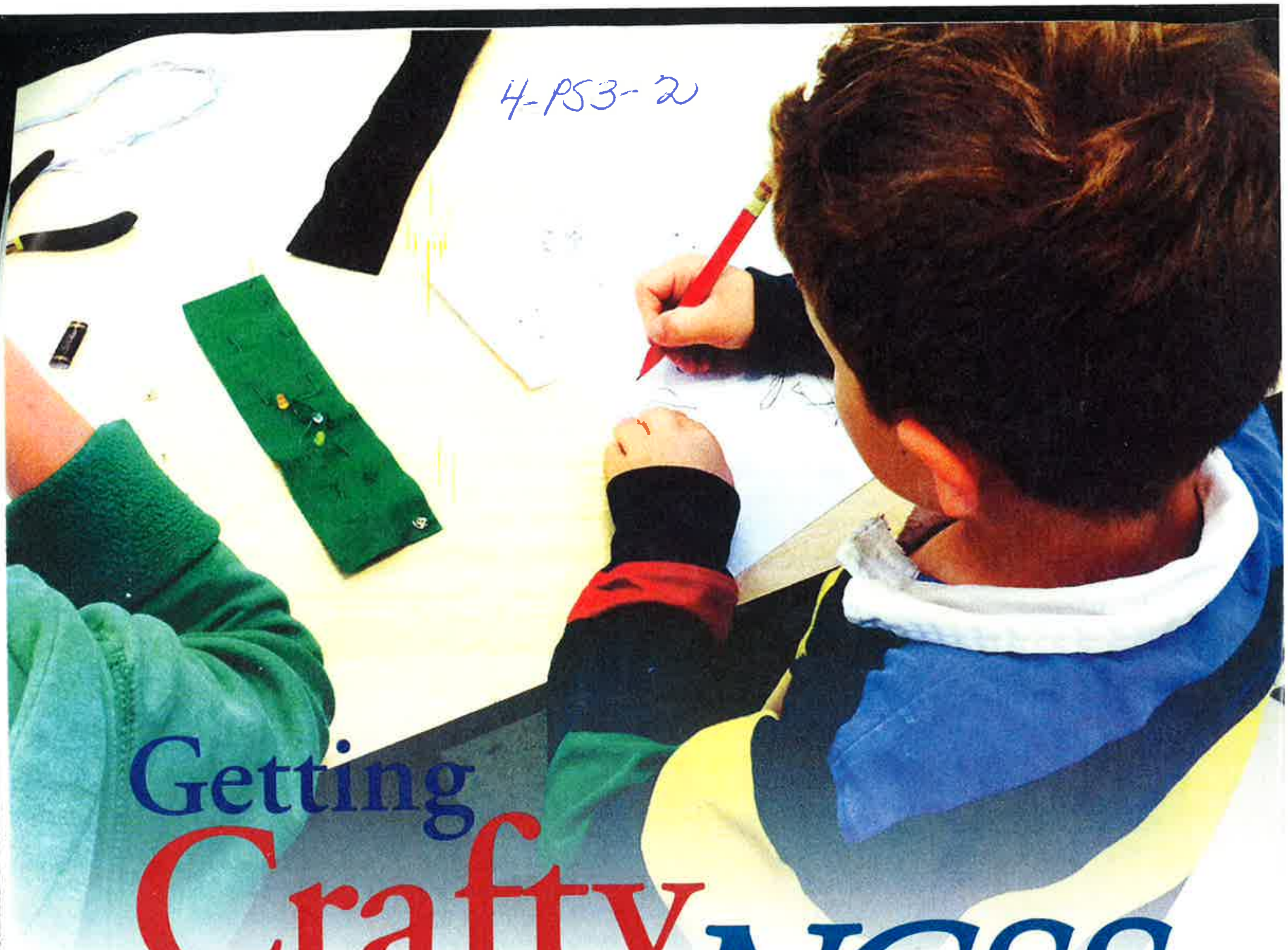
4-PS3-2



Getting Crafty With the NGSS

Using multimedia circuits to teach electricity in elementary school

By Colby Tofel-Grehl, Breanne Litts, and Kristin Searle

Traditionally, electricity and circuits are taught using alligator clips, lightbulbs, batteries, and wires. Although these circuits engage students in building, they don't always provide opportunities for students to deeply explore energy, electricity, polarity, and circuitry. Multimedia Circuits is a curricular unit made up of three projects that allow students and teachers to engage in science learning from a more artistic perspective by constructing circuits using different media (i.e., clay, paper, and fabric). By engaging students in a craft-based approach rather than a traditional classroom approach, Multimedia Circuits gives students a new way to engage with science content (Gu et al. 2016). Additionally, with its strong focus on modeling and the engineering practices of the *Next Generation Science Standards* (NGSS Lead States 2013), Multimedia Circuits empowers elementary teachers to engage their students in science learning and integrate their curriculum more fully. Current research finds that learning outcomes are as good, if not better, with multimedia circuits as with traditional circuit materials; additionally, student interest and identification with science improved significantly with these projects (Gu et al. 2016). Students who do not express interest in science are often engaged by this unit because they are able to craft circuits with familiar materials (e.g., paper, fabric, clay) and initially perceive the activities as art more than science.

Materials and Unit Description

Traditionally, wire is used to conduct electricity in circuits, but the Multimedia Circuits activities introduce a variety of materials designed to conduct electricity: salt-based clay for Squishy Circuits, copper tape for Paper Circuits, and stainless-steel thread for Sewable Circuits. We present Multimedia Circuits during a two-week, six-lesson electricity unit. These projects can be done in sequence or in isolation, depending on teachers' curriculum, goals, and time constraints. Table 1 provides an overview of the recommended time for each lesson, along with links for where to find lesson outlines and resources.

The unit is comprised of three projects that gradually increase in complexity and build student understanding through hands-on, craft-based learning:

- Squishy Circuits (Johnson and Thomas 2010): Students build model circuits by creating animals out of conductive and insulative clay, batteries, lights, and wires (Figure 1, p. 50). Students build circuits quickly using a familiar material (clay).
