Circuitry and Sensory Substitution

A Curriculum Unit for High School Physics
and Cambridge IGCSE Physics courses
April 2019

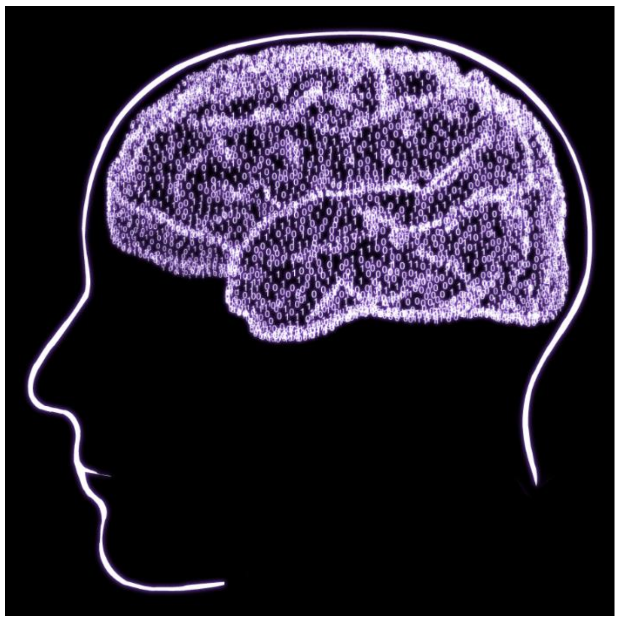

Image: Outline of the human head with the shape of the brain created out of purple 1s and 0s.
Source: 2003, Nicolas P. Rougier, Wikimedia Commons.

Research Experience for Teachers (RET) Program

CENTER *for* NEUROTECHNOLOGY
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Student Handout 2.10: Post Assessment: Complex Circuitry

Lesson Three: Engineering the Circuit

In this lesson, students will design their sensory substitution circuit (prototype of their sensory substitution device), build and test it, and make any necessary changes after the test.

Student Handout 3.1: Engineering Design Process

Student Handout 3.2: Sensor Circuit Engineering

Teacher Resource 3.1: Sample Student Lab Notebook Pages

Teacher Resource 3.2: Circuit Legend

Lesson Four: Evaluating the Prototypes

In this lesson, students will evaluate their sensory substitution circuit both in terms of engineering and ethics by taking part in a scientific poster session.

Student Handout 4.1: Pugh Chart

Teacher Resource 4.1: Survey 3: Engineering Survey Round 2 (slide deck)

Teacher Resource 4.2: Review for End-of-unit Test

Teacher Resource 4.3: End-of-unit Test

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.

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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

Program Contact Information:
Janis Wignall
CNT Pre-college Education Manager
University of Washington
Phone:
Email: wignallj@uw.edu

Kristen Bergsman, Ph.C.
CNT Engineering Education Research Manager
University of Washington
Phone: 206-221-1494
Email: bergsman@uw.edu

Eric H. Chudler, Ph.D.
CNT Executive Director & Education Co-Director
University of Washington
Phone: 206-616-6899
Email: chudler@uw.edu

CNT Address: Bill & Melinda Gates Center for Computer Science & Engineering; 3800 E Stevens Ways NE, Seattle, WA 98195

CNT Website: http://www.centerforneurotech.org

Credits:
Alexandra Pike, Science Teacher, Juanita High School (Lake Washington School District), Kirkland, WA

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Target Grade Level: Grade 10 (9-12)

Time Required: 405 minutes (two weeks with 45 minute classes each day)

Unit Description

In this two week unit, students extend their knowledge of basic electric circuits by studying the function and use of more complex components (e.g., thermistors, LDRs, logic gates, LEDs, etc.) in the context of a neural engineering design project. Students are introduced to basic neuroscience principles (e.g., the brain, neurons, motor cortex, brain-computer interfaces, etc.) and use these concepts to design, build, optimize, evaluate, and present a sensory-substitution device, modeled as an assistive device on circuit boards (the anchoring design problem).

