Designing Circuits for Neurodevices

A Curriculum Unit for High School Physics courses

September 2019

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Research Experience for Teachers (RET) Program

CENTER *for*
NEUROTECHNOLOGY
a National Science Foundation Engineering Research Center

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end the lesson by filling out a chart that goes over the different combinations of behavior seen in a science and classroom settings.

Student Handout 4.1: Productive Uncertainty

Lesson Five: Device Design Challenge

In this lesson, students will design and build a working model of a device that uses circuits and is based on neural input that would help someone improve their everyday life.

Student Handout 5.1: Engineering Design Journal

Student Handout 5.2: Project Rubric

Student Handout 5.3: Research Project Requirements

Lesson Six: Design Challenge Presentations

In this lesson, students will present their posters and prototypes to the class.

Student Handout 6.1: Peer Review

About the RET Program & the CNT

About the Research Experience for Teachers (RET) Program
The Research Experience for Teachers (RET) program is a seven week research experience for middle and high school STEM teachers, hosted by the Center for Neurotechnology (CNT) on the University of Washington's Seattle campus. Each summer cohort is selected through a competitive application process. Accepted teachers apprentice in a CNT lab alongside a team of researchers conducting cutting-edge neural engineering research. They enhance their understanding of lab safety, bioethics, engineering education, and curriculum design. Together, the teachers work to develop innovative neural engineering curriculum materials, which are then pilot-tested in their own classrooms the following academic year. More information about the RET program is available here.

About the Center for Neurotechnology (CNT)
The Center for Neurotechnology (CNT) is revolutionizing the treatment of spinal cord injury, stroke, and other debilitating neurological conditions by discovering principles of engineered neuroplasticity and developing neural devices that will assist, improve, and restore sensory and motor functions. Engineered neuroplasticity is a new form of rehabilitation that uses engineered devices to restore lost or injured connections in the brain, spinal cord, and other areas of the nervous system. Learn more about the center here.

Neural Engineering Skill Sets
The CNT has identified the following skill sets as essential for students to achieve neural engineering competency. All education activities supported by the CNT are designed to teach one or more of these skills.

1. **Fundamentals of neuroscience, neural engineering, and neuroethics research:** Knowledge of core concepts in neuroscience and neural engineering, designing and conducting experiments, analysis and interpretation of results, problem solving, understanding primary scientific literature, building scientific knowledge, and ethical and responsible conduct of research.
2. **Neural engineering best practices:** Oral and written communication of neural engineering knowledge and research, confidence, working independently, working on a team, participating in a learning community, innovation, and persistence.
3. **Connections to neural engineering industry and careers:** Awareness of career options in neural engineering and pathways

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Contact Information & Credits

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Target Grade Level: Grade 10-12

Time Required: 9+ 55 minute classes

Unit Description

In this two week unit, students will investigate the phenomena of a how neurodevices work, bringing together electrical circuitry with the human nervous system. In this case, the human nervous system offers an input (such as a biosignal) that is used to control a machine or computer. Neurodevices, such as brain-computer interfaces, are technologies arising from the field of neural engineering. Neural engineering is an interdisciplinary branch of science and engineering which ties together aspects of biomedical, electrical, and mechanical engineering with computer science, neuroscience, and mathematics. In addition, neuroethicists consider the ethical implications of this work on patients and their families.

In Lesson 1, students will view a demo of a robotic gripper hand that can be controlled by their own muscles (using EMG biosignals) and they will have time to discuss this phenomena with each other. Students will then learn about the basics of the nervous system by watching videos and will teach each other what they have learned. In Lesson 2, students will compare and contrast the nervous system to what they know already about circuitry and electricity. They will also experiment with their own nervous system and learn about and discuss the concept of plasticity. In Lesson 3, students will evaluate their prior beliefs on neuroethics, watch a documentary, then go back and reevaluate their beliefs and how they have or have not changed after viewing. In Lesson 4, students will read an article on productive stupidity (uncertainty) and engage in a class discussion on what it means to be productively uncertain in a science classroom. They will end the lesson by filling out a chart that goes over the different combinations of behavior seen in a science and classroom settings. In Lesson 5, students will design and build a working model of a device that uses circuits and is based on neural input that would help someone improve their everyday life. In Lesson 6, students will present their posters and prototypes to the class.

- Lesson 1: The Nervous System (1 55 min period)
- Lesson 2: Circuits vs. the Nervous System (1 55 min period)
- Lesson 3: Neuroethics (2 55 min periods)
- Lesson 4: Productive Uncertainty in Science and Engineering (1-2 55 min periods)
- Lesson 5: Device Design Challenge (4-6 55 min periods)
- Lesson 6: Design Challenge Presentations (1 55 min period)

Classroom Testing

This curriculum was enacted with students during the 2017-2018 and 2018-2019 academic years at Bethel High School in Spanaway, WA. Implementation occurred with two sections of 10th grade Physics students each year, for 113 students in total. Feedback from students and their teacher was used to inform revisions to these materials.

Alignment to National Learning Standards

This unit is aligned to the Next Generation Science Standards (NGSS).

This unit builds toward the following bundle of high school Performance Expectations (PEs). Alignment to the three dimensions of science and engineering education (Disciplinary Core Ideas, Crosscutting Concepts, and Practices) are outlined in the table below. Hyperlinks direct to relevant sections of the Next Generation Science Standards and *A Framework for K-12 Science Education*.

High School Performance Expectations		
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. (Grades 9-12). **HS-PS3-3:** 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). **HS-PS3-5:** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. (Grades 9-12). **HS-ETS1-1:** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. **HS-ETS1-2:** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.		
Science and Engineering Practices (SEPs)	**Disciplinary Core Idea(s)**	**Crosscutting Concepts (CCCs)**
Constructing Explanations and Designing Solutions Developing and Using Models *Asking Questions and Defining Problems	LS1.A: Structure and Function PS3.A: Definitions of Energy PS3.C: Relationship between Energy and Forces	Systems and System Models Cause and Effect Energy and Matter

*Obtaining, Evaluating, and Communicating Information	PS3.D: Energy in Chemical Processes ETS1.A: Defining and Delimiting an Engineering Problem ETS1.C: Optimizing the Design Solution Understandings about the Nature of Science: • Scientific Knowledge is Open to Revision in Light of New Evidence	Understandings about the Nature of Science: • Science Addresses Questions about the Natural World • Science is a Way of Knowing Connections to Engineering, Technology, and Applications of Science • Influence of Science, Engineering and Technology on Society and the Natural World •

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS.

Unit Overview

Day Time Lesson	Materials and Teacher Preparation	Outline of Activities and Timing	Assessment (Formative or Summative)
Day 1 55 min Lesson 1	Materials: • Backyard Brains Claw Bundle and accessories (or video of demo) • Computers for watching videos • Student Handouts Prep: • Copy handouts • Student access to youtube.com • Table groups (4 per) or some sort of discussion grouping already assigned/determined	**The Nervous System** • Demo of robotic gripper hand (5-10 min) • Group discussion within table groups (5-10 min) • Watch Nervous System Videos (10 min) • Jigsaw Activity (10-15 min) • Checking answers and exit ticket (5-10 min)	• Check in with groups during discussion • Whole class summary • Student Handout • Exit ticket
Day 2 55 min Lesson 2	Materials: • Rulers or meter sticks • Calculators • Student Handouts Prep: • Copy handouts • Prepare rulers	**Circuits vs. the Nervous System** • How fast can you react? Intro (5 min) • Mini lab: Ruler drop test of reaction time (20 min) • Class discussion 5-10 min) • Optional memory games • Comparing and contrasting (10-15 min)	• Venn diagrams on handouts • Whole class discussion • Exit ticket
Day 3 55 min Lesson 3	Materials: • Fixed documentary DVD/streaming/etc. • Student handout Prep: • Copy handouts	**Neuroethics** • Pre-assessment survey (5-10 min) • View FIXED documentary (60 min)	• Discussion • Surveys
Day 4 30 min Lesson 3	Materials: • Fixed documentary DVD/streaming/etc. • Student handout	**Neuroethics (continued)** • Finish FIXED documentary (as needed) • Post-Assessment survey and discussion (10-20 min)	• Discussion • Surveys • Exit ticket

Day 4 25 min Lesson 4	Materials: • NWABR lesson plan materials • Student handout Prep: • Student handout	**Productive Uncertainty in Science and Engineering** • Begin Lesson 4 with NWABR lesson on “stupidity” in science (25 min)	• Discussion
Day 5 55 min Lesson 4	Materials: • NWABR lesson plan materials • Student handout	**Productive Uncertainty (continued)** • Finish Lesson 4 with NWABR lesson on “stupidity” in science (min)	• Discussion • Handout
Days 6-10 or so 55 min Lesson 5	Materials: • Snap Circuit Pro kits • Craft supplies and tools • Poster paper • Student handouts Prep: • Gather materials • Copy handouts	**Device Design Challenge** • Introduction to the project (10-15 min) • Brainstorming (30+ min) • Designing and working on devices (2-3 class periods) • Research posters (1-2 class periods) • Reflection (15-30 min)	• Discussion • Handouts • Exit ticket • Engineering design journal • Finished device prototype • Research poster
Day 11 55 min Lesson	Materials: • Sticky notes • Student handout Prep: • Copy handouts	**Design Challenge Presentations** • Entry task (5 min) • Gallery walk (20-30 min) • Reflection and peer review (10-20 min)	• Self-assessment • Peer-assessment • Engineering design rubric • Research presentations

Unit: Designing Circuits for Neurodevices

Lesson 1: The Nervous System

Author: Sadie Frady

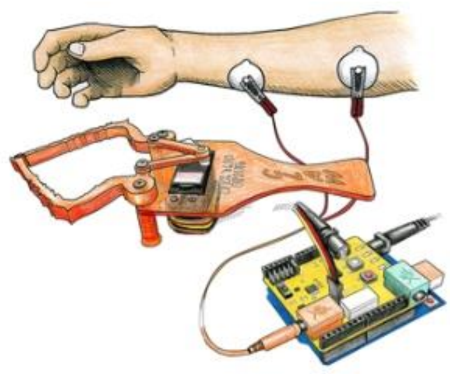


Image credit: BackyardBrains.com

LESSON OVERVIEW

Activity Time:
One 55 minute class period.

Lesson Plan Summary:
In this lesson, students will view a demo of a robotic gripper hand that can be controlled by their own muscles and they will have time to discuss this phenomena with each other. Students will then learn about the basics of the nervous system by watching videos and will teach each other what they have learned.

