

## Unit: Designing Circuits for Neurodevices

### Lesson 5: Device Design Challenge

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Image credit: [Elenco Electronics](#)

#### LESSON OVERVIEW

##### Activity Time:

Four to six 55 minute class periods (depending on build time).

##### Lesson Plan Summary:

In this lesson, students will design and build a working model of a device that uses circuits and is based on neural input. The device needs to help someone improve their everyday life. If your school has a maker space, you can make use of the materials and tools there, or gather your own from everyday classroom and craft supplies.

#### STUDENT UNDERSTANDINGS

##### Big Idea & Enduring Understanding:

- **Neural Engineering Design Challenge:** Students will work on designing and creating a device that works on neural inputs to help improve someone's life.

**Investigative Phenomenon:** The human nervous system generates electrical signals, which are a type of biosignal known as bioelectrical signals. Engineers can record and interpret bioelectrical signals from the human body, allowing for the design of neurodevices that use neural inputs. Engineers seek to design devices, machines, and technologies that help to solve authentic human problems.

**Driving Question:**

- What would a device that helps improve someone's life and also runs on neural inputs and circuitry do and look like? How does it work?

**Learning Objectives:**

*Students will know...*

- How to design and build a device that runs on neural inputs and circuitry.

*Students will be able to...*

- Design and build a device that runs on neural inputs and circuitry.

**Vocabulary:**

- **Biosignal:** A signal generated by the human body that can be measured. Bioelectrical signals are electrical signals produced by the nervous system (e.g., EMG, EEG, ECoG) or organ systems (e.g., ECG/EKG, GSR).
- **Circuit:** A closed-loop pathway through which an electrical current travels from its source (e.g., batteries). Inputs (e.g., sensors) and outputs (e.g., motors, LEDs, speakers) may be added to a circuit.
- **Constraint:** A limitation to an engineered design (e.g., cost, time, materials, etc.).
- **End-user:** A person or group of people who are the likely users or consumers of a new technology. Engineers need to consider end-users needs, wants, preferences, and desires when designing new products or devices.
- **Engineering:** A discipline that applies math and science to design and build products (devices, structures, tools, machines, etc.) to solve an authentic problem.
- **Input:** A component of an electrical circuit that provides information into the system (e.g., photoreceptor, microphone, proximity sensory, temperature sensor, etc.). In the human nervous system, this is analogous to the role of a **sensory neuron**, which carries information from the body's sensory receptors (eyes, nose, ears, tongue, skin, muscles, joints) to the central nervous system.
- **Output:** A component of an electrical circuit that communicates information out of the system and makes something happen (e.g., motor, speaker, LED, etc.). In the human nervous system, this is analogous to the role of a **motor neuron**, which carries information from the central nervous system to muscles, sending a message for the muscle to activate and initiate movement.

- **Prototype:** A model of a design, typically an early version of a model. Prototypes can be “looks like” and “works like” models. A prototype is often iterated on through multiple testing and re-design phases.

### Next Generation Science Standards:

This lesson builds toward the following bundle of Performance Expectation (PE) and their integrated three dimensions of learning.

High School Performance Expectations		
<p><b><u>HS-PS3-3:</u></b> Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. (Grades 9-12).</p> <p><b><u>HS-ETS1-1:</u></b> Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.</p> <p><b><u>HS-ETS1-2:</u></b> Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.</p>		
Science and Engineering Practices (SEPs)	Disciplinary Core Idea(s)	Crosscutting Concepts (CCCs)
<p><u>Constructing Explanations and Designing Solutions</u></p>	<p><u>PS3.A: Definitions of Energy</u></p> <p><u>PS3.D: Energy in Chemical Processes</u></p> <p><u>ETS1.A: Defining and Delimiting an Engineering Problem</u></p> <p><u>ETS1.C: Optimizing the Design Solution</u></p>	<p><u>Energy and Matter</u></p> <p>Connections to Engineering, Technology, and Applications of Science</p> <ul style="list-style-type: none"> <li>• <u>Influence of Science, Engineering and Technology on Society and the Natural World</u></li> </ul>

### Common Core State Standards:

In this lesson, students will engage in literacy practices in science and technical subjects that build toward competency with the following standard:

