Designing Circuits for Neurodevices

A Curriculum Unit for High School Physics courses
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Research Experience for Teachers (RET) Program

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

Table of Contents

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In this lesson, 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 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 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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Disclaimer:

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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