STUDENT UNDERSTANDINGS

Big Idea & Enduring Understanding:

- **The Nervous System:** The basics on how the nervous system works
- **The Brain**: The brain can be thought of similarly to an electric circuit, where sensory neurons receive input, the brain processes this, and motor neurons instigate a response.

Investigative Phenomenon: A robotic gripper arm translates EMG biosignals from the human body to control a simple machine.

Driving Question:

- How does the robotic gripper work with the nervous system?

Learning Objectives:

Students will know…

- Basic features of the nervous system and how they work.

Students will be able to…

- Explain to another student the basics of the nervous system.

Vocabulary:

- **Demo:** A demonstration of something, such as a technology, for others to see.
- **Nervous System:** Consists of the central nervous system (brain and spinal cord) and peripheral nervous system (all nerves throughout the body not part of the brain or spinal cord).
- **Population:** A specific group of people, distinguishable based on specific characteristics (e.g., gender, age, income level, ability).
- **Technology:** Equipment, machinery, devices, or computer programs that are developed through a knowledge of science and/or engineering.

Next Generation Science Standards:

This lesson builds toward the following Performance Expectation (PE) and its integrated three dimensions of learning. Additional dimensions are denoted with an asterisk (*).

High School Performance Expectations		
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. (Grades 9-12).		
Science and Engineering Practices (SEPs)	**Disciplinary Core Idea(s)**	**Crosscutting Concepts (CCCs)**
Developing and Using Models *Asking Questions and Defining Problems	LS1.A: Structure and Function	Systems and System Models

TEACHER PREPARATION

Materials

Material	Description	Quantity
Computers	Students will need internet-enabled computers, laptops, or tablets to watch a video.	1/student
Backyard Brains Claw Bundle	EMG robotic gripper/claw that works through a brain computer interface when hooked up to an arm (comes with 50 EMG electrode patches and 2 9v batteries). Source: https://backyardbrains.com/products/clawBundle	1 per class
Backyard Brains EMG Large Muscle Electrode Patches	Extra EMG electrode patches to use with the claw bundle. Source: https://backyardbrains.com/experiments/MuscleSpikerShield_GripperHand	As needed
9v Battery	Extra battery for use with claw bundle	As needed
Student Handouts	*Student Handout 1.1: Gripper Demo Questions*	1 per class/ group/ student
Student Handouts	*Student Handout 1.2: The Nervous System Jigsaw*	1 per student
Teacher Resource	*Teacher Resource 1.2: The Nervous System Jigsaw Answer Key*	1

Preparation

1. Set up the Backyard Brains claw bundle before class begins. Make sure to troubleshoot any issues. See the *Resources* section of this lesson.
2. Prepare entry task and exit tickets in a way that works for your classroom. For example you could print, post on board, or post online.
3. Have questions for Engage section ready to post on board or present to students in some way. Student Handout 1.1 can be used if you would like physical copies.
4. Make copies of Student Handout 1.2: Jigsaw Questions for Crash Course Videos, one per student.
5. Have the *Teacher Handout 1.2* ready to go after the jigsaw activity.

PROCEDURE

Engage: Robotic Gripper Hand Demo (5-10 min)

1. Post the following entry task on the board or in whatever format you use in your classroom.
    a. *What types of technologies exist that could be considered useful for people? List as many as you can think of.*

2. Show students the Backyard Brains claw/gripper. Have student volunteers come up and try it on their own arms as time allows.
    a. Students may want to try this for longer than time allows for. Consider allowing students to come up in staggered times during the Jigsaw portion of this lesson.

Explore: Group Discussion (5-10 min)

3. Have students, in table groups, discuss the following (this is also on *Student Handout 1.1*):
    a. *How did you think it worked?*
    b. *Have you seen anything like this before? Where? When?*
    c. *What is the importance of this type of technology and what population do you think would benefit from it?*
    d. *How does this relate to your life? Or someone close to you?*
    e. *What did you like most about it? What would you change about it?*
    f. *Do you have any further questions or anything else you want to know about it?*

4. Have each table representative share with the class what they have written down for each question on *Student Handout 1.1.*

Explain: Jigsaw of Nervous System Videos (10 min)

5. Number all students off by 1s, 2s, and 3s. Each number will watch and fill out a worksheet for a different Crash Course Nervous System video.

6. Each student will watch their video independently, while filling out the appropriate section of the *Student Handout 1.2: The Nervous System Jigsaw*. Close captioning is available by turning on the CC option on the bottom of the video viewer.
    a. **Group 1:** The Nervous System: Part 1 (10:35 min) (https://www.youtube.com/watch?v=qPix_X-9t7E)
    b. **Group 2:** The Central Nervous System (10:07 min) (https://www.youtube.com/watch?v=q8NtmDrb_qo)
    c. **Group 3:** Peripheral Nervous System (10:01 min) (https://www.youtube.com/watch?v=QY9NTVh-Awo)

Elaborate: Jigsaw Activity (10-15 min)

7. Have each student create a group that includes students who are numbered 1, 2, and 3. Make sure to help with this process if needed.

8. Each student will then be tasked with teaching their other group members about what they learned so that everyone can fill out their own worksheet. This will be done in order based on what video they watched.

Evaluate: Checking answers and exit ticket (5-10 min)

9. Go over answers to the *Student Handout 1.2: The Nervous System Jigsaw* with students using *Teacher Handout 1.2: The Nervous System Jigsaw Answer Key* so that students have the correct answers.
    a. Alternatively, you can collect and grade yourself and return to students.

10. Have students keep both handouts in their journal or using whatever organization you use in your classroom so that they may reference it as the unit continues.

11. Post the following exit ticket on the board or in whatever format you use in your classroom.
    a. *Write a one sentence summary of the nervous system and what you think the most important function is. Explain your reasoning.*

STUDENT ASSESSMENT

Assessment Opportunities:

- Teachers can check in with groups during the jigsaw discussion, as well as during the whole group summary.
- Students will go over the answers to the jigsaw activity to ensure that they are on the right track and have the correct information. *Student Handout 1.2* can be collected by the teacher if needed for assessment purposes. Example answers are provided on *Teacher Resource 1.2.*

Student Metacognition: Students will go over their answers and have ample opportunity to discuss the lesson with their table groups. Afterwards, they will keep both handouts in their journal or notebook to look back on and use as the unit goes on.

Scoring Guide: Students will be successful if they have filled out both of the student handouts and have all of the correct information. This information will be important for understanding the underlying concepts in the rest of the unit. *Teacher Resource 1.2* provides example answers for *Student Handout 1.2.*

EXTENSION ACTIVITIES

Extension Activities: Students could draw a diagram or create a model of the nervous system based on what they have learned through the jigsaw activity.

Adaptations: The jigsaw activity can be modified with different resources of varied levels (higher or lower) and it can be modified to be a partner activity before a group one (for example, students can be paired together to watch the video they are assigned and work together to determine the answers on the handout). All videos linked in this lesson have closed captioning and transcripts available.

TEACHER BACKGROUND & RESOURCES

Background Information: Teachers need to understand how the Backyard Brains claw bundle works, so they should visit the website and watch the videos (see Resources below). If the claw is not working well, try using fresh 9v batteries.

Teachers also need to have a good background on the nervous system and at least a general understanding of how it works. They should also watch the videos before having the students do so.

Resources:
Backyard Brains: The Claw https://backyardbrains.com/products/clawbundle

Backyard Brains Experiment: Controlling the Claw with your Muscles,
https://backyardbrains.com/experiments/MuscleSpikerShield_GripperHand

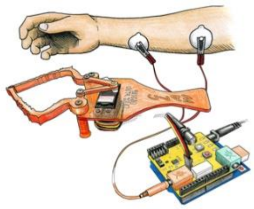
Crash Course: The Nervous System, Part 1: Crash Course A&P #8
YouTube, 2015, 10min 35sec, https://www.youtube.com/watch?v=qPix_X-9t7E

Crash Course: Central Nervous System: Crash Course A&P #11
YouTube, 2015, 10min 7sec, https://www.youtube.com/watch?v=q8NtmDrb_qo

Crash Course: Peripheral Nervous System: Crash Course A&P #12
YouTube, 2015, 10min 1sec, https://www.youtube.com/watch?v=QY9NTVh-Awo

Unit: Designing Circuits for Neurodevices
Student Handout 1.1: Gripper Demo Questions

Name:____________________________ Date:_______________ Period:___________



After viewing the demo, please answer the following questions:

1. How did you think it worked?

2. Have you seen anything like this before? Where? When?

3. What is the importance of this type of technology and what population do you think would benefit from it?

4. How does this relate to your life? Or someone close to you?

5. What did you like most about it? What would you change about it?

6. Do you have any further questions or anything else you want to know about it?

Image credit: BackyardBrains.com

Unit: Designing Circuits for Neurodevices
Student Handout 1.2: The Nervous System Jigsaw

Name:____________________________ Date:______________ Period:__________

Video 1: The Nervous System

1. What kind of signals do nerve cells use?

2. What are the three principal functions?

3. Define each of the following:
    a. Integration

    b. Motor output

    c. Central Nervous System

    d. Peripheral Nervous System

    e. Neurons

4. Describe and/or draw the main parts of a neuron.

5. List at least 2 other things you learned that you found interesting.

Video 2: The Central Nervous System

1. What are the two main parts of the nervous system?

2. What is the brain’s purpose?

3. What is the spinal cord’s purpose?

4. Define what is meant by “specialized regions”.

5. What do each of the following control and/or do:
    a. Cerebellum
    b. Brain stem
    c. Cerebrum
    d. Frontal Lobe
    e. Occipital Lobe
    f. Parietal Lobe

6. List at least 2 other things you learned that you found interesting.

Video 3: The Peripheral Nervous System

1. Why is your peripheral nervous system important?

2. What is the function of the sensory nerve receptors?

3. What input do each of the following receptors respond to?
    a. Thermoreceptors
    b. Photoreceptors
    c. Chemoreceptors
    d. Mechanoreceptors
    e. Nociceptors

4. Draw and/or describe a generic pathway in your peripheral nervous system in response to a stimuli.

5. What is the difference between an innate reflex action and a learned reflex?

6. List at least 2 other things you learned that you found interesting.

Unit: Designing Circuits for Neurodevices
Teacher Handout 1.2: The Nervous System Jigsaw ANSWER KEYS

Video 1: The Nervous System

1. What kind of signals do nerve cells use?
   Electrical and chemical

2. What are the three principal functions?
   Sensory input, integration, motor output

3. Define each of the following:
   a. Integration: The processing of an input and deciding what needs to be done by the nervous system.

