Systems Thinking: Batteries and Electric Cars

Madison Fitzpatrick and Mark Vondracek

Purpose

The purpose of this lesson is to introduce basic systems thinking skills in the context of a topic that is highly relevant to both physics and chemistry, with many interesting real-world applications.

Overview

In this two-part lesson, students will learn how batteries work and observe several simple batteries made from everyday household materials. They will then apply this knowledge of batteries to think conceptually about a battery as a component of a larger system, an electric car. This exercise will introduce students to the concept of systems thinking and allow them to practice some systems thinking skills in the context of an interesting real-world application.

Student Outcomes

Part 1: How Batteries Work

Students should be able to...

- Identify and define the parts of a battery
- Describe how molecules and electrons move during battery charging and discharging
- Identify performance measures of a battery and factors that affect them.

Part 2: Batteries and Electric Cars

Students should be able to...

- Identify how pollutants are generated over the life cycle of an electric car
- Explain how properties of the battery affect the environmental impact of an electric car

Time

This lesson was designed for two 80-minute periods. More time will be needed for students who do not have the necessary background knowledge (see "Prerequisites").

Level

This lesson was originally done with AP students in physics who have also taken chemistry. It is ideal for students who have already had some exposure to redox reactions and basic circuits. If students do not have this background, it may be necessary to spend additional time explaining these concepts as part of the interactive lecture.

Materials and Tools

In addition to the handouts provided with this lesson, the following materials are required:

- 3 aluminum strips, 1 aluminum plate (about hand-sized)
- 3 copper strips, 1 copper plate (about hand-sized)
- 2 zinc strips (zinc-coated nails or screws are a suitable substitute)
- 1 C cola
- 1 C salt water
- 1 C diluted bleach

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- 2-4 citrus fruits (can be all the same kind or different kinds)
- 5 voltmeters
- 3 non-metal cups
- 6 binder clips or clothes pins (optional)

Preparation

To prepare for this lesson, the teacher should review the background information about batteries, electric cars, and systems thinking (see "Background") and ensure that all the necessary lab materials are available. It is a good idea to test each battery ahead of time.

Prerequisites

Students should have a basic understanding of redox reactions and resistor circuits, or at least a conceptual understanding of electricity. It is also helpful if students have used voltmeters before, although this is not required if there is sufficient time to explain how they work.

Background

- Batteries: http://sxxz.blogspot.com/2005/03/how-do-batteries-work.html
- Electric cars: http://auto.howstuffworks.com/electric-car.htm
- Systems thinking: "Development of System Thinking Skills in the Context of Earth System Education"

Teaching Notes

Part 1: How Batteries Work

1. **Interactive lecture: batteries.** This portion of the lesson is intended to convey the essential information about how batteries work. Any lecture method can be used, but in order to foster an interactive learning environment, it is helpful to use visual aids that can be edited in real time, such as a chalkboard/whiteboard, document camera, or digital notebook, rather than pre-made slides. There is a note-taking guide that students may use to help them stay on task and organized (Battery Lecture Notes). In order to prepare this lecture, the teacher should refer to the background information provided.

2. **Homemade battery observations.** Students will then work in groups to measure the voltage from five different simple batteries, with specific instructions provided in the lab handout (see Battery Materials Performance Lab). The batteries are configured as follows:

    - Soda + aluminum + copper
      Place the liquid in a non-metal cup. Insert the metal strips into the cup, ensuring that they do not touch each other (it may be helpful to use a binder clip or clothes pin to hold the strips to the side of the cup). Attach the leads from the voltmeter to the metal strips.
    - Bleach + aluminum + copper
      See above.
    - Salt water + aluminum + zinc
      See above.
    - Citrus fruit + copper + zinc

Insert the metal strips into the fruit, ensuring that they do not touch each other. Attach the leads from the voltmeter to the metal strips.

- Hand + aluminum + copper
  Use the larger metal plates for this battery. Attach the leads from the voltmeter to the metal plates, ensuring that the plates do not touch each other. Place one hand on each plate.

3. **Class discussion: battery properties.** Following completion of the lab, the teacher should guide a class discussion in which the students brainstorm ways in which one could describe the properties of a battery other than voltage. The teacher should encourage the students to think about this in the context of an application, such as an electric car, a computer, or some other battery-powered device. The following are some good examples (for the teacher's reference).
   - Total energy
   - Energy density
   - Operating temperature
   - Charging and discharging rate
   - Calendar life
   - Cost
   - Recyclability
   - Material toxicity

   The purpose of this discussion is for students to understand what properties of a battery might be important in a given context and how there are trade-offs between these properties, which is why batteries may be made in very different ways for different applications. Efforts to improve various aspects of battery performance continue to drive battery research. If desired, the teacher can conclude the discussion by showing and explaining the two charts provided (Discussion Diagrams), which were taken from a 2009 research report on batteries for electric vehicles.

Part 2: Batteries and Electric Cars

1. **Interactive lecture: electric cars.** In case students are not familiar with how electric cars work, a brief lecture may be necessary to explain how they are different from internal combustion engine cars. One important point to understand are that electric motors operate using electricity from batteries rather than fuel combustion. This means that electric cars have no tailpipe emissions. However, they have to get electricity from power plants, and power plants do generate emissions, with the type and quantity of emissions depending on the type of power plant (e.g. coal, gas, wind, hydroelectric). Another important point is that with current battery technology, an electric car can only hold enough energy to drive 50-100 miles on a single charge (depending on car model and driving conditions). In order to go farther, a car would need more batteries, which adds volume and weight, or we would have to develop battery technology that allows more energy to be stored in the same space.

2. **Work in pairs: environmental impacts of electric cars.** Students will work in pairs on the handout entitled "Environmental Impacts of Electric Cars." This exercise asks students to identify where waste and pollutants are generated in the lifecycle of an electric car. It then asks them to describe how battery properties affect the total environmental impact of the car.

Assessment

This lesson involves two written assessments, one for each part. For Part 1 of the lesson, students will complete the lab handout, which asks them to record and interpret their observations of the homemade batteries, and also to recall information about how batteries work from the lecture. For Part 2, students will turn in their "Environmental Impact of Electric Cars" handout.

It is also suggested that the teacher use informal methods to assess student understanding and engagement throughout the lesson. The interactive lecture is a good opportunity to ask students questions and use their contributions to drive the lesson. While students are conducting the lab observations or working on their conceptual diagrams, the teacher should check in with each group periodically and ask them to explain what they have been working on. This can help the teacher identify whether the students are struggling with a particular aspect of the material.

Additional Information

See attached documents:

- Battery Lecture Notes handout
- Battery Materials and Performance Lab handout
- Environmental Impact of Electric Cars handout
- Charts for part 1 class discussion (supplemental)