- Paper Circuits (Qi and Buechley 2014): Students use copper tape, LED lights, and batteries to explore simple, series, and parallel circuits (Figure 2, p. 50).
- Sewable Circuits: Students design and craft circuit bracelets using LED lights, batteries, and conductive thread (Figure 3, p. 51). This project engages students with polarity and short circuits.

During these activities, students integrate their own aesthetic choices into scientifically viable and accurate circuits. Students also explore nonmetallic materials that are conductive. These projects are expansive and adaptable, so they can easily be tailored to suit the teachers' specific needs. For example, a teacher using an open-ended approach can spend an hour or more on paper circuits to deeply address particular concepts, whereas another teacher using a direct instruction approach can complete paper circuits in as little as 20 minutes to prepare students for a subsequent circuity project.

Teachers who have implemented these activities typically begin with an age-appropriate lesson, such as a group discussion with clarification and explanations regarding the content being taught. Often, a KWL (Know, Want to know, Learned) chart acts as an entry point for assessing students' prior knowledge and misconceptions about electricity. The KWL chart also serves as a tool that helps teachers choose the activity best suited as a starting point

TABLE 1.

Unit overview.

Project Name	Time Required	Materials List	Link for Lesson Guides
Paper Circuits	20–40 minutes	1. Copper tape 2. Batteries 3. LED bulbs 4. Scotch tape 5. Binder clips 6. Paper	Tutorials *http://chibitronics.com/resources* Circuit Sticker Tutorial Booklet *http://bunniefoo.com/chibi/sketchbook-en-v1.pdf*
Squishy Circuits	45 minutes	1. Conductive clay 2. Insulating clay 3. Batteries 4. Squishy Circuit battery holders 5. LED bulbs	Tutorials *http://courseweb.stthomas.edu/apthomas/SquishyCircuits/index.htm*
Bracelet Circuits	2–5 hours	1. Felt 2. Needles 3. Scissors 4. Thread or embroidery floss 5. Metal snaps 6. Conductive thread 7. Batteries 8. Battery holders 9. LED bulbs	Tutorials *http://itls.usu.edu/files/projects/ETextiles_Bracelet_Guide.pdf*

for students. For example, one teacher used Squishy Circuits to explore how insulative and conductive doughs differed, so she was able to facilitate students iteratively testing and investigating ways to make something more or less conductive. She was also able to provide students with the opportunity to test different types of circuits and how effectively they used electricity.