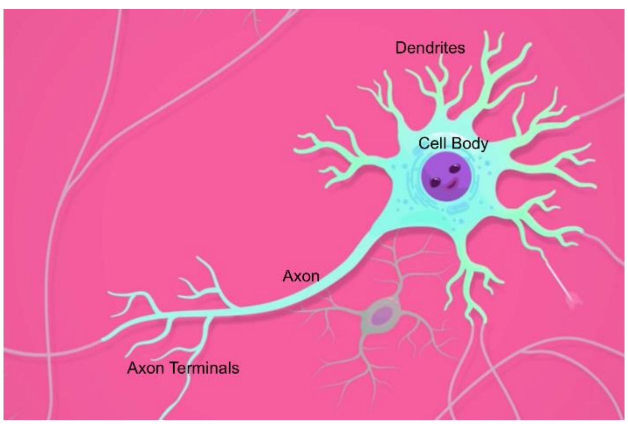
   b. Motor output: The response that occurs when your nervous system activates certain parts of your body.

   c. Central Nervous System: The brain and spinal cord.

   d. Peripheral Nervous System: All nerves that branch from the brain to the rest of the body.

   e. Neurons: Nerve cells that respond to stimuli and transmit signals.

4. Describe and/or draw the main parts of a neuron.



5. List at least 2 other things you learned that you found interesting.
   Varies by student.

Video 2: The Central Nervous System

1. What are the two main parts of the nervous system?
   Central nervous system and peripheral nervous system

2. What is the brain's purpose?
   Sorts out all sensory information and gives orders. Carries out complex functions.

3. What is the spinal cord's purpose?
   Two-way signaling between brain and body. Controls muscle reflexes and activities not controlled by the brain.

4. Define what is meant by "specialized regions".
   Parts of the brain that control different functions.

5. What do each of the following control and/or do:

   a. Cerebellum: Coordinate muscle activity

   b. Brain stem: Relays info from body to brain

   c. Cerebrum: Controls voluntary movement and higher thinking

   d. Frontal Lobe: Governs muscle control and cognitive functions

   e. Occipital Lobe: Processes visual cues

   f. Parietal Lobe: Processes touch, pain, and pressure

6. List at least 2 other things you learned that you found interesting.
   Varies by students.

Video 3: The Peripheral Nervous System

1. Why is your peripheral nervous system important?
   Keeps your brain in touch with the physical environment and allowing it to respond.

2. What is the function of the sensory nerve receptors?
   To see what is going on in the world for the central nervous system.

3. What input do each of the following receptors respond to?

   a. Thermoreceptors: Changes in temperature

   b. Photoreceptors: Light

   c. Chemoreceptors: Chemicals

   d. Mechanoreceptors: Pressure

   e. Nociceptors: Pain

4. Draw and/or describe a generic pathway in your peripheral nervous system in response to a stimuli.
   Change in environment (stimulus activates sensory receptors), receptors provide sensation, spinal cord, brain

5. What is the difference between an innate reflex action and a learned reflex?
   Innate-super fast and not voluntary, learned-from experience and with time, can be fast

6. List at least 2 other things you learned that you found interesting.
   Varies by students.

Unit: Designing Circuits for Neurodevices

Lesson 2: Circuits vs. the Nervous System

Author: Sadie Frady

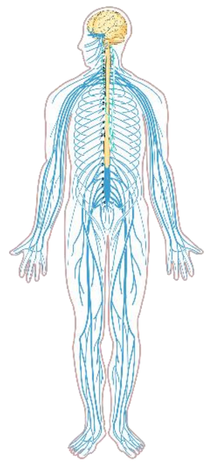


Image credit: Wikimedia Commons

LESSON OVERVIEW

Activity Time:
One 55 minute class period.

Lesson Plan Summary:
In this lesson, students will compare and contrast the nervous system to what they know already about circuitry and electricity. They will also experiment with their own nervous system and learn about and discuss the concept of plasticity.

STUDENT UNDERSTANDINGS

Big Idea & Enduring Understanding:

- **The Nervous System:** The nervous system can be directly compared to electronic circuitry and it also has an element of plasticity.
- **The Brain**: The brain can be thought of similarly to an electric circuit, where sensory neurons receive input, the brain processes this, and motor neurons instigate a response.

Investigative Phenomenon: The human brain can adapt, organize, and change its neural connections through a process called neuroplasticity.

Driving Question:

- How does the nervous system compare to electronic circuitry?

Learning Objectives:

Students will know…

- How the nervous system works on a macro scale.
- How the brain has plasticity.
- How the nervous system compares to electronic circuitry.

Students will be able to…

- Explain and demonstrate plasticity of the brain with simple experiments.
- Explain to another student the differences and similarities between an electronic circuit and the nervous system.

Vocabulary:

- **Auditory:** Sensory information obtained through your auditory system (e.g., outer/middle/inner ear, cochlear nucleus, auditory cortex in brain).
- **Nervous System:** Consists of the central nervous system (brain and spinal cord) and peripheral nervous system (all nerves throughout the body not part of the brain or spinal cord).
- **Neuroplasticity:** Also known as brain plasticity. The brain's ability to reorganize itself by forming new neural connections throughout life. This happens through learning and memorization. Neuroplasticity occurs during brain development when the brain processes sensory information from infancy through adulthood. Neuroplasticity also occurs as an adaptive mechanism; for example, in the case of the brain injury, the brain may compensate for lost functions or amplify remaining functions.
- **Stimuli/Stimulus:** Something that evokes a functional reaction, for instance visual stimulus that evoke a response in the brain. Some examples of stimuli include visual, tactile, auditory, smell, and motor.
- **Tactile:** Sensory information obtained through your sense of touch (e.g., pressure, temperature, texture).
- **Visual:** Sensory information obtained through your visual system (e.g., eyes, visual cortex in brain).

Next Generation Science Standards:

This lesson builds toward the following Performance Expectation (PE) and its integrated three dimensions of learning. Additional dimensions are denoted with an asterisk (*).

High School Performance Expectations
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. (Grades 9-12).

HS-PS3-5: Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. (Grades 9-12).		
Science and Engineering Practices (SEPs)	**Disciplinary Core Idea(s)**	**Crosscutting Concepts (CCCs)**
Developing and Using Models *Asking Questions and Defining Problems	LS1.A: Structure and Function PS3.C: Relationship between Energy and Forces	Systems and System Models Cause and Effect

TEACHER PREPARATION

Materials

Material	Description	Quantity
Rules or meter sticks	For nervous system reaction time activity. Each pair of students will need two rulers taped together (0 end to 30 end) or a meter stick.	1/pair of students
Calculators	For nervous system reaction time activity.	1/pair of students
Student Handouts	*Student Handout 2.1: How Fast Can You React?*	1/student
Student Handouts	*Student Handout 2.2: Venn Diagram*	1/student or pair
Teacher Resource	*Teacher Resource 2.2: Venn Diagram Answer Key*	1

Preparation

1. Read and learn about neural plasticity if you do not already have an understanding or background. See the *Resources* section at the end of this lesson plan.

2. Make copies of *Student Handouts 2.1* and *2.2.* Cut copies of *Student Handout 2.2* in half.

3. Gather all necessary supplies.

4. Prepare supplies. If using rulers, tape two rulers together end-to-end, with the 0 end of one ruler taped to the 30 end of the other ruler, making one very long ruler.

PROCEDURE

Engage: How Fast Can You React? Intro (5 min)

1. Post the following entry task on the board or in whatever format you use in your classroom:
    a. *Which cue would give you the fastest reaction time: visual (see), auditory (hear), or tactile (touch)? Why? Which would give you the slowest reaction time? Why?*

2. Ask students to complete the first step of *Student Handout 2.1*. They should be making predictions on how fast they think they can react to various cues. You may need to address how long an actual second is with them. Many students do not realize the actual length of a second or that they can answer with fractions of seconds.

3. Have students discuss the predictions they made with their table group.

Explore: How Fast Can You React? Mini Lab (20 min)

4. In pairs, have students complete the rest of *Student Handout 2.1*. They should be completely filling out all of the data tables and answering all of the questions.

Explain: Class Discussion (5-10 min)

5. Engage the class in a discussion about what they did and observed. Make sure to specifically go over their answers to the questions. Lead students into more of a discussion about the last question and what this means for their nervous system.

6. Tell students about plasticity and how it relates to the nervous system. Explain the different causes of neuroplasticity (see *Teacher Background*), and note that they are experiencing it right now, whenever they are engaged in learning and memorization.

7. *Optional:* To help students understand how neuroplasticity works to change, organize, or strengthen the neural connections in the brain, challenge students to a fun memory task. There are many options; here are a few:

    a. **Concentration/Memory:** Use a deck of cards that has pairs of picture cards. Place all cards face down. Take turns choosing two cards, trying to find the pairs.
    b. **Sorting Cup Game:** Get three matching plastic cups. Place a coin or other small object under one cup. Shuffle the cups by sliding and changing their position on the table. Try to keep track of which cup has the object. Slowly increase the amount of moves you make with the cup, seeing how many moves can be easily remembered.
    c. **Number Line:** How big of a number can you remember? The first person says a single-digit number. The second person says that number, followed by a new single-digit number, and so on. Continue until someone forgets a number.
    d. **What's Missing?** Place an assortment of objects on a table or tray, covered with a piece of cloth. Life the cloth and allow a brief amount of time for everyone to look at the objects and memorize them. Cover with the cloth. Discreetly remove one object and rearrange them. Uncover the objects and ask, what's missing? Start with 4 objects, then increase in each round. As you get to larger numbers of objects, you can have students write down a list to see how many objects they can remember.

8. Ask students to decide whether or not their answer to Question #3 on *Student Handout 2.1* relates to this concept and what that means about their own nervous systems.
    a. If students look across their three trials, was there an improvement in reaction time or not? Why may this be?
    b. One kinds of things might affect reaction time?
    c. In particular, you might discuss how the test subjects may develop strategies to improve their reaction time (e.g., eliminating distractions, increasing focus) or that the brain is acquiring a new motor skill (catch the ruler!) by refining a sensory-motor

pathway. In addition, the tester herself might also develop strategies to make the experiment run more smoothly and consistently (e.g., knowing where to hold the ruler when dropping it, making a consistent noise when dropping, etc.).

