Driving Question:
How can we design and power electric art circuits?

Overview
In this lesson, students apply the engineering for sustainable community (EfSC) principles to their first engineering design challenge: creating electric art. Through this design challenge, students will understand how circuits work, including load (power requirement of the load, such as an LED light), switch, power source and the conductive element. As part of this, they will learn that circuits with more than one light bulb can carry different power requirements.

The iterative engineering design cycle will allow students to investigate how circuits work, design their own electric art, and share what they learn with each other and then optimize their design. This is a process that students will utilize multiple times throughout this unit.

Lesson Standards

| MS-ETS1-1 | Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. |
| MS-ETS1-3 | Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. |

Objective
Students will design an electric art circuit.

I Can Statement
I can optimize an electric art circuit using our engineering for sustainable communities principles.

Materials
- Copper Tape
- Cardstock
- Construction Paper
- LED Lights
- 3V Batteries
- Scotch Tape
- Masking Tape
- Glue Sticks
- Markers
- Craft Sticks
- Washi Tape
- Pipe Cleaners
- Yarn

Equipment
- Scissors
- Markers
- Colored Pencils
Background for Teachers
In this lesson, students will be creating circuits, or closed loops through which electricity travels. Every circuit requires a power source. Electrons, or a particle with a negative electric charge, travels from areas of high electric potential to areas of low electron potential along a conductive path. The conductive path will be copper tape in this lesson, and the power source will be small coin batteries.

Key Terms

Circuit → the path that electrons flow, that begins and ends in the same place.

Current → how much electricity is flowing through the circuit. A higher current means more electricity is flowing. Current is measured in amperes. The symbol for amperes is A.

Simple Circuit → a circuit that only has a single load, such as one lightbulb or one noisemaker.

Parallel Electric Circuit → the current divides as it flows through separate branches and then is combined again.

Series Electric Circuit → the current passes through each load in a single branch in consecutive order.

Switch → small device that is used to allow or interrupt the flow of electrons in a circuit.

Key Parts of a Circuit: Power Source | Load | Pathway | Switch

Power source → The energy source that powers the circuit.

Load → The electricity energy transferred in a circuit.

Pathway → The way electricity flows through a circuit.

Switch → The object that opens and closes a circuit to complete it.

Voltage → how hard electricity is being "pushed" through a circuit. A higher voltage means the electricity is being pushed harder. Voltage is measured in volts. The symbol for volts is V.

Kinetic Energy → Energy of motion.

Potential Energy → Energy that is stored.
Examples

Electric art can be two or three-dimensional (pictured above left and right).

All of the electric art needs to have switches. Here is one simple example. When the card is closed, the copper tape touches the battery and there is a complete circuit.

This electric art’s switch requires the user to press the button to complete the circuit.

After students complete their initial prototyping, have students show their working electric art. Then have them draw and explain how it works on the class’s board.
Electric Art Examples
I. Design challenge introduction

A. Introduce the electric art challenge

Begin by saying, “You realized that you wanted to give a present to a friend or family member, but you forgot to buy something for them. You searched around your home and you found some odds and ends, including:

- LED light bulbs
- small batteries
- copper tape
- lots of craft supplies

B. Show the students the materials. Hold up the different items and ask students:

- Have they seen or used them before?
- What could these materials be used for?
- How can they be used?

C. Connect this engineering challenge to the engineering design cycle by pointing out different aspects of the engineering design cycle while asking:

- How will you design the card to help the person you give the electric art card now and in the future?
- How does this help us care for our environment?
- How will you balance the technical dimensions of your electric art design with community needs?

D. Observations

- Have students take a couple of minutes to explore and observe the copper tape, lights and battery.
- Have students share their observations and ask them how those observations might help them in their electric art circuit building.
- On the board record the student’s responses. See the example chart below and in the slideshow.
TIP

It is important that students notice the + on the battery, understand that copper tape conducts electricity and understand the different LED leads are +/- . Explain that the LED lead length shows positive (longer) and negative (shorter) ends.

Ask students, how they will turn their lights on and off? If they do not talk about switches, have them look at the light switch in their room. Show examples of switches on electric art cards.

A good prompting question is:

What do you think it means for your circuit if there is a + on the battery, and there are negative and positive leads?

