Making the connection: Addressing students’ misconceptions of circuits

Electricity is an abstract phenomenon that students interact with every day. Interestingly enough, many eighth-grade students do not fully understand the requirements for a complete circuit. I developed this circuits unit in a 5 Es instructional model (Engage, Explore, Explain, Elaborate, Evaluate) of inquiry to help students build on their prior ideas with new experiences and understanding (see Table 1). I find these easy-to-do activities emphasize a number of National Science Education Standards (NSES) (see box below right).

The misconceptions addressed by this lesson are nothing new, and have been targeted by curriculum materials dating back to 1966. The Batteries and Bulbs unit produced by the Elementary Science Study, which began producing curriculum materials in 1960, provides activities similar to this one, and targets the same misconceptions.

The primary goal for this lesson is to address the misconception that no matter where the battery and bulb are connected, a complete circuit is made (Stepans 1996) (see Figures 1–4). For example, all four setups (see Figures 1–3) represent a setup that will not light the bulb. Setups one and two (Figure 1) are not closed circuits. Although setups three (Figure 2) and four (Figure 3) appear to be closed circuits, the contact points inside the bulb are not in circuit, therefore the current does not travel through the bulb. Only in the case where the rivet and screw threads are touching will the bulb light (see Figure 4). This misconception can be addressed in either two 50-minute class periods or one 90–100 minute class period. Students work in groups of three. Students need to know the following science content to understand open and closed circuits:

- **Contact points**—Two specific points on a light bulb must be in circuit to make the bulb light. The rivet and screw threads are the bulb’s contact areas for this lesson.
- **Short circuit**—A short circuit occurs if there is a closed circuit, but the current is not traveling through the bulb. This can occur several ways (see Figures 1–3). A short circuit will cause the wires to get hot because a current is produced.

### Materials
- aluminum foil
- one AA battery
- one plastic flashlight that requires two batteries
- three flashlight bulbs (plastic flashlights, which include the bulb, can be bought at several different department stores for $1.35–$1.75)
- wire
- wire cutters/splicer
- electrical tape

### Safety
- Do not use household/school electrical outlets (use only nonrechargeable D batteries).
- Use the specified materials only. Short circuits produced using a rechargeable nickel-cadmium cell will cause instant burns.

<table>
<thead>
<tr>
<th>National Science Education Standards</th>
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<tr>
<td>Content Standard: 5–8, Science as Inquiry: Students in grades 5–8 can begin to recognize the relationship between explanation and evidence (NRC 1996, p. 145).</td>
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<td>Content Standard: 5–8, Science as Inquiry: Students in grades 5–8 identify questions that can be answered through scientific investigations (NRC 1996, p. 146).</td>
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<tr>
<td>Content Standard: 5–8, Science as Inquiry: Students in grades 5–8 think critically and logically to make the relationships between evidence and explanations (NRC 1996, p. 146).</td>
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<td>Content Standard: 5–8, Science as Inquiry: In the vision presented by the Standards, inquiry is a step beyond “science as a process,” in which students learn skills, such as observation, inference, and experimentation. The new vision includes the “processes of science” and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science (NRC 1996, chapter 6).</td>
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• Students should wear safety glasses. Precautions should be taken when working with glass lightbulbs and wire.
• There should be a charged fire extinguisher in the classroom. Fire precautions need to be taken when students explore electricity hands-on.
• General classroom behavior: Do not allow students to connect multiple batteries together to create a circuit.

Using the 5 Es model of inquiry to teach about circuits

Engage
Teachers can begin their unit on circuits by engaging students in a problem-based scenario that addresses scientifically oriented questions (NRC 2000). This is a simple way to elicit students' prior knowledge about circuit setup and motivates them with a problem set in a real-life context. I begin by passing out the problem scenario to students:

Finally, the tent is set up, wood has been gathered for the campfire, and the camp cookout will begin in less than two hours. It is the perfect time for a quick hike into the woods before dusk. In a hurry you grab the essentials: one flashlight, a sandwich, and your hiking stick. Dark settles in much sooner than anticipated and the path of the trail is becoming harder to see. Luckily you have your old, trusty flashlight to help you get back. As you hit the switch nothing happens. Quickly you unscrew the battery cap. Yikes, it only has one battery and needs two! Before panic sets in, you take a seat on a rock to think through the situation. The flashlight has one small lightbulb, one small transparent plastic piece to protect the bulb, one battery, and some wires housed in its plastic shell. You also have a sandwich that is wrapped in aluminum foil. Your walking stick is made of wood. How can you use what you know about circuits to light the bulb and make it back to camp safely?