Elaborate: Comparing and Contrasting (10-15 min)

9. In pairs or table groups, have students fill out *Student Handout 2.2*. Remind them that they can also reflect on what they learned about the nervous system with the jigsaw activity and videos from *Lesson One*.

10. Lead the class in a discussion on what they put on the handout in each category. Make sure that they have come up with examples in at least each category.

11. Students will save this handout to draw from later on in Lesson 5.

12. Post the following exit ticket on the board or in whatever format you use in your classroom:
    a. *Write a one sentence summary of the Venn Diagram we just created.*

STUDENT ASSESSMENT

Assessment Opportunities:

- Teachers can check on student understanding and engagement during the class discussions and while visiting the students as they conduct the experiment.
- The Student Handouts and entry/exit tickets can be used for assessment.

Student Metacognition: Students will have time to work on the handouts collaboratively and discuss the lesson with their partners. Afterwards, they will keep both handouts in their journal or notebook to reference, particularly for Lesson 5.

Scoring Guide: Students will be successful if they complete the lab and complete both of the handouts.

EXTENSION ACTIVITIES

Extension Activities: More time could be spent on neuroplasticity and what it means. Students could potentially do some sort of mini research project associated with it. See the following websites for more information or the possibility of extending the learning.

> **Video: Neuroplasticity,** Khan Academy (9:40 min)
> Close captioning and video transcript available
> https://www.khanacademy.org/science/health-and-medicine/nervous-system-and-sensory-infor/neural-cells-and-neurotransmitters/v/neuroplasticity

Web Article: Brain Plasticity: What is it?, Neuroscience for Kids
Grade 12 reading level
https://faculty.washington.edu/chudler/plast.html

Adaptations: This lesson can be adapted based on the student pairings for the activity. Younger students could still do the lab activity, with more help/scaffolding during it.

All videos linked in this lesson have closed captioning and transcripts available.

TEACHER BACKGROUND & RESOURCES

Background Information: For this lesson and the one proceeding it, teachers need to have a working understanding of the nervous system. It is also important to understand the scientific concept of neuroplasticity. The resources listed elsewhere in this lesson are helpful for that purpose. In addition, this resource helps explain brain plasticity and neural pruning in more depth.

What is Brain Plasticity and Why is it so Important?
The Conversation 4/4/16
http://theconversation.com/what-is-brain-plasticity-and-why-is-it-so-important-55967

It is also important to understand the difference between the scientific concept of neuroplasticity and the educational psychology concept of growth mindset. **Neuroplasticity** is the brain's ability to reorganize itself by forming new neural connections. Neuroplasticity occurs during brain development when the brain processes sensory information from infancy through adulthood. Neuroplasticity happens throughout the lifetime through learning and memorization processes. Neuroplasticity also occurs as an adaptive mechanism; for example, in the case of the brain injury, the brain may compensate for lost functions or amplify remaining functions. **Growth mindset** is a belief that intelligence is not fixed, but that can be developed. It is inspired by the scientific concept of neuroplasticity, but growth mindset itself is a *behavior* or *strategy* that impacts how people think about themselves, their brain, and their ability to learn.

Resources:
What is Brain Plasticity and Why is it so Important?
The Conversation 4/4/16
Reading level: College level
http://theconversation.com/what-is-brain-plasticity-and-why-is-it-so-important-55967

Video: Neuroplasticity, Khan Academy (9:40 min)
Close captioning and video transcript available

https://www.khanacademy.org/science/health-and-medicine/nervous-system-and-sensory-infor/neural-cells-and-neurotransmitters/v/neuroplasticity

Web Article: Brain Plasticity: What is it?, Neuroscience for Kids
Reading level: Grade 12
https://faculty.washington.edu/chudler/plast.html

Unit: Designing Circuits for Neurodevices

Student Handout 2.1: How Fast Can You React?

Name:___________________________ Date:______________ Period:__________

INTRO: Make predictions for how fast (in seconds) it will take you to react and grab a ruler based solely on the three cues provided on the data table: Visual (see), Auditory (hear), and Tactile (touch). Each cue will be the only one (for example, if it is auditory, you cannot see the ruler dropping). Make sure to record this in the Predicted Reaction Time column of *Table 2: Data Summary* on the next page.

PROCEDURES:

1. Assign one person to be the catcher and the other to be the dropper.

2. The catcher stands with their dominant hand in front of them in a half open grip, like they are ready to catch a ruler with their pincher grip (thumb and forefinger).

3. The dropper holds the taped rulers or meter stick, 0 side down, just above the catcher's hand so that if the ruler were to drop, it would go between their fingers.

4. **For the visual cue**, the dropper simply drops the ruler and the catcher attempts to catch it as quickly as possible. It is important that the dropper does this silently. Once the ruler is caught, the catcher must not move their hand until the distance dropped is recorded (in cm).

5. Repeat Step #4 two more times.

6. **For the auditory cue**, the setup is the same as Step #4, except that the catcher now closes their eyes. The dropper tells the catcher when they are dropping it instead of being able to see it being dropped, by making a noise ("Go!" or "Drop!"). Again, record the distance dropped (in cm).

7. Repeat Step #6 two more times.

8. **For the tactile cue**, the setup is the same as Step #6, except that instead of telling the grabber when they are dropping the ruler, the dropper gently taps the catcher's foot with their own foot, as they are simultaneously dropping the ruler. Again, record distance dropped (in cm).

9. Repeat Step #8 two more times.

10. Using the distance dropped data, calculate the actual reaction time for each trial using the following equation where *t* is time, *d* is distance, and *g* is gravity (10 m/s^2): $t = d/g$

11. Average each cue's reaction times by adding them up and dividing by three. Record the average reaction time for each cue.

DATA:

Table 1: Data Collection

Cue	Trial 1: Distance Dropped (cm)	Trial 2: Distance Dropped (cm)	Trial 3: Distance Dropped (cm)
Visual			
Auditory			
Touch			

Table 2: Data Summary

Cue	Predicted Reaction Time (s)	Trial 1: Actual Reaction Time (s)	Trial 2: Actual Reaction Time (s)	Trial 3: Actual Reaction Time (s)	Average Reaction Time (s)
Visual					
Auditory					
Tactile					

QUESTIONS:

1. Were your predictions accurate or not? Why or why not?

2. What was most surprising about this lab? Why?

3. Do you think that you could improve any of your reaction times? Why or why not? How?

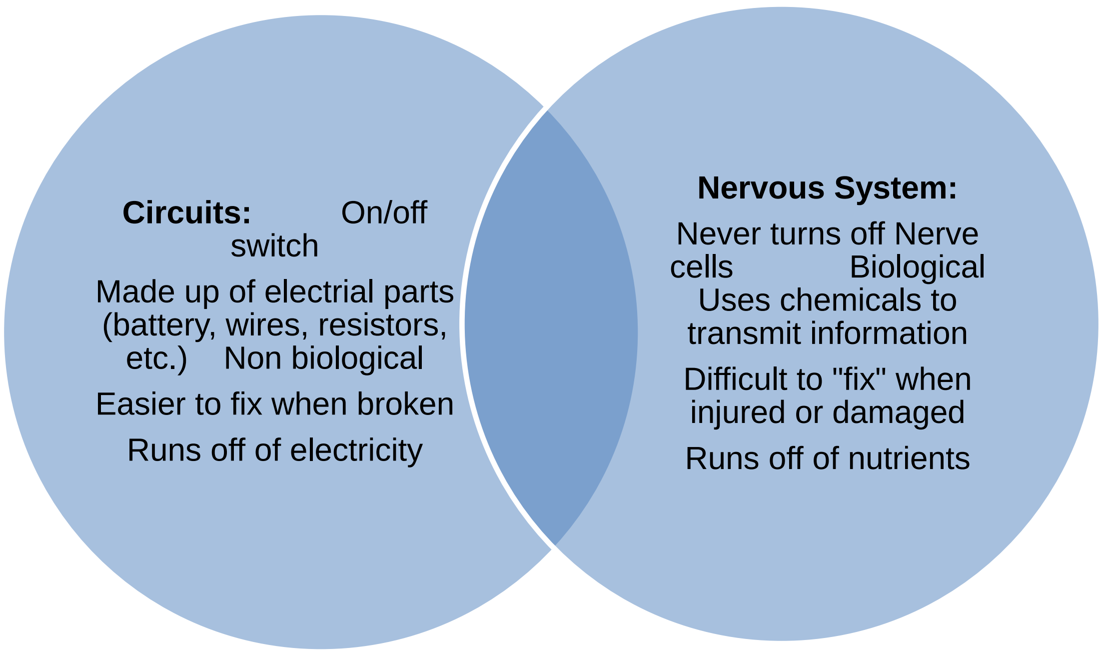
4. What is the best/fastest cue for reaction time? Why?

5. Do you think that where you are touched would affect your reaction time? Why?

6. How does this activity affect your view on how different populations react to different stimuli?

Unit: Designing Circuits for Neurodevices
Teacher Resource 2.2: Venn Diagram Answer Key

Some possible student answers are listed below. Note this is not an exhaustive list.