Students should come up with two answers: there must be a negative side of the battery and there must be a reason why there are + and – in the circuit design.

At first, have them explore this, but you may need to explain that electricity flows from high potential to low potential. Therefore, a +–+ pattern is necessary.

Observation of materials

- **Copper Tape**
  Shiny, metal, sticky
  Used for: connecting the batteries and LED lights, electricity travels through the copper tape

- **Battery**
  3V, + on one side, the – must be on the other sides
  Used for: power source

- **LED lights**: Long wire, short wire
  Used for: long wire (+), short wire(-)

Then ask students to brainstorm:

What could you do with these materials? Generate a list of possible ideas. Explain to the students that they can make an electric card.
II. Prototype I: Electric Art

A. Have students form groups of 3

**TIP**

Have a “ask 3 before me” norm. This positions students as experts.

B. Show students the different electric art templates (simple, 2 lights in parallel and 2 lights in series circuits (for this they will need 2 batteries to make it light)) and show the video in the slide show about how to complete the electric art circuit on the templates.

C. Explain to the students that they are going to look at how the three different circuits are similar and different. Remind them that these differences will matter when they design their own electric art card.

D. Have students complete all three of their electric art templates

E. In groups, have students complete the observation questions on the top of the templates. This work will help students to understand:

- The flow of electricity through circuits
- The transfer of energy in each circuit
- The differences between series and parallel circuits
- The necessary components of a circuit

F. Group discussion: have a student show how the simple, parallel and series circuits work. Have the class discuss:

- What do all of the circuits have? They have: a pathway (copper tape), power source (battery), load (light bulb), switch. All of the circuits needed to be completed or closed for the lights to light.
- How are the circuits different?
  - The parallel circuit only needed 1 battery. The electrons only pass through 1 light not two.
  - The series circuit needed 2 batteries. The electrons had to travel the whole pathway, and pass through both light bulbs.
  - The simple circuit only had 1 light bulb.
- How does the electricity flow through the circuit?
- What are the affordances of each circuit?

**NOTE:** have groups store their templates in the zip bags with their names on them and keep them in the classroom. They will use those materials in the next class.
III. Prototype 2: Build electric art cards

A. Group discussion: Generate a list of the necessary parts of a circuit and the affordances of series and parallel circuits. Ask students to brainstorm: what would they want to change to their original templates to turn them into a gift? (They will generate ideas like use different colors, make the circuit different shapes and personalize it. Fold it like a card) Tell students that is what they will get to do now.

B. Show the slide that provides examples of electric art circuits that will not work. Have students explain why they do not work and how the energy is or is not transferred.

Example responses

a) The battery needs to be connected to the copper tape not wrapped around by the copper tape
b) The battery can’t connect directly to the battery
c) The copper tape needs to go in on loop
d) Copper tape must touch the bottom and top of circuit
e) Short circuit failure mode

Often kids just put the light leads on the battery and make it work. This is a good first step, but push them further by having them include copper tape.

C. Show the three examples of different cards and put them in places for youth to go and see the cards, but not take them back to their work areas. Make sure to point out the 3 different types of switches.

D. Sketching Plan and Feedback Interview:

- Have students draw their circuit on the electric art card. Have them include the switch, power source, light and pathway. Have students check their design with their classmates then show the design to teacher.
- Have students complete the pre-interview script by explaining how their design works and who it is for.
- Have students draw their circuit on the electric art card. Have them include the switch, power source, light and pathway. Have students check their design with their classmates then show the design to teacher.
- Have students complete the pre-interview script by explaining how their design works and who it is for.
- Once students have their design approved by the teacher, they should receive about 20 inches of copper tape and get the light bulbs and batteries off of their templates.
- Have students build and test their electric art card.

Guidelines

a) Like electric art prototype 1, draw the circuit on your electric art. Raise your hand to have your teacher check your design and get the materials.
b) Must use copper tape
c) Light cannot be directly attached to the battery
d) Must have an on/off switch
e) Can use up to two LED lights
III. Prototype 2: Build electric art cards

E. Early finishers:

- Have students help other students
- Complete their analysis hand-out
- Have students try:
  - Using different switches
  - 3D art instead of 2D art

**TIPS**

Cut tape with scissors to avoid copper tape cuts

Press hard and rub the copper tape when it is over the light wires

The longer lead on the LED light is the positive connection; the shorter lead is the negative connection

No copper tape should be directly under the bulb

**NOTE:** Building will take most students two lessons. Have students store their works in progress in their bags.
III. Share solutions and engineering discussion

A. **Showcase:** Have students show their cards to the class. Then draw and explain their designs at the same time on the board. Make sure students answer these questions:

- How did you get your circuits to work?
- Where is the switch?
- In what direction does the electricity flow?
- What problems did you encounter and how did you solve them?