Then, each individual brainstorms the problem by writing or drawing out their ideas on a sheet of paper. After five minutes, students get into groups of three and share their ideas with each other.

Explore
Groups of three to four students are given a basket of materials. The basket contains a plastic flashlight, one battery, and a piece of aluminum foil. I tell students, “You don’t want to get lost in the woods. Get the light to work!” Students first refer to their drawings to light the bulb. Often, to students’ surprise, the bulb does not light. If by chance the bulb lights on the first try, the group should explore why the bulb lit.

<table>
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<tr>
<th>Phase</th>
<th>Purpose</th>
<th>Learning activities</th>
<th>Time</th>
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<tbody>
<tr>
<td>Engage</td>
<td>Determine prior knowledge and engage students</td>
<td>Problem-based scenario</td>
<td>25 mins.</td>
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<tr>
<td>Explore</td>
<td>Collect data and conduct hands-on work to investigate ideas</td>
<td>Students explore plastic flashlight, one battery, and a piece of aluminum foil</td>
<td>30 mins.</td>
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<tr>
<td>Explain</td>
<td>Build explanations based on the data collected in exploration</td>
<td>Students debate on the correct setup to light the flashlight. Teacher introduces open and closed circuits</td>
<td>15 mins.</td>
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<td>Elaborate</td>
<td>Apply knowledge in new situations</td>
<td>Students take apart old wall switches to determine how they operate</td>
<td>50 mins.</td>
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<tr>
<td>Evaluate</td>
<td>Assess understanding of unit concepts</td>
<td>Students present their circuit reports</td>
<td>30 mins.</td>
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Once students test their initial setup to see if the bulb does or does not work, they need to try other ways to light the bulb. I tell the groups to draw their successful and unsuccessful attempts. With time, students collect evidence and figure out how to light the bulb, but they still do not know why. Some students observe that when they hooked up the circuit, the battery terminals became hot, but the light did not glow. This is one observation that can be explored further.

After 15 minutes of exploring ways to light the bulb, I tell the class to observe the wires in the flashlight bulb. The clear bulb allows students to make visual observations of the contact points inside the bulb. Many students do not know that there are two contact points in a standard lightbulb. These contact points or areas—the rivet and screw threads—must be in circuit (Figure 4). Each contact point must go to an opposite battery terminal.

Students write their questions and observations (e.g., Where are the contact points in the bulb?) and then reattempt to light this bulb using the battery and aluminum foil they used earlier. Students’ knowledge of the bulb’s contact points results in success.

**Explain**

I begin by drawing two circuits on the board. One circuit will not light due to a short circuit, and the other one will. I ask, “Which circuit will light?” I follow this up by asking them “Why?” I call upon students for their explanations. Then I ask, “Does anyone want to comment or have a question about this explanation?” I probe the class, asking for multiple explanations. After students have argued their points, I simply tell the class to test their hypotheses. I draw on the board a circuit that relates the conflicting explanations. Students test their conflicting ideas with their group materials.

After a thorough investigation of ideas, I introduce the class to the concept and requirements of a closed circuit. The light will glow when the first battery terminal is connected to the light’s first contact point and the second battery terminal is connected to the light’s second contact point. This allows the current to flow from one battery terminal to the bulb, out of the bulb to the second battery terminal. I ask the class, “Did anyone’s circuit get hot, but the bulb did not light?” This introduces the idea of a short circuit. A short circuit is frequently observed by students, yet they do not know why it occurs. A short circuit is observed when the battery terminals are connected through wire leads, but the bulb is not connected in the circuit. The current flows from the first battery terminal directly to the second battery terminal without traveling through the bulb.

Students revisit the initial activity of the lesson. For a second time, I ask students to draw a circuit that would make a bulb light using one battery, one bulb, and a piece of foil. I then ask them to compare and contrast this drawing to the first drawing they made at the start of the class. I ask students, “How has your drawing of a closed circuit changed from when we started the lesson? Was your initial drawing a closed circuit, short circuit, or an open circuit? Why has your drawing changed?” I collect their drawings and their explanations. After class, I read their explanations, investigating if any individual is holding onto a misconception.

**FIGURE 1** Incomplete circuits because wire does not form a complete loop
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**Elaborate**

Studying the use of electricity in our everyday lives is possibly the best way to get our students even further motivated and involved. Bring in some old wall switches and have students examine and take them apart and explain how they work.

**Evaluate**

Like engineers and scientists, my students share their research in a presentation to their peers. I ask students to write a short report describing overall conclusions about closed and open circuits. I provide them with a scoring guide.

**References**


**Resources**


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