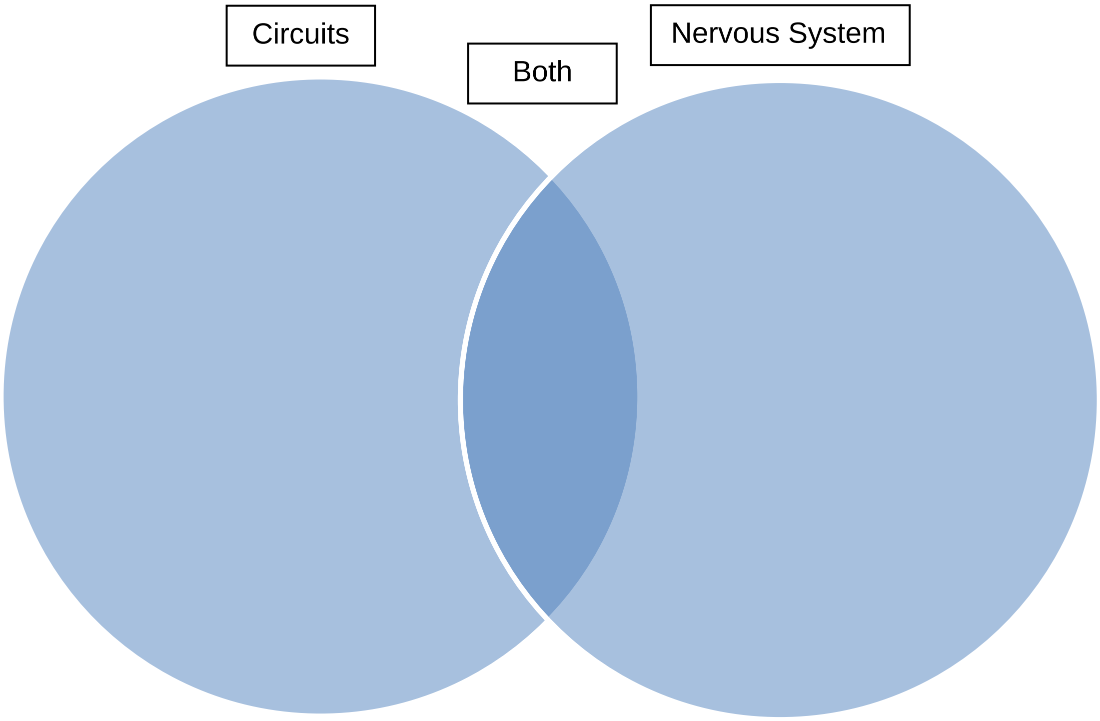


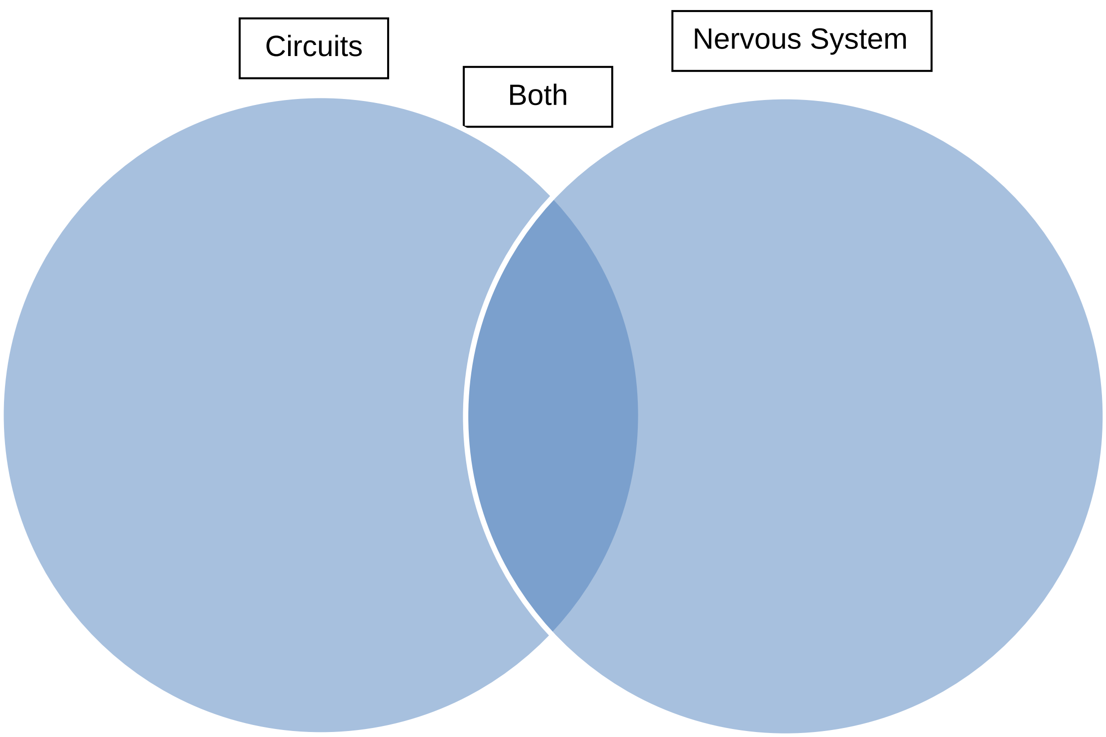
Both:
Electrical/generates electricity
Transmits signals
Receives signals
Communication
Must be connected
Inputs and outputs

Unit: Designing Circuits for Neurodevices

Student Handout 2.2: Venn Diagram

Name:______________________________ Date:________________ Period:_________





Unit: Designing Circuits for Neurodevices

Lesson 3: Neuroethics

Author: Sadie Frady

Image credit: Wikimedia Commons.

LESSON OVERVIEW

Activity Time:
Two 55 minute class periods.

Lesson Plan Summary:
In this lesson, students will evaluate their prior beliefs on neuroethics. They will then watch a documentary, then go back and reevaluate their beliefs and how they have or have not changed after viewing.

STUDENT UNDERSTANDINGS

Big Idea & Enduring Understanding:

- **Neuroethics:** Neuroethics is the study of the ethical implications of neurotechnologies. It combines an understanding of neuroscience, philosophy, and the legal system. Neuroethical issues can arise during the design of a device, drug, or therapy, all the way to the impacts it has once used with patients. Neuroethics deals with complex philosophical issues, such as identity, security, privacy, autonomy, fairness, and justice. These type of ethical considerations and decisions are not black and white. There are many different factors that come into play and every person has their own personal beliefs and bias that affect this.

Investigative Phenomenon: There are ethical implications to the design, testing, and use of neurotechnologies, such as drugs, devices, and therapies.

Driving Question:

- How do your own personal beliefs and bias affect your view on neuroethics?

Learning Objectives:

Students will know…

- That one's stance on neuroethical issues is affected by personal beliefs and bias.

Students will be able to…

- Provide a definition of neuroethics and describe an example of a neuroethical issue.
- Share their own personal beliefs and bias as they relate to neuroethical issues and decide whether they have changed after viewing a documentary.

Vocabulary:

- **Atypical:** Not representative of a type or group; unusual or uncommon.
- **Cognitive:** The brain's role in thinking or learning.
- **Deficit:** A deficiency or impairment.
- **Disability:** Human variation is normal, therefore there are differences in the ways that people move, sense, and think. Disabilities are the restrictions created by society that impact people with impairments, such as infrastructure (i.e., lack of wheelchair ramps; movies without closed captioning), beliefs, or biases.
- **Enhancement:** Something that causes an increase in quality or function. Human enhancement is making purposeful changes to the human body in order to increase its physical or mental capabilities, such as supplements, drugs, implants, or other technologies.
- **Impairment:** A state of something being impaired, damaged, or functioning in an atypical way. This includes physical or mental conditions that causes a limitation or difference in the way a person moves, senses, or thinks. Impairments can be can be physical, sensory, intellectual, or psychological. They can be temporary, long-term, or permanent.
- **Inherent:** Something that is an essential or permanent part of something else.
- **Neuroethics:** The study of philosophical issues related to neurotechnologies. It combines an understanding of neuroscience, philosophy, and the legal system. Neuroethical issues can arise during the design of a neurologically-focused device, drug, or therapy, all the way to the impacts it has once used with patients. Neuroethics deals with complex philosophical issues, such as identity, security, privacy, autonomy, fairness, and justice.
- **Sector:** A portion that is different or distinct from other portions.

- **Society:** The people who live together in a community. Also known as the public.
- **Therapeutic:** Something that helps to heal, repair, or restore a disease or injury.

Note: *Definitions were inspired by a variety of website resources, including Wikipedia and online dictionaries.*

Next Generation Science Standards:

This lesson does not builds toward a specific NGSS Performance Expectation (PE). Rather, it focuses on an element of the Nature of Science standards.

Science Addresses Questions about the Natural and Material World:

- Not all questions can be answered by science.
- Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.
- Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.
- Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.

TEACHER PREPARATION

Materials

Material	Description	Quantity
"FIXED: The Science/Fiction of Human Enhancement"	1 hour documentary on neuroethics. Available for educational streaming on Kanopy or New Day Films. http://www.fixedthemovie.com/ https://www.newday.com/film/fixed	1
Classroom computer	Classroom computer with projector, internet access, and speakers for showing documentary	1
Student Handouts	*Student Handout 3.1: FIXED Pre and Post Survey*	1/student

Preparation

1. Make copies of *Student Handout 3.1*, one per student.

2. Obtain a copy of the Fixed Documentary DVD or prepare for streaming. Pre-view the film.

PROCEDURE

Engage: FIXED Pre Assessment Survey (5-10 min)

1. Post the following entry task on the board or in whatever format you use in your classroom.

a. What does the term ETHICS mean to you?

2. Hand out a copy of *Student Handout 3.1* to each student.

3. Each student will complete Part 1 of the survey honestly and will then set it aside.

Explore: FIXED Documentary (60 min)

4. Students will watch the documentary, *"FIXED: The Science/Fiction of Human Enhancement."* The running time is 56 minutes plus credits. This viewing may need to be split between two class periods.

Evaluate: FIXED Post Assessment Survey (10-20 min)

5. After watching the film, have each student return to *Student Handout 3.1* and in a different color of ink, retake the survey.

6. Have each student write a brief reflection using Part 2 of *Student Handout 3.1* on what changed or did not change for them upon seeing the documentary.
7. Provide students with the opportunity to discuss their changes they have just written about within their table groups. The following can be used as prompts to help with discussion:
    a. What shifted or changed for you from before and after viewing the film? Why?
    b. Was there anything that didn't change for you? Why?
    c. What was your reasoning for the ratings you gave before and/or after viewing the film? Why do you think that is?
    d. Were there any similarities and/or differences between you and your group members?
    e. What most surprised you about the film?
    f. What questions do you have?

8. After students have had a chance to discuss within their groups, provide the opportunity for students to share their thoughts, comments, questions, etc. as a class.

9. Post the following exit ticket on the board or in whatever format you use in your classroom.
    a. *Write a one sentence summary of the class discussion on the FIXED documentary.*

STUDENT ASSESSMENT

Assessment Opportunities:

- Teachers can check on student understanding and engagement during the class discussions.
- *Student Handout 3.1* will include a completed pre and post survey and reflective writing

Student Metacognition: Students will be able to see if and how their opinion changed prior to and after viewing the documentary and will be given time to reflect on why this is. This provides students with an opportunity to identify and consider some of their biases about disability.

EXTENSION ACTIVITIES

Extension Activities:
Student could write a paper further detailing their viewpoints and how they have changed or not after viewing the documentary. Students could also have a class debate on the topics covered in the video, requiring them to do identify topics and conduct research.

To further deepen your investigation into the topic of neuroethics, there are many lesson plans available from the Northwest Association for Biomedical Research's Teacher Center. In particular, the *Ethics Primer* and *Bioethics 101* curriculum units are relevant to the topic of neuroethics.