Neural engineering is an interdisciplinary branch of science and engineering which ties together aspects of biomedical and electrical engineering with neuroscience. Biomedical engineers work to understand what types of devices are needed, electrical engineers support in the creation of these devices, and neuroscientists work to understand how they are performing in individuals with neurological illnesses or disabilities.

In Lesson 1, students are introduced to the similarities and differences between the brain and computers and how they are connected through use of an EMG-controlled gripper claw. They learn about and discuss some of the practical and ethical considerations in neuroscience and specifically of sensory substitution devices. In Lesson 2, students explore more complex circuit components through the use of SnapCircuits, and practice problem-solving with complex circuit diagrams. In Lesson 3, students engage in the practices of engineering design as they work in teams to design, build, and iterate on their model sensory substitution devices. In Lesson 4, students will evaluate their prototypes and the unit will culminate in a scientific poster session in which students present and evaluate their final models.

- Lesson 1 - Brain and Computer Connections (45 min)
- Lesson 2: Sensor and Logic Circuits (180 min)
- Lesson 3: Engineering the Circuit (180 min)
- Lesson 4: Evaluating the Prototypes (45 min)

Classroom Testing

This curriculum was implemented in February 2017 and February 2018 at Juanita High School, in Kirkland, WA. Implementation occurred with two sections of 10th grade Physics students each year, for 113 students in total.

Alignment to National Learning Standards

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

This unit is also aligned to the International Technology Education Association (ITEA) Standards for Technological Literacy.

Next Generation Science Standards: Performance Expectations

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-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. (Grades 9-12).

HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. (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).

Science and Engineering Practices (SEPs)	Disciplinary Core Idea(s)	Crosscutting Concepts (CCCs)
Constructing Explanations and Designing Solutions	ETS1.A: Defining and Delimiting an Engineering Problem ETS1.B: Developing Possible Solutions ETS1.C: Optimizing the Design Solution PS3.A: Definitions of Energy	Energy and Matter *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.

International Technology Education Association (ITEA) Standards for Technological Literacy

This unit builds toward the following high school ITEA Standards. Hyperlinks direct to relevant sections of the *Standards for Technological Literacy*.

ITEEA 2000, grades 9-12, 3.H	**3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.** H. Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.
ITEEA 2000, grades 9-12, 4.I	**4. Students will develop an understanding of the cultural, social, economic, and political effects of technology.** I. Making decisions about the use of technology involves weighing the trade-offs between positive and negative effects.
ITEEA 2000, grades 9-12, 8.H	**8. Students will develop an understanding of the attributes of design.** H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

ITEA and its Technology for All Americans Project. (2006*). Standards for Technological Literacy: Content for the Study of Technology*, 3rd Ed. International Technology Education Association: Reston, Virginia.

IGCSE Physics Standards

This unit builds toward the following high school Cambridge IGCSE Physics standards.

Standards	Lesson 1	Lesson 2	Lesson 3	Lesson 4
AO1-2. Demonstrate knowledge and understanding of scientific vocabulary and conventions				
AO1-3: Demonstrate knowledge and understanding of scientific instruments and apparatus				
AO1-4: Demonstrate knowledge and understanding of scientific and technological applications with their social, economic, and environmental implications.				
AO2-3: In words or using other written forms of presentation, manipulate numeric & other data				
AO2-5: In words or using other written forms of presentation, present reasoned explanations for phenomena, patterns and relationships.				
AO2-6: In words or using other written forms of presentation, make predictions and hypotheses.				
AO3-1: Demonstrate knowledge of how to safely use techniques, apparatus, and materials.				
AO3-2: Plan experiments and investigations				
AO3-3: Make and record observations and measurements				
AO3-4: Interpret and evaluate observations and data.				
AO3-5: Evaluate methods and suggest possible improvements.				
AO4-3: Action and use of circuit components				
AO4-4: Digital electronics				

Cambridge International Examinations (2016*). Syllabus: Cambridge IGCSE Physics.* Available https://www.cambridgeinternational.org/Images/167041-2016-2018-syllabus.pdf.