Many of the materials for these projects can be found locally, but some are somewhat specialized. While "Squishy Circuit" and "Paper Circuit" kits can be found online, they also can be done using less expensive supplies from the local hobby shop. Likewise, "Play-Doh" brand play dough is inherently conductive, but recipes for making conductive and insulative play dough are available on the Squishy Circuits resource site (see Table 1, p. 49). More specialized Sewable Circuit supplies, like sewable LEDs, can be found on websites like SparkFun, which offers educator discounts. The cost for these projects is variable with Squishy and Paper Circuits costing as little as $1 per student and Sewable Circuits costing approximately $5 per student.

CAUTION

Follow all of your school's safety guidelines. None of our students has been shocked by these low-voltage supplies, but we have had students get paper cuts from the copper tape or prick themselves with a needle while sewing. Students and teachers should be mindful of these possibilities and should exercise care when using these materials.

Project 1: Squishy Circuit Animals

Clay circuits are a playful way to introduce basic scientific concepts related to circuitry. Given the flexibility of clay, teachers can use several activity designs depending on students' interests or topics related to recent studies. Each student receives two lumps of clay (one conductive and one insulative), a battery pack with extended negative and positive leads, and LED lights. Students use the materials to create a clay animal that lights up. For example, one student made a butterfly with light-up eyes: One wing is connected to the positive charge, the other wing is connected to the negative charge, and the body is the insulator. Clay circuits afford students an easy medium to learn about circuitry, specifically conductivity and polarity, through inquiry. Troubleshooting serves as a kind of assessment in that students resolve polarity problems by flipping around an LED or fix short circuits by adding insulating clay to the problem area. Additionally, students can learn about the differences between parallel and series circuits as well as the varying amounts of resistance different color bulbs present.

FIGURE 1.

A squishy circuit.

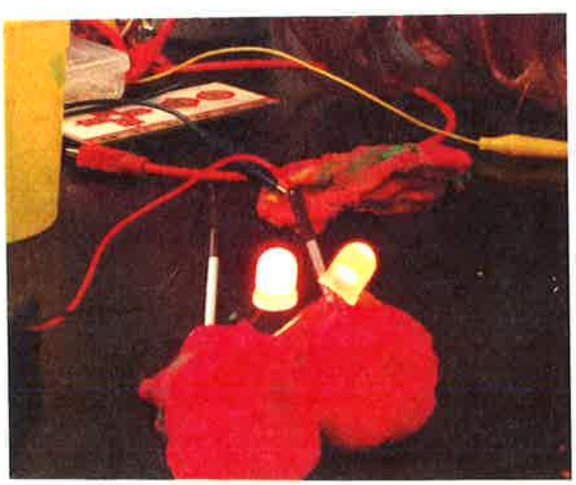


FIGURE 2.

A paper circuit.

Project 2: Paper Circuit Cards

Paper circuits build on concepts students learned from the clay circuits and equip them to work with more complex circuitry materials. As with the clay circuits, there are many possible activity designs for paper circuits. After exploring several options, we made paper circuit cards our go-to activity. Students craft a card (e.g., greeting, seasonal, or thank-you) and add LED lights using a battery and copper tape. First, students plan out their circuit design with a pencil, add LED lights and copper tape where appropriate, and connect the positive and negative leads to the battery (often using a binder clip). Students continue to learn about polarity and conductivity and begin to explore basic switches and circuit design. Paper circuits offer an ideal way to expeditiously have students explore the differences between parallel and series circuits. Within their inquiry about these differences, students can explore the way in which current flows as well as what makes electric current flow more efficiently. One teacher, working with fourth-grade students, assessed student learning by asking students to design a paper circuit that was able to light blue lightbulbs, which have greater resistance than other bulbs due to their place on the light spectrum. The design and quick iterative testing possible with paper circuits provides an exciting way to engage students in engineering practices as well as assess learning.

FIGURE 3.

A bracelet circuit.