Northwest Association for Biomedical Research Teacher Center
https://www.nwabr.org/teacher-center

In addition, the Center for Neurotechnology (CNT) provides instructional resources and lesson plans related to neuroethics. All of the lesson plans featured on this webpage (http://csne-erc.org/content/lesson-plans) have neuroethics lessons embedded in them, however the one listed below most specifically focuses on ethics.

CNT Neuroethics & Philosophy Teaching Resources
http://csne-erc.org/education-resources-teachers/neuroethics-philosophy

CNT Curriculum Unit: Neural Engineering & Ethical Implications
http://csne-erc.org/education-k-12-lesson-plans/neural-engineering-and-ethical-implications

Adaptations:
This film is not rated. However, the documentary may not work well with younger audiences, so that decision will have to be made by the teacher.

The DVD version of the film includes closed captions, video descriptions, and French, Spanish, English, and Portuguese subtitles.

If it is not possible to show the entire film, a 7 minute extended trailer is available here:
http://www.fixedthemovie.com/about/trailer/

If the reading level on *Student Handout 3.1* is too high, use the vocabulary definitions provided at the beginning of this lesson plan to develop a scaffolded version of the document.

TEACHER BACKGROUND & RESOURCES

Background Information: Teachers should view this documentary prior to showing it. A full synopsis of the documentary can be found here:
http://www.fixedthemovie.com/about/synopsis/

The 2014 documentary is described by New Day Films as follows:

> Through a dynamic mix of verité, dance, archival and interview footage, FIXED challenges notions of normal, the body and what it means fundamentally to be human in the 21st century.

Key concepts include: ableism; access; adaptive technology; bioethics; biomechatronics; bionics; brain-machine interfaces; differing frameworks of understanding disability; disability arts and culture; emerging human enhancement technologies; exoskeletons; eugenics; genetics; health; humans 2.0; innovation; neuro-enhancement; performance enhancing drugs / smart drugs; prenatal screening; science; technology; transhumanism and more.

For a review of the film which provides helpful framing for each of the film's four acts, see this review:

De Saille, S. (2014). Fixed: The science/fiction of human enhancement. *Journal of Responsible Innovation, 1*(1), 142-145.
https://www.tandfonline.com/doi/full/10.1080/23299460.2014.882096

When teaching about neuroethics and neurotechnologies, it can be helpful to have some framing about socioscientific issues in general. These STEM Teaching Tools may be helpful:

Practice Brief #44: Addressing Controversial Science Topics in the K-12 Classroom
http://stemteachingtools.org/brief/44

Practice Brief #2: Why Should Students Investigate Contemporary Science Topics—And Not Just "Settled" Science?
http://stemteachingtools.org/brief/2

Resources:

Northwest Association for Biomedical Research Teacher Center
https://www.nwabr.org/teacher-center

CNT Neuroethics & Philosophy Teaching Resources
http://csne-erc.org/education-resources-teachers/neuroethics-philosophy

CNT Curriculum Unit: Neural Engineering & Ethical Implications
http://csne-erc.org/education-k-12-lesson-plans/neural-engineering-and-ethical-implications

Practice Brief #44: Addressing Controversial Science Topics in the K-12 Classroom
http://stemteachingtools.org/brief/44

Practice Brief #2: Why Should Students Investigate Contemporary Science Topics—And Not Just "Settled" Science?
http://stemteachingtools.org/brief/2

De Saille, S. (2014). (Review) Fixed: The science/fiction of human enhancement. *Journal of Responsible Innovation, 1*(1), 142-145. https://www.tandfonline.com/doi/full/10.1080/23299460.2014.882096

Citations: *Student Handout 3.1: Fixed Pre and Post Survey* is used with permission from the curriculum unit, *Neuroethics: Complicating Views*, authored by Hannah Earhart (2016), Center for Neurotechnology.

Unit: Designing Circuits for Neurodevices

Student Handout 3.1: FIXED Pre and Post Survey

FIXED - The Science/Fiction of Human Enhancement

Used with permission from *Neuroethics: Complicating Views* curriculum by Hannah Earhart (2016), Center for Neurotechnology.

Name:___________________________ Date:______________ Period:__________

Part 1: Survey

Circle the number that most closely reflects how you feel about each statement.

1. Society ought to determine what makes life worth living.

Disagree Agree
1 2 3 4 5 N/A

2. The individual ought to determine what makes life worth living.

Disagree Agree
1 2 3 4 5 N/A

3. All members of society should function at a similar, normal level.

Disagree Agree
1 2 3 4 5 N/A

4. Persons with atypical body structure and cognitive abilities have a deficit.

Disagree Agree
1 2 3 4 5 N/A

5. Functional impairments ought to be addressed by technology.

Disagree Agree
1 2 3 4 5 N/A

6. Society inherently excludes those with disabilities.

Disagree Agree
1 2 3 4 5 N/A

7. Being human means being a typical, functioning member of the human species.

Disagree Agree
1 2 3 4 5 N/A

8. Artificial implants make an individual less human.

Disagree Agree
1 2 3 4 5 N/A

9. Technology is taking us beyond natural human capabilities, which is positive.

Disagree Agree
1 2 3 4 5 N/A

10. Scientists and Engineers have a responsibility to pursue human enhancement.

Disagree Agree
1 2 3 4 5 N/A

11. The public sector ought to determine who funds scientific research.

Disagree Agree
1 2 3 4 5 N/A

12. Research and development should be privately funded.

Disagree Agree
1 2 3 4 5 N/A

13. The ethical objections to genetic modification outweigh any positives.

Disagree Agree
1 2 3 4 5 N/A

14. All people with a disability have equal access to assistive devices and therapeutic technology.

Disagree Agree
1 2 3 4 5 N/A

Part 2: Reflection

Looking at your responses before and after viewing the documentary, why have your opinions changed and/or not changed? Be sure to provide specific examples of where there were changes or not and why.

Unit: Designing Circuits for Neurodevices

Lesson 4: Productive Uncertainty in Science and Engineering

Author: Sadie Frady

Image credit: pngimg.com

LESSON OVERVIEW

Activity Time:
One or two 55 minute class periods.

Lesson Plan Summary:
In this lesson, students will read an article on productive stupidity (uncertainty) and engage in a class discussion on what it means to be productively uncertain in a science classroom. They will end the lesson by filling out a chart that goes over the different combinations of behavior seen in professional science and classroom settings.

STUDENT UNDERSTANDINGS

Big Idea & Enduring Understanding:

- **Productive Uncertainty:** Making advances in scientific research requires that scientists feel comfortable with pushing on the boundaries of their knowledge and living with a feeling of uncertainty. It is okay to not know everything and to have some level of productivity based around this uncertainty. This can lead to deeper meaning and discovery.

Investigative Phenomenon: What does it mean to be comfortable with uncertainty? Scientists, engineers, and researchers continually push on the boundaries of knowledge and practice, inhabiting a world of uncertainty. This search for knowledge, discovery, and solutions to problems is what leads to advances in their fields.

Driving Question:

- What role does productive uncertainty play in the engineering design process and in science?

Learning Objectives:

Students will know…

- That productive uncertainty is an okay and encouraged place to be at during the engineering design process.

Students will be able to…

- Feel confident in their ability to engage in the engineering design process, even if it means that they are not certain.

Vocabulary:

- **Certain:** Knowing with confidence.
- **Engineering:** A discipline that applies math and science to design and build products (devices, structures, tools, machines, etc.) to solve an authentic problem.
- **Productive:** Achieving a desired goal or a result.
- **Productive uncertainty:** Recognizing how little you know about a topic in order to develop important questions to deepen your knowledge. "Being ignorant by choice" in order to push the boundaries of your knowledge.
- **Uncertain:** Not known.
- **Unproductive:** Not achieving a desired goal or a result.

Note: *Definitions were inspired by a variety of website resources, including online dictionaries.*

Next Generation Science Standards:

This lesson does not builds toward a specific NGSS Performance Expectation (PE). Rather, it focuses on elements of the Nature of Science standards connected to the Cross Cutting concepts and practices.

Science is a Way of Knowing:

- Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise, and extend this knowledge.
- Science is a unique way of knowing and there are other ways of knowing.
- Science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and skeptical review.
- Science knowledge has a history that includes the refinement of, and changes to, theories, ideas, and beliefs over time.

Scientific Knowledge is Open to Revision in Light of New Evidence

- Scientific explanations can be probabilistic.
- Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.
- Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.

Common Core State Standards

This lesson is aligned to the following CCSS for literacy.

- CCSS.ELA-LITERACY.RST.9-10.7
  Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

- CCSS.ELA-LITERACY.RST.9-10.8
  Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

- CCSS.ELA-LITERACY.RST.9-10.2
  Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.

TEACHER PREPARATION

Materials

Material	Description	Quantity

"Stupidity" in Science: A text based discussion	An NWABR lesson on "stupidity" in science. Addresses how it is okay to not know in science and research. https://www.nwabr.org/sites/default/files/2Stupidity_in_Science_SNoSR_1.pdf	See lesson plan URL
Student Handouts	*Student Handout 4.1: Productive Uncertainty* A quadrant chart on the different types of certainty and productivity. Credit: Jeanne Chowning, Fred Hutchinson Cancer Research Center.	1/student plus 1 teacher copy
Teacher Resource	*Teacher Resource 4.1: Productive Uncertainty Answer Key*	1

Preparation

1. Go to https://www.nwabr.org/sites/default/files/2Stupidity_in_Science_SNoSR_1.pdf and follow all instructions for running a Socratic Seminar on "Stupidity" in Science.
    a. There are some handouts and an article that will need to be printed.
    b. Unless completing other lessons on the NWABR website, do not complete the *Closure* section of the lesson.

2. Print *Student Handout 4.1* for students and consider making a large-format copy for teacher use in front of class, or else project on screen using document camera.

PROCEDURE

Engage, Explore, Explain, Elaborate (40 – 95 min)

3. Post the following entry task on the board or in whatever format you use in your classroom.
    . *What is the difference between productive and unproductive?*

4. Use the NWABR lesson plan to run the class discussion (see Teacher Preparation section for URL).

Evaluate (10 – 15 min):

5. Pass out *Student Handout 4.1: Productive Uncertainty* to each student.

6. Have students complete each section of the handout with the behaviors they think fit into the different categories.

7. Direct students to discuss in small groups what they wrote and allow them to change or edit anything at this point.

8. Ask for one person per group to share out something they wrote, and write these down on the teacher version for everyone to see.
    a. See *Teacher Handout 4.1* for some ideas of what to put if students are stuck or you are unsure.
9. Post the following exit ticket on the board or in whatever format you use in your classroom.
    a. *Which type of practice(s) are best in a science classroom? Why?*

STUDENT ASSESSMENT

Assessment Opportunities:

- Teachers can check on student understanding and engagement during the class discussions.
- See NWABR lesson for assessment opportunities.
- The completed chart can be assessed or checked off.