- **CCSS.ELA-LITERACY.RST.9-10.3:** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

## TEACHER PREPARATION

### Materials

Material	Description	Quantity
Snap Circuits Pro Kits	Elenco Electronics Snap Circuits Pro kits, <a href="https://www.amazon.com/Snap-Circuits-SC-500-Electronics-Discovery/dp/B00008W73Z">https://www.amazon.com/Snap-Circuits-SC-500-Electronics-Discovery/dp/B00008W73Z</a>	1 kit/ group of 2- 4 students
Craft Supplies and Tools	Supplies can include, but are not limited to: Cardboard, cardstock paper, string, glue, colored pencils, brass brads, markers, paper cups, rubber bands, popsicle sticks, wood skewers, gears, etc.  Tools can include, but are not limited to: Hot glue gun, ruler, hole punch, scissors, stapler, etc.  See <a href="http://www.papermech.net/">http://www.papermech.net/</a> for ideas on what supplies to include.	Enough for all students to have an assortment of material choices.
Poster Paper	Poster paper or large sheets of butcher paper for students to create their research posters.	1/group
Student Handout 5.1	<i>Engineering Design Journal: Project Introduction, Device Brainstorm, Designing the device, Working on the device, Reflecting on the device</i>	1/student
Student Handout 5.2	<i>Project Rubric</i>	1/student or 1/group
Student Handout 5.3	<i>Research Poster Requirements</i>	1/group

### Preparation

1. Obtain enough Snap Circuit kits as needed for each small group to have access to one kit.
2. Obtain craft supplies. Consider asking for donations or the art teacher for ideas/extra supplies.
3. Make copies of student handouts as indicated. Decide if you want students to each have a handout, or share them within their groups.

## PROCEDURE

### Engage: Introduction to Project (10-15 min)

1. Post the following entry task on the board or in whatever format you use in your classroom.
  - a. *What do you wish existed if there were no limitations on money and resources and technology?*
2. Pass out *Student Handout 5.1: Engineering Design Journal* to each group or student.
3. Read the introduction on *Student Handout 5.1* as a class. Answer questions as they come up.

### Explore: Brainstorming (30 or more min)

4. Group students into groups of 1-3 (this may depend on your class size). You may want to allow students to self-select their groups.
5. Have students begin on Part 2 of *Student Handout 5.1*.
  - a. This process can be scaffolded. Consider doing only Question 1 and giving time to pause and talk. Then Question 2, etc.
  - b. Make sure students know that the prototype doesn't have to be something that they are making production quality. A prototype should be an early version, a model, or a mock-up. As long as it meets the requirements, it will be okay.
  - c. Students can create both a prototype that "looks like" what they want to make and another one that "works like" what they want to make. These are okay to be separate prototypes.
6. Check off Part 2 before allowing students to continue on to Part 3 of the handout.
  - a. A clipboard with spots for each group and the different parts would work well here.

### Explain: Designing and Working on Device (2-3 class periods)

7. Direct students to work on Parts 3 and 4 of the handout, as they get checked off.
  - a. Remind them to follow the guidelines.
8. Pass out the project rubric (*Student Handout 5.2*) so that students and groups have a guide to what they will be producing.
9. Check off Part 3 and 4 of the handout before allowing students to continue on to Part 5 and the poster.

**Elaborate: Research Posters (1-2 class periods)**

10. Pass out or show the poster requirements (*Student Handout 5.3*).
11. Go over these requirements in detail with all students. Answer any questions.
  - a. Indicate to students that research posters is a way that scientists and engineers present their research and findings at conferences and meetings. Consider showing students what this actually looks like through a web search for “scientific posters” or “research posters.”
12. Pass out poster paper and allow students time to complete this activity.
13. When posters are complete, set up a Gallery Walk in which one group member stays to present while others visit the other posters. Alternatively, set up a poster session split into two phases. During the first session, half of the group members stay to present their posters while the others circulate to the other groups as audience members. For the second session, switch roles. Ask students to provide feedback to their peers by using a feedback form or sticky notes.

