

A design-and-build capstone project helps students connect science with everyday life.

By Cody Sandifer

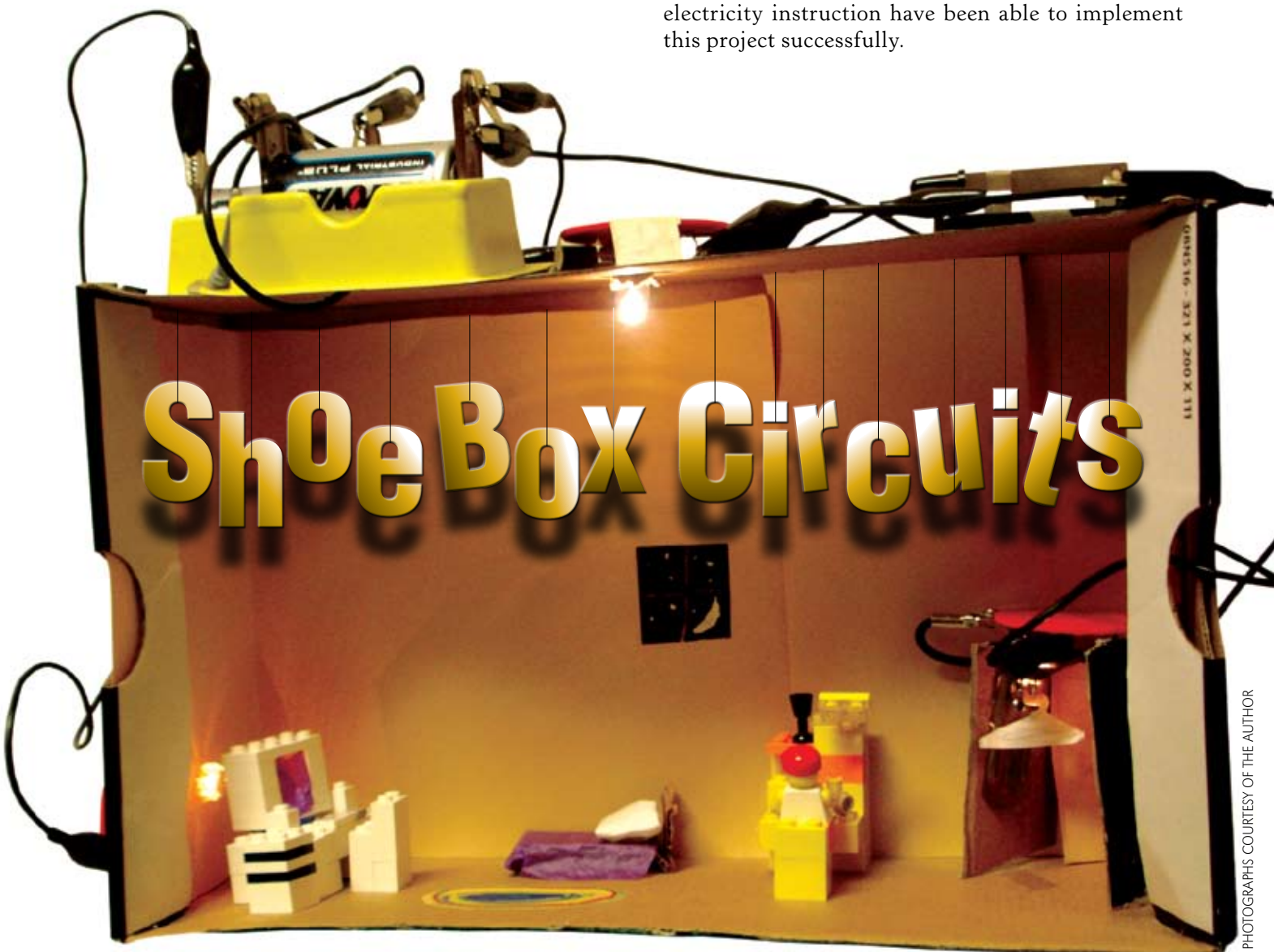
Students' eyes grow wide with wonder as they get a motor to work or make a bulb light for the first time. As these daunting feats of electrical engineering remind us, teaching electricity is invariably rewarding and worthwhile. During a typical inquiry-based upper elementary electricity unit, students explore an array of concepts and activities as they attach wires to batteries, install and use electrical switches, and explain the workings of different circuits. Yet as engaging as these learning experiences

may be, electricity units sometimes don't quite accomplish the final critical step of science learning: the clear connection of the classroom content to the scientific phenomena in students' everyday lives. This is why the preservice teachers in my elementary science internship course—in which the interns teach inquiry-based science weekly in elementary classrooms—now regularly round out their teaching of a six-hour electricity unit with a capstone project that summarizes and extends the original unit.