Student Metacognition:

- See the NWABR lesson for opportunities for student metacognition.
- The completed chart can serve as a resource for students to reflect on what is okay and not when it comes to productivity and certainty in science.

Scoring Guide:

- See NWABR lesson for scoring of the discussion.
- The completed chart can be assessed or checked off using the Teacher Handout as a guide (it is by no means a complete and final chart--there are many different and acceptable responses not listed).

EXTENSION ACTIVITIES

Extension Activities:

- Students can be given a writing assignment to reflect further on the reading and the chart that they create.

Adaptations:

- Students can be given teacher marked versions of the text. The article can also be read aloud as a class and gone over by the teacher in front of the class. Modeling of how to closely read an article can be done as well.
- Provide a word bank (see provided vocabulary list in this lesson plan) review it with students before reading to help those students who have a developing vocabulary.

TEACHER BACKGROUND & RESOURCES

Background Information:

- Teachers should understand and have a background with running a Socratic Seminar. See https://www.nwabr.org/teacher-center/ethics-primer#overview for information on how this can be done.

- When teaching about productive uncertainty in science, this STEM Teaching Tool may be helpful:

  Practice Brief #60: Designing 'Productive Uncertainty' into Investigations to Support Meaningful Engagement in Science Practices.
  http://stemteachingtools.org/brief/60

Resources:

Bioethics 101: Reasoning and Justification (Curriculum)
Northwest Association for Biomedical Research
https://www.nwabr.org/teacher-center/ethics-primer#overview

The Social Nature of Scientific Research (Curriculum)
Northwest Association for Biomedical Research
https://www.nwabr.org/teacher-center/nature-scientific-research-0#overview

Citations:

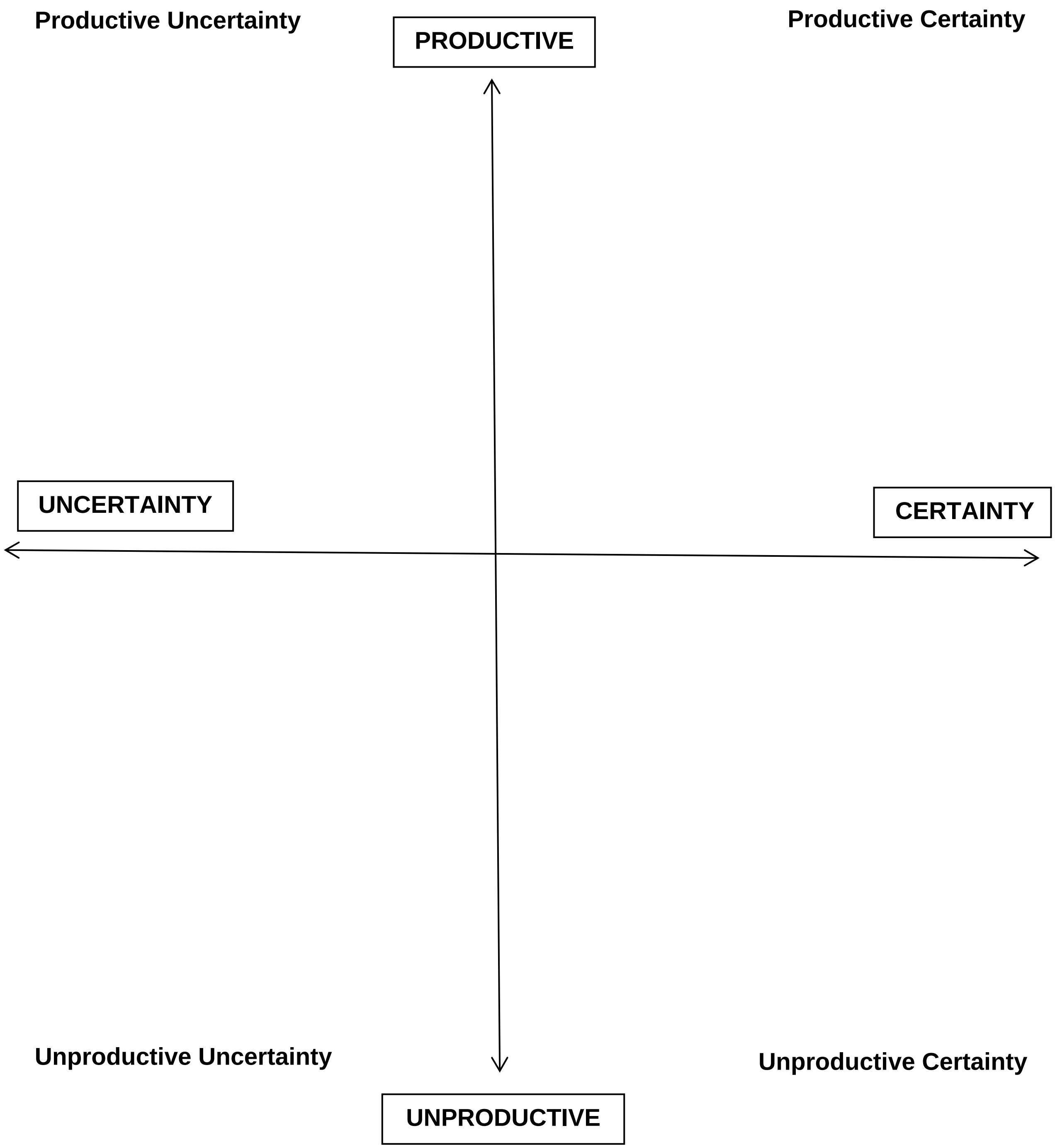
NWABR (2013, September 05). *The Social Nature of Scientific Research*. Retrieved from https://www.nwabr.org/teacher-center/nature-scientific-research-0#overview

Student Handout 4.1: Productive Uncertainty. Credit: Jeanne Chowning, Fred Hutchinson Cancer Research Center.

Unit: Designing Circuits for Neurodevices

Student Handout 4.1: Productive Uncertainty

Name:______________________________ Date:_______________ Period:___________



Teacher Resource 4.1: Productive Uncertainty Answer Key

PRODUCTIVE

Productive Uncertainty

- Trying to figure out what to do
- Working together
- Solving a problem
- On task
- May need help or guidance
- Moving forward even when uncertain

Productive Certainty

- On task
- Confident
- Correct
- No need for redirection or help
- Understands what to do

UNCERTAINTY

CERTAINTY

- Off task
- Not working
- Doesn't understand
- Disorganized
- Needs a lot of redirection and/or help

- Confident
- Not doing what supposed to
- Misunderstanding
- Possibly reading textbook or filling out worksheet without discussion or investigation
- Doesn't want help

Unproductive Uncertainty

Unproductive Certainty

UNPRODUCTIVE

Unit: Designing Circuits for Neurodevices

Lesson 5: Device Design Challenge

Author: Sadie Frady

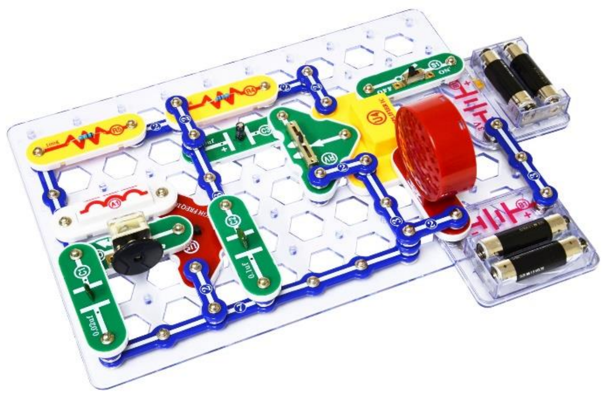


Image credit: Elenco Electronics

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.

<table>
<tr><th colspan="3">High School Performance Expectations</th></tr>
<tr><td colspan="3">HS-PS3-3: 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).

HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.</td></tr>
<tr><th>Science and Engineering Practices (SEPs)</th><th>Disciplinary Core Idea(s)</th><th>Crosscutting Concepts (CCCs)</th></tr>
<tr><td>Constructing Explanations and Designing Solutions</td><td>PS3.A: Definitions of Energy

PS3.D: Energy in Chemical Processes

ETS1.A: Defining and Delimiting an Engineering Problem

ETS1.C: Optimizing the Design Solution</td><td>Energy and Matter

Connections to Engineering, Technology, and Applications of Science
• Influence of Science, Engineering and Technology on Society and the Natural World</td></tr>
</table>

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, https://www.amazon.com/Snap-Circuits-SC-500-Electronics-Discovery/dp/B00008W73Z	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 http://www.papermech.net/ 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	*Engineering Design Journal: Project Introduction, Device Brainstorm, Designing the device, Working on the device, Reflecting on the device*	1/student
Student Handout 5.2	*Project Rubric*	1/student or 1/group
Student Handout 5.3	*Research Poster Requirements*	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

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

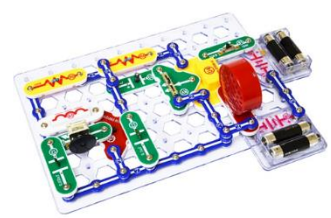
Unit: Designing Circuits for Neurodevices
Student Handout 5.1: Engineering Design Journal
Name:___________________________ Date:______________ Period:__________

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?

6. Define your primary end-users. Who will you be building this design for? What are their wants, needs, and preferences?

7. Who else might be end-users of your product?

8. What do you already know/understand in starting your design? How can you use this knowledge and expertise?

9. What else do you need to know/understand to start your design? How might you acquire this knowledge?

STOP! Get teacher approval!

Teacher signature:___________

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 4: Build a Prototype of the Device

1. Use this space to draw your design, take notes on what worked, what didn't work, what changes you made, etc.

2. After designing, building, and testing a prototype of your device, please fill out the following:

    a. What is the name of your device?

    b. Who is the intended end-users of your device?

    c. How will your device help your end-users?

    d. Describe/draw your final device here (you may take a photo and paste it here or email to your teacher).

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?