**Evaluate: Reflection (15-30 min)**

14. Direct students to complete Part 5 (reflecting on device) of *Student Handout 5.1*.
15. Have students turn in their completed *Student Handout 5.1*.
16. Post the following exit ticket on the board or in whatever format you use in your classroom.
  - a. *Are you ready for your poster presentation? Why or why not?*

**STUDENT ASSESSMENT****Assessment Opportunities:**

- Teachers can check on student understanding and engagement during the class discussions.
- The engineering design journal (*Student Handout 5.1*) and the finished research poster will provide assessment opportunities.

**Student Metacognition:**

- Students will be able to monitor their progress and reflect on their learning through the engineering design journal.

**Scoring Guide:**

- *Student Handout 5.2* provides a rubric for students’ research posters. This may be used by the teacher as well for scoring the posters.

## EXTENSION ACTIVITIES

### Extension Activities:

- Student could complete a group discussion on the project as a part of the reflection.
- Students with prior expertise in circuitry and programming could choose to use a microcontroller (e.g., Arduino Uno, Raspberry Pi, etc.) for their prototype rather than the Snap Circuit kits.

### Adaptations:

- This activity could be adapted with scaffolding provided in each part of the engineering design journal. Vocabulary terms that are new to students should be defined. See the Vocabulary section at the beginning of this lesson plan.
- This activity could also be adapted by providing an actual template for the poster portion as opposed to an example.
- If students need an introduction to basic circuitry and how to use Snap Circuit kits, consider consulting these lesson plans:

#### ***Lesson 6 of Modeling and Designing a Sensory Substitution Device***

Level: Middle School

In this lesson, students will learn about the basic components of a circuit. Students will design circuits using Snap Circuit kits, online animations, and classroom materials and draw corresponding circuit diagrams. Students will begin exploring control of output using various inputs (photo resistors, whistle chip, motor) in a circuit.

<http://centerforneurotech.org/education-k-12-lesson-plans/sensory-substitution-devices>

#### ***Lesson 2 of Circuitry and Sensory Substitution***

Level: High School

In this lesson, students will use Snap Circuits to explore what types of sensors and logic gates are commonly used in electronic circuits and how they function.

<http://centerforneurotech.org/education-k-12-lesson-plans/circuitry-and-sensory-substitution>

## TEACHER BACKGROUND & RESOURCES

### Background Information:

- Teachers will need to understand the engineering design process and how to create a scientific/research poster. See Resources below.
- When engaging students in engineering design, these STEM Teaching Tool may be helpful in preparing you for facilitating design tasks:

**Practice Brief #36: Failing Forward—Managing Student Frustration During Engineering Design Projects**

<http://stemteachingtools.org/brief/36>

**Practice Brief #45: How to Focus Students' Engineering Design Projects on Science Learning**

<http://stemteachingtools.org/brief/45>

### Resources:

**Make a Better Research Poster (video)**

American Journal Experts, 2016, 3:53 min

[https://www.youtube.com/watch?v=AwMFhyH7\\_5g](https://www.youtube.com/watch?v=AwMFhyH7_5g)

**Ten Simple Rules for a Good Poster**

Erren & Bourne, 2007. *PLOS Comput Biol*

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1876493/>

### Citations:

Student Handouts 5.1-5.4: Used and modified with permission from *NeuroEngineering Student Lab Notebook*. Phelana Pang. (2016). *Modeling & Designing a Sensory Substitution Device*. Center for Neurotechnology. <http://centerforneurotech.org/education-k-12-lesson-plans/sensory-substitution-devices>

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### Student Handout 5.1: Engineering Design Journal

Name: \_\_\_\_\_ Date: \_\_\_\_\_ Period: \_\_\_\_\_

Used and modified with permission from NeuroEngineering Student Lab Notebook by Phelana Pang (2016).  
*Modeling & Designing a Sensory Substitution Device*. Center for Neurotechnology.