In this project, elementary students work in pairs to design and wire a shoe box "room" that meets well-defined circuit requirements. In so doing, the students solidify their understandings of electricity and gain a better understanding of the ways in which electricity concepts are related to the electrical circuits in their homes.

Here we describe the five-phase three-hour project for fourth- or fifth-grade students. The project involves simple circuits, and even teachers new to electricity instruction have been able to implement this project successfully.

Shoe Box Circuits



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Addressing Concepts

To have the greatest potential for success, students should complete a hands-on electricity unit just prior to the project to develop basic concepts related to conductivity, series and parallel circuits, bulb brightness, and switches. These concepts, which will be reinforced as the students plan and build their shoe box circuits, are the following:

- Circuit components such as bulbs, wires, and switches have two distinct ends (connection points), and both ends must be connected to the circuit for the component to function properly.
- Working circuits consist of closed loops that contain an energy or voltage source.
- Switches turn bulbs and other circuit components on and off by completing and breaking, respectively, the circuit loop.
- When bulbs are connected one after the other in the same loop (i.e., in series), each additional component results in less current, and therefore, dimmer bulbs. Switches in a series circuit affect all bulbs in the circuit loop.
- When bulbs are connected to the same voltage source via their own separate (parallel) loops, each bulb experiences the entire voltage of the battery and therefore maintains nearly full brightness. Switches in one loop of a parallel circuit do not significantly affect the bulbs in other loops.

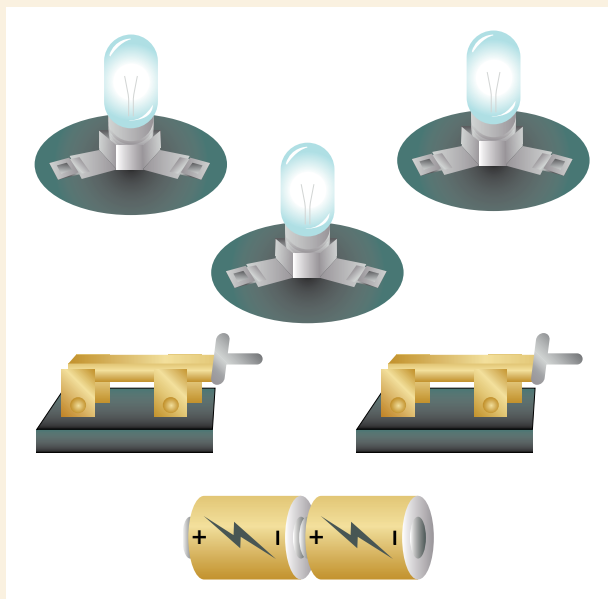
Project Overview

In the project, pairs of students engage in a five-phase process in which they: (1) choose a real-life room (e.g., bedroom, kitchen) to model and generate a circuit blueprint for their model room, (2) test their circuit blueprint to be sure that their planned circuit functions properly (and revise and retest if necessary), (3) install the final version of the circuit into their shoe box room, (4) decorate the newly wired room, and (5) engage in a class discussion and write a brief summative report. Each phase should take approximately 30 minutes, with the exception of the class discussion and brief written report, which will take approximately 60 minutes.

Students should be warned before beginning the project that the open exploration of electric circuits is only safe when done in a supervised school environment. It is not safe for students to conduct this sort of electricity exploration with switches and wall sockets at home. In the classroom, students might inadvertently create a short circuit by having the current bypass the bulbs and travel solely through the wires. This action could potentially cause wires to heat up significantly. The resulting safety concern is heat injury, not a serious electrical shock, and is avoidable. Remind students that



Figure 1.
Circuit component cutouts.



all circuit loops should contain at least one circuit component (i.e., a loop should not consist solely of wires) and all bulbs should be kept in their bulb holders. Students aren't allowed to build their circuits until their plans are approved by the teacher.

