<ul style="list-style-type: none"> a type of fusible interfacing which includes a paper backing available in sheets (pictured here) or rolls
hot glue gun (with glue sticks)		fabric & craft stores hardware stores <ul style="list-style-type: none"> any glue gun will work, but "mini" glue guns work especially well with small craft materials and electronics components
LEDs (lights)		Digi-Key ¹ SparkFun ² RadioShack <ul style="list-style-type: none"> Digi-Key part #'s: 160-1127-ND, 160-1133-ND, and 160-1131-ND (red, yellow, and green) SparkFun SKU #'s: COM-09590, COM-09594, and COM-09592 (red, yellow, and green - or search for "Basic LED")
metal snaps		JoAnn Fabrics A.C. Moore fabric & craft stores <ul style="list-style-type: none"> magnetic snaps work particularly well and are easy to sew into a project
mini iron*		JoAnn Fabrics Target Walmart fabric & craft stores <ul style="list-style-type: none"> a regular iron will also work, but will require an ironing board (or other large suitable surface on which to iron)
multimeter*		SparkFun ² RadioShack Sears hardware stores <ul style="list-style-type: none"> SparkFun SKU #: TOL-09141 (or search for "Digital Multimeter") RadioShack catalog #: 22-813 (or search for "29-Range Digital Multimeter") digital multimeters will be easier to use than analog ones your multimeter should be able to measure continuity (with a buzzer/beep sound)
needle nose pliers		SparkFun ² RadioShack Sears hardware stores <ul style="list-style-type: none"> SparkFun SKU #: TOL-08793 (or search for "Needle Nose Pliers") RadioShack catalog #: 64-062 (or search for "Mini Long-Nose Pliers")
needle threaders		fabric & craft stores

Item	Where to Purchase	Notes
puffy fabric paint*	A.C. Moore Michaels fabric & craft stores	• can be used as an insulator when painted over sewn traces
safety pins	drug stores fabric & craft stores	
sewing chalk	A.C. Moore Michaels fabric & craft stores	• also known as "tailor's chalk" or "designer's chalk"
sewing needles	fabric & craft stores	• needles with bigger eyes will be easier to thread (look for "crewel" or "embroidery" needles) • needles must be slender enough to sew through the holes of the battery holders
sewing thread	fabric & craft stores	

* optional

¹ <http://www.digikey.com> - lowest prices, difficult to navigate

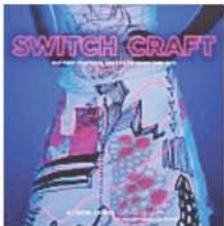
² <http://www.sparkfun.com> - slightly higher prices, easier to navigate

FURTHER RESOURCES

Print



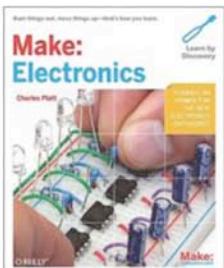
Fashioning Technology
by Syuzi Pakhchyan



Switch Craft: Battery-Powered Crafts to Make and Sew
by Alison Lewis (with Fang-Yu Lin)



Fashion Geek
by Diana Eng



Make: Electronics
by Charles Platt

Web

Craft

<http://www.craftzine.com>

Craft:

transforming traditional crafts

Fashioning Technology

<http://www.fashioningtech.com>

fashioning technology

a "smart" crafting community

HOW TO
GET WHAT
YOU WANT

instructables

LilyPond

<http://lilypond.media.mit.edu>

LilyPond

Make

<http://www.makezine.com>

Make:

technology on your time

Soft Circuit Saturdays

<http://softcircuitsaturdays.com/>

soft circuit
saturdays

talk2myShirt

{ **B** }

Questionnaires

Electronic Patches: Pre-Session Survey

Are you male or female? *male* *female*

How old are you?

Do you have any previous experience with sewing? If so, briefly describe it.

Do you have any previous experience with electronics or circuits? If so, briefly describe it.

Do you have any previous experience with computer programming? If so, briefly describe it.

How comfortable would you feel...

... writing a short computer program?

not comfortable at all 1 2 3 4 5 6 7 *very comfortable*

... soldering two electronics components together?

not comfortable at all 1 2 3 4 5 6 7 *very comfortable*

... sewing a button onto a shirt?

not comfortable at all 1 2 3 4 5 6 7 *very comfortable*

... drawing a diagram of a simple circuit, including a light and a battery?

not comfortable at all 1 2 3 4 5 6 7 *very comfortable*

... making a simple circuit from a light and a battery?

not comfortable at all 1 2 3 4 5 6 7 *very comfortable*

... figuring out why a simple circuit (made from a light and a battery) isn't working?

not comfortable at all 1 2 3 4 5 6 7 *very comfortable*

What do you like to do in your free time?

Electronic Patches: Post-Session Survey

Rate the difficulty of today's session:

too easy 1 2 3 4 5 6 7 *too hard*

Rate the pace of today's session:

too slow 1 2 3 4 5 6 7 *too fast*

Rate the length of today's session:

too short 1 2 3 4 5 6 7 *too long*

What was your favorite thing about today's session?

What was your least favorite thing about today's session?

How comfortable would you feel...

... writing a short computer program?

not comfortable at all 1 2 3 4 5 6 7 *very comfortable*

... soldering two electronics components together?

not comfortable at all 1 2 3 4 5 6 7 *very comfortable*

... sewing a button onto a shirt?

not comfortable at all 1 2 3 4 5 6 7 *very comfortable*

... drawing a diagram of a simple circuit, including a light and a battery?

not comfortable at all 1 2 3 4 5 6 7 *very comfortable*

... making a simple circuit from a light and a battery?

not comfortable at all 1 2 3 4 5 6 7 *very comfortable*

... figuring out why a simple circuit (made from a light and a battery) isn't working?

not comfortable at all 1 2 3 4 5 6 7 *very comfortable*

... explaining the circuit that you made today to a friend?

not comfortable at all 1 2 3 4 5 6 7 *very comfortable*

Did you learn anything new today? If so, what?

Was there anything that you found challenging or confusing during today's session? If so, what?

Would you be interested in making a similar project on your own? yes no

Would you be interested in attending another session like this one? yes no

What would you want to learn or make in a similar future session?

If you have any other feedback, please share it here.