**TIP**

Have as many students share their designs as possible so they can be recognized for their work.

IV. Drawing and explaining electric art cards

A. **Explain to students that engineers need to share their designs.** Ask them what they think makes a good design. **Answers should include things like: it needs to be clear, labeled, specific. Others should be able to take your design and build it.**

B. Have students draw and label their final electric art design

C. Have students write down how their circuit works (technical specifications).

D. Have students explain why they think the person who is getting the electric art will like it (social specifications).

**TIP**

Encouraging and valuing the encountering and solving of problems recognizes students engage in the engineering practices of designing solutions.
INTERVIEW SCRIPT

DIRECTIONS: 1. Complete the interview script. 2. Interview at least 2 people. 3. Make changes to your electric art card sketch based on the interviews. 4. Make your electric art card.

Electric art design: This is my design. It uses a ___________ (simple, parallel, series) circuit to light up ________ (1, 2) light bulbs. This is a description of how it works:

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

Show the interviewee how the electricity will flow across your circuit.

Do you think this design will work? Why?

I am making this design for ________________________. Here are some details that I added to make sure they like it:

a. ______________________________________________________________________

b. ______________________________________________________________________

c. ______________________________________________________________________

Do you think they will like it? What else can I do to make it better for them?

Write one more question you would like others to give you feedback on for your card design:

CHECKLIST

1. Who did you interview? ________________________________________________

2. Did you make changes to your electric art card sketch based on the interviews? ______

3. Let your teacher know so you can start making your electric art card.
Group Members: ________________________________
__________________________________________

SIMPLE CIRCUIT
Group Members: __________________________________________
_______________________________________________________

**DIRECTIONS**

- Did your 2 lights light up? ________________

- Were they as bright as in a simple circuit? If not, how could you make them bright?

- Show the flow of electricity with an arrow and label on the template.

- Label the components of the circuit: power source, load, switch, and pathway.

![Series Circuit Diagram](image-url)
Group Members: __________________________________________
_______________________________________________________

**DIRECTIONS**

- Did your 2 lights light up? ______________
- Were they as bright as in a simple circuit? If not, how could you make them bright?
  ____________________________________________________________________
- Show the flow of electricity with an arrow and label on the template.
- Label the components of the circuit: power source, load, switch, and pathway.

**PARALLEL CIRCUIT**
Name: ____________________________________________

CHECKLIST

My design uses:
- A battery
- A LED light bulb
- Copper tape
- Has a switch

INSTRUCTIONS

1. Draw and label your electric art circuit.

2. Label: Copper tape, LED light, battery, switch, current flow (use arrows).
Name: __________________________________________

**QUESTIONS**

How does your design work? (Make sure to discuss the energy transformations)

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

Who is going to receive your electric art?

____________________________________________________________________________________

Why do you think they will like your electric art?

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________
Lesson 2 Objective: Students will design an electric art circuit