Unit: Designing Circuits for Neurodevices

Student Handout 5.2: Engineering Design Rubric

Name:___________________________ Date:______________ Period:__________

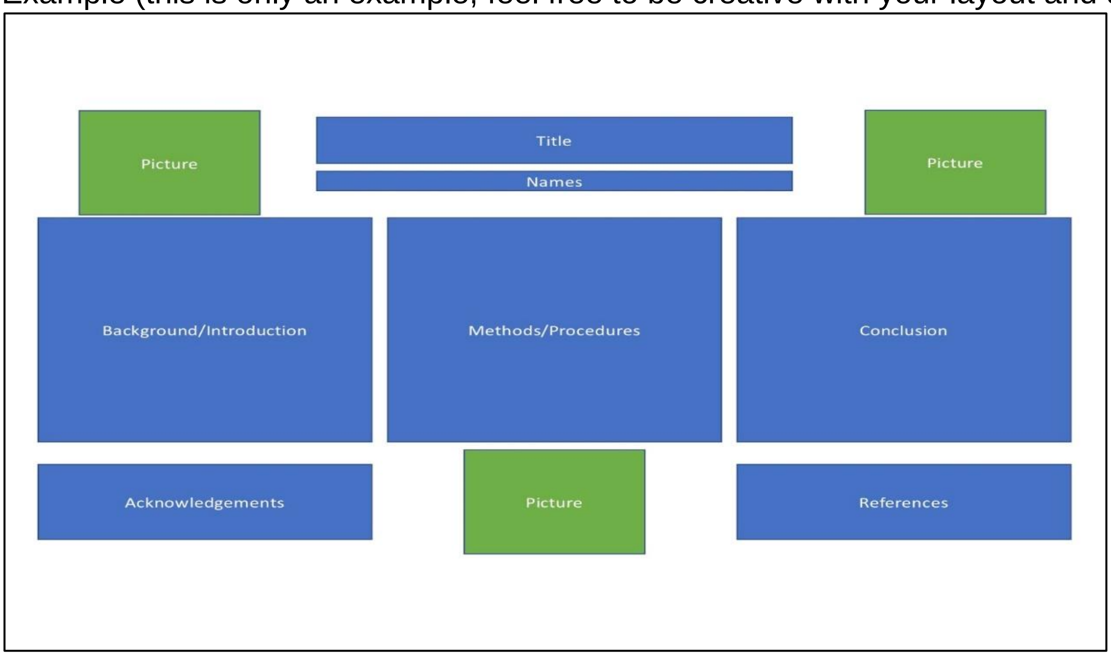
Requirement	*Description*	*Full Points*	*Partial Points*	*No Points*	*Points Available*
Engineering Design Challenge Journal	A journal that students are required to complete during the course of the project.	To earn full points the student must have fully utilized the journal, used proper grammar and 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.	**/25**
Research Team Peer Grades	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.	**/5**
Finished Product Prototype	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.	**/5**
Final Presentation	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.	**/15**
				Total Points	**/50**

Unit: Designing Circuits for Neurodevices
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!)



Unit: Designing Circuits for Neurodevices
Lesson 6: Design Challenge Presentations
Author: Sadie Frady

Image credit: Center for Neurotechnology

LESSON OVERVIEW

Activity Time:
One 55 minute class period.

Lesson Plan Summary:
In this lesson, students will present their posters and prototypes to the class, providing an opportunity to develop scientific communication practices.

STUDENT UNDERSTANDINGS

Big Idea & Enduring Understanding:
- **Scientific Communication:** Students will present their completed prototypes of neural devices and share with each other their design processes.

Design Challenge/Scientific Phenomenon: Scientists, engineers, and researchers publicly communicate their findings through talks at professional conferences, media interviews, publications in academic journals, and other mediums. A particular form of scientific communication is the poster presentation, where a scientific poster is developed to communicate highlights of a research study and presented during a poster session, in which participants engage in informal conversations about the research.

Driving Question:

- How can I best present my completed prototype to my peers?

Learning Objectives:

Students will know…

- How to best present to their peers about their completed prototypes of their designed devices.

Students will be able to…

- Inform their peers on how their prototype works and what purpose it serves.

Vocabulary:

- **Poster:** A scientific poster provides a particular format for communicating a research study. Generally, scientific posters are presented during a poster session at a conference or scientific meeting. A scientific poster includes information about the research study such as title, authors, background, research question/hypothesis, methods, findings, discussion, and acknowledgements.
- **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. Additional dimensions are denoted with an asterisk (*).

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HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.</td></tr>
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PS3.D: Energy in Chemical Processes</td><td>Energy and Matter

Connections to Engineering, Technology, and Applications of Science</td></tr>
</table>

	ETS1.A: Defining and Delimiting an Engineering Problem ETS1.C: Optimizing the Design Solution	• Influence of Science, Engineering and Technology on Society and the Natural World

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.SL.11-12.4: Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.

TEACHER PREPARATION

Materials

Material	Description	Quantity
Sticky Notes	Sticky notes in three different colors. Each student will receive enough of each color to place one of each color on each poster they view (e.g., Student B will view 6 posters, so they will need 6 of each color of sticky note)	See notes
Student Handout 6.1	*Peer Review* 1 handout per group member for each student (e.g., student A is in a group of 3, so they would receive 2).	See notes

Preparation

1. Make copies of *Student Handout 6.1: Peer Review*. You will need enough copies so that each student has one copy for every group member they have (e.g., student A is in a group of 3, so they would receive 2 copies of the handout).

2. Pre group sticky notes so that you can easily pass them out when they are needed.
   a. Each student will need 3 different colors and one of each color per poster they will be viewing.

PROCEDURE

Engage (5 min): Entry Task

1. Post the following entry task on the board or in whatever format you use in your classroom.
   What was the most challenging part of this project? Least challenging?

Explore, Explain, Elaborate (20-30 min): Gallery Walk

2. Direct students to get out their posters and sit with their group if they are not already.

3. Divide the class into two: one half of the groups will be presenting in the first session and the other half of the groups will be presenting in the second session. Those groups not presenting in each session will serve as the audience.

4. Have the groups of students that are presenting first set up their posters and completed prototypes/devices next to them.

5. While they are setting up, pass out sticky notes of 3 different colors to each group not presenting.

6. Project the following information on what the sticky notes mean. Consider using sticky notes that match the color of the text highlighting for a quick reference for students (you can change the color of highlighting to match the color of the sticky notes you have on hand).
    a. *Using the sticky notes provided, write one thing you think, you wonder and any next step suggestions you have.*

7. Ensure that students know that they will not be allowed to write anything rude or inappropriate, and that they are required to leave one of each color of sticky note at each poster.

8. Have students travel in their groups to visit each poster and leave feedback using the sticky notes. Consider timing this or allowing students to walk freely to each poster based on your students and classroom environment.

9. Switch which groups are presenting for the second session. Repeat steps 4-7 with the other half of the groups, ensuring each group gets the chance to present and to be part of the audience.

Evaluate (10-20 min): Reflection and Peer Reviews

10. Post the following questions/prompts on the board.
    a. *What are you most proud of in your poster?*
    b. *What was one of the biggest challenges you encountered? Why was it challenging? How did you feel initially?*
    c. *How did you overcome your challenges? What resources did you seek to help you through your challenges?*
    d. *What tips would you give to a student who will be designing a research poster in the future?*
    e. *If you were to grade yourself using the rubric now, what grade would you give yourself and why?*

11. Have students discuss these questions within their groups. Consider having students write down their responses.

12. Have one student from each group share out a brief summary of what was discussed.

13. Distribute copies of *Student Handout 6.1*: *Peer Review* to students, one per group member that they had.

14. Direct them to complete *Student Handout 6.1* anonymously and turn in to you when done.

STUDENT ASSESSMENT

Assessment Opportunities:

- Teachers can check on student understanding and engagement during the class discussions.
- Students can be asked to write down and turn in their responses to the discussion prompts in Step 10, which includes their own self-assessment.
- Peer assessments will be provided through completion of *Student Handout 6.1.*

Student Metacognition:

- Students will reflect on their learning and teamwork processes through the reflective discussion prompts and through peer assessment.

Scoring Guide:

- Students are successful when they have completed the gallery walk in an academically appropriate manner and have completed the peer review (*Student Handout 6.1*).
- Consult *Student Handout 5.2: Engineering Design Rubric* that was provided in Lesson 5.
- Each group's poster should be graded using *Student Handout 5.3: Research Poster Requirements* and *Student Handout 5.2: Engineering Design Rubric.*
- The peer review provided by students' completion of *Student Handout 6.1* for their group members is used to assign up to 5 points on the scoring rubric from Lesson 5. A peer review(s) that is low for valid reasons is used to assign anywhere from 0-5 points in this section. See below for the portion of the rubric based on the peer review.

Research Team Peer Grades	**An average of the score given to the student by their research team.**	**Student received all good 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 bad scores/reviews. There were issues.**	**/5**

EXTENSION ACTIVITIES

Extension Activities:

- You can facilitate an informal gallery walk activity or professionalize it as poster session to provide students with more authentic experiences with scientific communication. Invite authentic audience members, such as engineers or graduate students from a local university or industry. See the resources in the Teacher Background & Resources section about how to present a scientific poster at a poster session.

Adaptations:

- If a student(s) is unable to participate in presenting their poster, they could record a video of themselves presenting it.

TEACHER BACKGROUND & RESOURCES

Background Information:

- Teachers will need to understand how to coach students in presenting a scientific poster and how to engage in peer assessment. The resources below may be helpful.

Resources:

Peer Assessment
Cornell Center for Teaching Innovation
https://teaching.cornell.edu/teaching-resources/assessment-evaluation/peer-assessment

How to Present an Academic Research Poster Video (5:00 min)
The iSchool, Syracuse University
https://www.youtube.com/watch?v=0ozwCEeaVWE

Ten Simple Rules for a Good Poster Presentation
Erren & Bourhne, 2007, PLOS Computational Biology
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1876493/

A Guide to Presenting a Poster
Cain Project, Rice University
http://www.owlnet.rice.edu/~cainproj/presenting.html

Unit: Designing Circuits for Neurodevices
Student Handout 6.1: Peer Review
Name:____________________________ Date:______________ Period:__________

Team Member Name:		
Question	***Response***	***Other Comments***
Did this team member contribute to the design challenge process?		
Did this team member act as a part of the team?		
Do you feel like this team member did what they were supposed to?		
If you were given $1,500 to split amongst your group from the National Science Foundation for your work, how much would you give this team member? Explain in the comments.		
Your Name:		