#### Part 1: Introduction

You have been tasked by the University of Washington to create and develop a device or new technology that will help a specific population of people. You will be working on your device or technology in a research team of 1-4 people. **Each team member will be responsible for contributing to this project and you will be given the opportunity to honestly grade each other on how you worked as a team at the end of the project.**

The basic requirements for this challenge are:

- Your device must use an electrical circuit that you will create using a Snap Circuit kit.
- Your device must involve the nervous system either directly or indirectly (think back to when we discussed how the nervous system is like a circuit).
- You must be able to present a prototype or representation of your device to your peers on a scientific poster during the poster session. **Each team member will be a part of the poster process. Not participating will earn you a zero. See the rubric for what you need on this project.**



During the course of the project, you and your group will also be maintaining an engineering design journal that shows the progress of your project from beginning to end. **Each team member will maintain their own journal and will turn it in at the end of the project.**

**You will be required to have certain phases of your project checked off by your teacher before you move on. They will be marked in the engineering design journal. If you do not have approval to move on, you will not receive credit for those parts.**

List the names of your group members:

**Part 2: Brainstorm, Define, Empathize, and Understand**

1. Think of some big ideas! “Dreams/Things I wish could exist...”
2. Flip your big ideas into possible design challenges. “How might we.....”
3. What are the end goals? What will I work to create/produce?
4. How will I know if it’s successful? What measures and indicators will inform me of the success of our design?
5. What constraints will I need to manage?



### Part 3: Design the Device & Ideate

1. Sketch out your basic ideas for how you might connect different parts of the circuit for your device. Make sure to include correct circuit diagrams and the inputs and outputs of the device.



***STOP! Get teacher approval!***

Teacher signature: \_\_\_\_\_



**Part 5: Reflection**

1. What are you most proud of in designing your device?
2. What was one of the biggest challenges you encountered? Why was it challenging? How did you feel initially?
3. How did you overcome your challenges? What resources did you seek to help you through your challenges?
4. How did you and your teammates work together? What interactions were you proud of? What interactions would you like to improve?
5. What tips would you give to a student who will be learning the same things you did to design your device?
6. If you were to grade yourself using the rubric, what grade would you give yourself and why?

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**Student Handout 5.2: Engineering Design Rubric**

Name: \_\_\_\_\_ Date: \_\_\_\_\_ Period: \_\_\_\_\_

<i>Requirement</i>	<i>Description</i>	<i>Full Points</i>	<i>Partial Points</i>	<i>No Points</i>	<i>Points Available</i>
<b>Engineering Design Challenge Journal</b>	A journal that students are required to complete during the course of the project.	To earn full points the student must have fully utilized the journal, used proper grammar and sentence formats, and only typed (no handwriting).	To earn partial points the student will have done some/only part of the full points requirements.	The student did not meet any of the requirements of the engineering design journal and/or the student did not get their journal checked off.	<b>/25</b>
<b>Research Team Peer Grades</b>	An average of the score given to the student by their research team.	Student received all positive scores/ reviews from their team. There were no issues with the student's participation and contribution.	Student received a mix of scores and reviews from their team. There may have been some issues.	Student received all negative scores/ reviews. There were issues.	<b>/5</b>
<b>Finished Product Prototype</b>	A representation of the finished device or new technology. Does not have to be a full working device.	Student was able to create a representation of their finished device or technology. It accurately represents how the device would look/work/function.	Student was able to create a representation of their finished device, but it did not accurately represent the function.	Student was not able to create a representation of their device.	<b>/5</b>
<b>Final Presentation</b>	A poster outlining the finished product and the design challenge process to be used during a gallery walk. It will include the representation of the finished product.	Student created a poster that presents their finished device and an overview of the design challenge.	Student created a poster that did not do both.	Student did not create a poster.	<b>/15</b>
<b>Total Points</b>					<b>/50</b>

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### Student Handout 5.3: Research Poster Requirements

Name: \_\_\_\_\_ Date: \_\_\_\_\_ Period: \_\_\_\_\_

You will be creating a research poster to summarize and display your engineering design project. The poster must have all of the following information to earn full credit.

1. **Title**
  - a. Be creative!
2. **Names**
  - a. Your group names
3. **Background/Introduction**
  - a. Why did you do/design what you did?
4. **Methods/Procedures**
  - a. What you did exactly.
5. **Conclusion**
  - a. What went right, what went wrong, what you would do differently, etc.?
6. **Pictures**
  - a. Can be drawn and/or printed.
7. **Acknowledgements**
  - a. Who do you want to thank?
8. **References**
  - a. Who/what do you need to give credit to?

Example (this is only an example; feel free to be creative with your layout and design!)