Finally, metal wire ends and scissor points are sharp, so safety glasses or safety goggles must be worn when doing the "installing the circuit" activity. Remind students to use caution when handling wires and scissors to prevent skin scratches and punctures.

Necessary Materials

Each pair of students needs a shoe box (or similarly sized box), one or two knife switches, three miniature bulbs, three bulb holders, two D-cell batteries, two battery holders, 10 connecting wires (alligator clip wires work well), masking tape, scissors, decorating materials, a resealable plastic bag containing cutouts of the circuit components (except the wires; Figure 1), a circuit blueprint worksheet (see NSTA Connection), and goggles.

Most of the circuit materials should be available in an electricity kit, if you have one available. Any materials not readily available can be ordered from educational retailers (see Internet Resources).

Making a Blueprint

Once students choose the type of room that they want to model with their shoe box, they use cutout circuit components (Figure 1; see NSTA Connection) to design a circuit blueprint that meets certain bulb brightness, battery place-

ment, and switch functionality requirements. We provide circuit requirements to ensure that students apply their understanding of electricity concepts in the design process, rather than simply use trial-and-error methods to build circuits that are not sufficiently challenging.

- Both batteries should be connected together and placed in the same location.
- One of the bulbs should be significantly brighter than the other two bulbs.
- A switch should turn only the brighter bulb on and off.
- *Optional:* A second switch should act as an emergency breaker switch that can turn all three bulbs on and off. Students draw in the wires to complete the blueprint.

The optional circuit requirement—one that includes a second switch acting as a breaker switch—can be included for those groups desiring a greater design challenge. Once the blueprint has been checked by the teacher (for completion and safety, not accuracy), materials are provided. Sample circuits that meet the original and more challenging circuit requirements can be found in Figure 2.

Testing and Revising

After the circuit is built, students then use the materials to confirm whether their proposed blueprint meets the circuit requirements. If it does not, the students can use the materials to revise and retest the circuit until the requirements are met. The time dedicated to revising and retesting has been included in the overall project timeframe.

A shoe box is distributed to students only when the teacher has verified that the pair's final circuit accurately meets the circuit requirements. The circuit cutouts should be glued in place on the blueprint once the final version of the circuit has been approved.

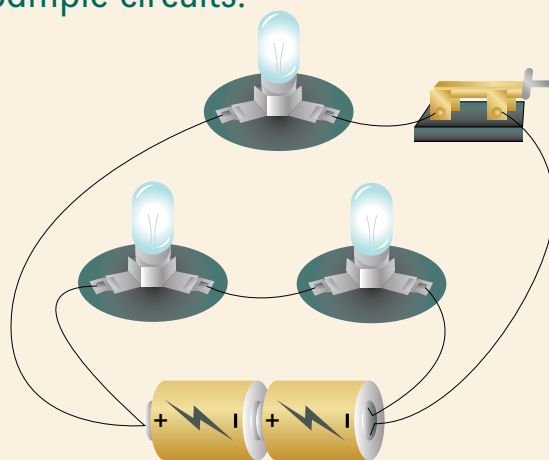
Installing the Circuit

Now that the final circuit has been approved by the teacher, the students jointly install the circuit in their shoe box room in any manner that they deem fit. Typically, students cut holes in the shoe box to allow lights to hang from the walls and ceiling of the model room, with the wires and bulbs attached to the inside or outside of the shoe box with tape. The batteries are most often allowed to remain outside the shoe box, because they would take up too much room inside the box.

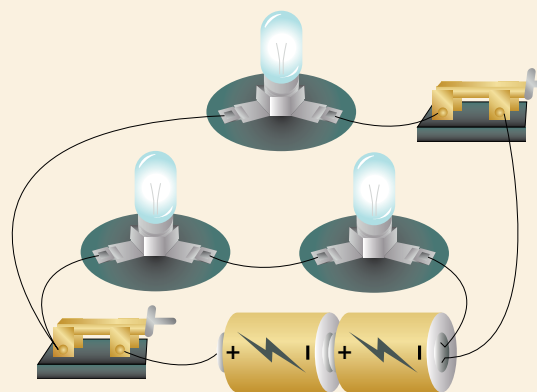
Shoe box Decoration

Students love decorating their model rooms with miniature beds, mirrors, chandeliers, and wallpaper. Construction paper is provided so that students can cut out and build their decorations, although some students prefer to bring in small

Figure 2.
Sample circuits.