## Electric Art Sketch Up and Explanation Sheet Rubric

<table>
<thead>
<tr>
<th>I-Engineering Big Ideas</th>
<th>Criteria</th>
<th>Is this present?</th>
<th>Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No Evidence</td>
<td>Evidence Present</td>
</tr>
<tr>
<td>Engineering for Sustainable Community Principles</td>
<td>Uses community members’ ideas in engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Modified design based on classmate, community member and teacher feedback</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tailored the social and technical aspects of the card for its intended purpose (Made the card in a way they knew the person they were giving it to would like it.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Practices</td>
<td>Designing Solutions</td>
<td>No Evidence</td>
<td>Evidence Present</td>
</tr>
<tr>
<td></td>
<td>Utilized social design aspects to help solve problem</td>
<td>No Evidence</td>
<td>Evidence Present</td>
</tr>
<tr>
<td></td>
<td>Designed a working circuit</td>
<td>No Evidence</td>
<td>Evidence Present</td>
</tr>
<tr>
<td>Energy Content Knowledge</td>
<td>Types of Energy</td>
<td>No Evidence</td>
<td>Evidence Present</td>
</tr>
<tr>
<td></td>
<td>Explain that the battery was the source of energy</td>
<td>No Evidence</td>
<td>Evidence Present</td>
</tr>
<tr>
<td>Energy Flow</td>
<td>Energy Flow</td>
<td>No Evidence</td>
<td>Evidence Present</td>
</tr>
<tr>
<td></td>
<td>Labeled the components of a circuit (switch, pathway, light or load, battery)</td>
<td>No Evidence</td>
<td>Evidence Present</td>
</tr>
<tr>
<td></td>
<td>Explained/labeled the direction flow through the parallel or series circuit</td>
<td>No Evidence</td>
<td>Evidence Present</td>
</tr>
<tr>
<td></td>
<td>Explained how energy was transferred in the circuit</td>
<td>No Evidence</td>
<td>Evidence Present</td>
</tr>
</tbody>
</table>
Arte eléctrico
Diseño de arte eléctrico
Lección 2

Miembros del grupo:
____________________________________

Circuito simple
Arte eléctrico
Diseño de arte eléctrico
Lección 2

Miembros del grupo: ______________________________________
________________________________________________________________________
________________________________________________________________________

Instrucciones:

• ¿Se encendieron ambas luces?__________________________

• ¿Brillaban igual que en un circuito simple? Si no, ¿qué harían para que brillen más?

• Demuestren el flujo de la electricidad con una flecha y un rótulo en el modelo.

• Identifiquen los componentes del circuito: fuente de energía, carga, interruptor y conductor.

Circuito en serie
Miembros del grupo: __________________________________________
______________________________________________________________

**Instrucciones:**

- ¿Se encendieron ambas luces?________________________

- ¿Brillaban igual que en un circuito simple? Si no, ¿qué harían para que brillen más?

- Demuestren el flujo de la electricidad con una flecha y un rótulo en el modelo.

- Identifiquen los componentes del circuito: fuente de energía, carga, interruptor y conductor.

**Circuito de paralelo**
Nombre: ____________________________________________

**Lista de cotejo**

Mi diseño usa:
- Una batería
- Una bombilla LED
- Cinta de cobre
- Un interruptor

**Instrucciones:**

1. Dibuja y rotula tu circuito de arte eléctrico.
2. Identifica: la cinta de cobre, la bombilla LED, la batería, el interruptor y el flujo de corriente (usa flechas).
¿Cómo funciona tu trabajo de diseño? (Asegúrate de discutir las transformaciones energéticas.)

____________________________________________________________________________________
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____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

¿A quién le regalarás tu obra de arte eléctrico?
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

¿Crees que le gustará tu obra de arte eléctrico?
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________


### I-Grandes ideas de ingeniería

#### Criterios

| Modifica el diseño basado en los comentarios de los compañeros de clase, miembros de la comunidad y el maestro. |
| Ajusta los aspectos sociales y técnicos de la tarjeta para su propósito deseado (Hizo la tarjeta pensando en los gustos de la persona a quien se la regalaría.) |

<table>
<thead>
<tr>
<th>¿Esto se encuentra?</th>
<th>Comentarios:</th>
</tr>
</thead>
<tbody>
<tr>
<td>No hay evidencia</td>
<td></td>
</tr>
<tr>
<td>Hay evidencia</td>
<td></td>
</tr>
<tr>
<td>Evidencia sólida</td>
<td></td>
</tr>
</tbody>
</table>

#### Practicas energéticas

- **Diseño de soluciones**
  - Usa aspectos sociales del diseño para ayudar a solucionar el problema.
  - Diseña un circuito de trabajo.

#### Conocimiento de contenido energético

- **Tipos de energía**
  - Explica que la batería era la fuente de energía.

- **Flujo de energía**
  - Identifica los componentes de un circuito (interruptor, conductor, luz o carga, batería).

- **Transformación energética**
  - Explica o identifica la dirección del flujo de electricidad por el circuito en paralelo o en serie.
  - Explica cómo la energía fue transferida al circuito.

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**Nombre: _____________________________**

**Lesson 2 Objective:** Students will design an electric art circuit