Project 3: Sewable Bracelet Circuits

During this activity, students build a series or parallel circuit that causes a bracelet to light up once it is snapped onto a wrist; the snap acts as a switch and completes the circuit. This novel approach for creating a switch often reveals students' misconceptions about how a switch works, such as not understanding the need for a break in the circuit. The bracelet is made from felt, conductive thread, sewable LED lights, and sewable snaps. Addressing topics such as polarity, types of circuits, short circuits, and switches, the bracelet allows students to build a model circuit to explore different types of circuits. While students are provided with basic information about how a circuit works, either through an initial group discussion or through previous inquiry, sewable circuits present new materials that look and behave differently, requiring further investigation by the students. For example, the sewable LED lights are sensitive, as they light up differently when in parallel or series, and the various colors light up at different

Being able to design their bracelets spurred students' creativity.

TABLE 2.

Assessment questions.

Standard Assessed	Type of Assessment	Example Assessment
Transfer of Energy	Drawing	Draw a circuit using arrows to show the movement of electrons that makes a lightbulb light up.
Energy in Everyday Life	Short Answer	What kind of circuits do have in your home? What makes you think they are that type of circuit?
Cause and Effect	Long Answer	Explain the process by which a lightbulb goes on when you flip the light switch.
Design	Multiple Choice	Which type of circuit is most efficient for lighting lightbulbs? A. Parallel B. Series C. Neither. They both are equally efficient.

levels of brightness according to their levels of resistance. This tangible feedback makes complex scientific concepts more concrete and accessible. A circuitry blueprint made prior to sewing and the completed bracelet serve as forms of authentic assessment. A correctly drawn circuitry blueprint and functional switch bracelet indicate understanding of the key circuitry concepts involved in the project.

A student chooses parts for his bracelet.

Assessment

We assessed student learning in multiple ways. Table 2 (p. 51) provides examples of assessment questions used to assess learning. Table 3 presents a model of a rubric used for assessing student projects.

Integrated Curriculum

This unit allows teachers to create integrated curricular units. Integrated curricular units often focus on artistic projects that engage student interest through the process of creation. For example, as part of a book report, students are often asked to draw a new cover for a novel, and Paper Circuits provides a new way to reinvigorate this standard assignment by adding lights and circuitry. Squishy Circuits can be implemented in a unit on ancient civilizations. Students can craft clay circuits to develop models of the aquifers of ancient Rome. Or, while exploring the pantheon of ancient gods, teachers can ask students to design an e-textile bracelet that shares information about one Greek myth or creature. Furthermore, teachers have

TABLE 3.

Assessment rubric.

Criteria	1 point	2 points	3 points
Circuit Design Drawing	Design is not clear and lacks evident thought.	Design is interesting and complete. It may lack personalization, but it demonstrates clear thought.	Design is clear, demonstrates thought to integrating form and function. It shows originality.
Function	Circuit is not functional/ works intermittently.	Circuit functions but is not the most efficient type of circuit design for the desired goal.	Circuit works well and demonstrates effort toward energy efficiency.
Aesthetic	Little to no effort is visible toward the artist or craft aspects of the project.	Project demonstrates effort toward making it attractive. Student demonstrates intentional effort.	Artistic design is compelling and evidences a clear effort toward a specific look for the project.
Reflection	Reflection document does not show thought in addressing issues that arose.	Reflection demonstrates thinking about the process and the product jointly. Indicates where problems or challenges arose and how they were dealt with.	Reflection contains thinking about process and product as well as thinking on ways to improve in future iterations or incorporate more efficient design.

used these projects as means for talking to students about their own use of electricity and the ways in which circuits are designed for efficiency in their own lives. For example, after working with Squishy Circuits, one primary grade teacher had students take pictures of the different types of lights and circuits they found at home. ■

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Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013):

4-PS3: Energy

www.nextgenscience.org/topic-arrangement/4energy

The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities. The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

Performance Expectation	**Connections to Classroom Activity** *Students:*
4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.	• build circuit models using a wide range of materials that allow them deeper understanding of how electric currents work.
Science and Engineering Practices	
Planning and Carrying Out Investigations Constructing Explanation and Designing Solutions	• build models of circuits, compare circuit designs, compare the effectiveness of types of circuits, and construct models of circuits that demonstrate an understanding of electric current.
Disciplinary Core Idea	
PS3.B: Conservation of Energy and Energy Transfer • Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light.	• design and build electric circuits using a variety of materials and systems to transfer energy and produce light.
Crosscutting Concepts	
Energy and Matter Cause and Effect	• explore various techniques in which energy can be transferred in various ways and between objects • work to understand the relationships between parts of circuits and how changes affect output.