Circuit meeting single-switch requirements



Circuit meeting double-switch requirements

toys from home (e.g., building bricks, dollhouse furniture) to decorate their rooms. Students should be as creative as possible in their decorative endeavors—although be sure to keep an eye on the clock! Students will spend all day decorating their projects if you give them the chance.

Class Discussion and Report

Once the model rooms have been fully wired and decorated, the class discusses the ways their circuits are similar to or different from the circuits in their homes. For example, possible similarities between shoe box circuits and at-home circuits include the use of closed loops, parallel wiring, and most of the same circuit components. Possible differences include that shoe box circuits use batteries as a power source, whereas at-home circuits are powered by the utility company; in addition, in at-home circuits, differences in brightness are the result of different bulb wattages rather than the wiring of bulbs in series.



Keywords: Electricity
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It is not unusual for students to identify many of these similarities and differences on their own, although they are more likely to identify the differences I've listed if the teacher (a) asks students to explicitly consider the source of the electricity in their homes, and (b) brings in common household bulbs of different wattages and asks the students to compare these bulbs to the bulbs that are used in their shoe box circuits (which are all identical).

One thing to note: the battery-driven circuits used in science kits are unlike the circuits in our homes in that electricity provided from real-life power lines is driven by alternating current (AC) rather than direct current (DC); however, the vast majority of basic concepts apply to both AC and DC circuits.

For assessment, students write a brief summative report. Teachers can use the following prompts for the written report:

- Explain what you did in your circuit to make one bulb brighter than the other two bulbs. In your explanation, be sure to include any electricity concepts that are important. Sample answer: "The brighter bulb was hooked up to the batteries in its own loop. The two dimmer bulbs were hooked together to the batteries in a separate parallel loop."
- Explain why, in your circuit, you put the switch (or switches) where you did. In your explanation, be sure to include any electricity concepts that are important. Sample answer: "A circuit has to be a closed loop to work properly. We placed the switch in the loop with the single bulb so the loop could be opened and closed, which turns the bulb off and on."
- How is your shoe box circuit similar to how a real-life room might be wired? Sample answer: "Like my room at home, the shoe box circuit has wires, bulbs, and switches. My room also uses parallel loops like the shoe box circuit so that different things can be turned on and off."
- How is your shoe box circuit different from how a real-life room might be wired? Sample answer: "In a real-life room, the electricity comes from the power company rather than batteries. Also, bulbs aren't put in series to make them dimmer. Different bulbs with different wattages are used instead."

Enhancing the Shoe Box Project

If you are comfortable with the shoe box project, there are many ways the project might be enhanced. For example, a motor with an attached propeller can be used as a ceiling fan, knife switches can be replaced with genuine wall-type switches, and a buzzer can be used as a door-

Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

Teaching Standards

Standard D: Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science.

Content Standards

Grades K–4

Standard B: Physical Science

- Light, heat, electricity, and magnetism

Grades 5–8

Standard B: Physical Science

- Transfer of energy

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academies Press.

bell. These additions, however, may require their own separate battery sources.

I cannot overemphasize how much elementary students enjoy the shoe box circuit project. Even better, this project effectively reinforces their understanding of electricity concepts and the relevance of these concepts to real-life circuits in their homes. As the teacher, it's satisfying to hear students announce to their partner during the design process that "you need to close that loop for the bulb to light" or "this switch works just like the ones at my house"—statements that speak volumes about the project's effectiveness.

I encourage you to try this capstone project after you conclude one of your electricity units. After all, who knew that such tremendous work could be accomplished without an electrician's certification and a contractor's license? ■

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Internet Resources

Delta Education
www.delta-education.com
 Elenco Electronics
www.elenco.com
 Fisher Scientific
www.fishersci.com

NSTA Connection

Download circuit component cutouts and the project worksheet at www.nsta.org/SC0912.

