**Lesson 4:** Pugh Chart and BCIs



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**LESSON OVERVIEW**

**Activity Time:** One 50 minute class period, plus additional time for homework and summative assessment.

**Lesson Plan Summary:**

In this lesson, students will read about different biofeedback brain devices being used to treat seizures in drug resistant epilepsy (DRE) patients. Students will then use an engineering tool called the Pugh Chart to evaluate which brain device they would recommend to the parents for use on their DRE child.

**STUDENT UNDERSTANDINGS**

**Investigative Phenomenon/Problem:**

There are a number of treatment options to treat seizures in epilepsy patients that includes medication, change in diet, and surgery. While the use of drug and chemicals is the main treatment option, nearly 7-20% of children and 30-40% of adult patients become resistant to drug therapies (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6708813/>). DRE patients and their doctors can look into different brain technologies as alternative treatments.

Child patients rely on their parents/guardians and doctors to make informed decisions for them. In this lesson, students will make a recommendation to the parents of a DRE child patient as to what brain technology option is suitable for their child by using an engineering decision matrix called the Pugh Chart.

* **Description of Phenomenon/Problem:** When drug based therapies are no longer effective for addressing seizure occurrences, patients look to surgical therapies to implant brain devices as an alternative form of treatment.
* **Driving Question:** Which closed-loop neurological device is most appropriate for a child who is resistant to drug therapies in order to control their epileptic seizures?

**Learning Objectives:**

* In their small groups, students will collaboratively come up with 5-10 different criteria in order to evaluate 3 brain devices for seizure treatments.
* Students will use an engineering tool called a Pugh Chart to evaluate 3 surgical therapies currently available against previously identified criteria.
* Students will then make a recommendation for which brain device is suited for the DRE child patient, and explain why.

**Vocabulary**:

* **Brain:** An organ contained in the skull that functions as the body’s command center. The brain, along with the spinal cord, is part of the central nervous system. It controls movement, functions, sensations, memory, and thoughts. 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.
* **Brain-Computer Interface (BCI):** A communication pathway linking neural signals from the brain with an external device. The neural signals are decoded by a computer using an algorithm that translates the signals into a motor output (action), such as controlling a neuroprosthetic hand or steering a wheelchair. BCIs may operate using either EEG or ECoG recordings or single unit activity from neurons. Also called a Brain-Machine Interface or a Brain-Control Interface.
* **Closed Control loop:** A closed loop sensorimotor device receives signals from the nervous system and provides feedback to the body. With a Brain-Computer Interface, a closed loop is achieved by providing sensory feedback to the user of the device, such as visual feedback (seeing the position and movement of the device) or tactile feedback (feeling the position and movement of the device).
* **Drug Resistant Epilepsy (DRE):** A condition when a person has failed to become (and stay) seizure free with adequate trials of two antiseizure medications (called ASMs).
* **Electrode:** A conductor in which electricity enters or leaves an object. In neuroscience, electrodes are used to detect biosignals produced by the body. Electrodes are used in EEG, EMG, ECoG, and signal units to record the electrical activity within neurons. They may be laid on the surface of the skin, onto the surface of the brain under the skull, or inserted directly into brain tissue or the spinal cord. Some electrodes are being engineered to also be able to provide electrical stimulation, light (optogenetic) stimulation, and/or deliver small amounts of pharmaceutical drugs. These kinds of electrodes are made from metals, glass, glassy carbon, and other materials that do not react when surgically implanted in an animal’s body. Some are made to be flexible so that they can move with the spinal cord.
* **Epilepsy**: A neurological disorder marked by sudden recurrent episodes of sensory disturbance, loss of consciousness, or convulsions, associated with abnormal electrical activity in the brain.
* **Feedback:** The process of the output of a system is used to make changes in the operation of the system.
* **Implant:** A medical device manufactured to replace or enhance a structure in the body. For example, a cochlear implant used to restore hearing, a retinal implant used to restore vision, or an electrode array implanted in the brain to stimulate a damaged area.
* **Pugh Chart:** A matrix tool used to facilitate a disciplined, team-based process for concept generation and selection.
* **Seizure**: A burst of uncontrolled electrical activity between brain cells (also called neurons or nerve cells) that causes temporary abnormalities in muscle tone or movements (stiffness, twitching or limpness), behaviors, sensations or states of awareness.

**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-LS1-3**](https://www.nextgenscience.org/pe/hs-ls1-3-molecules-organisms-structures-and-processes)**:** Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.  [**HS-ETS1-3**](https://www.nextgenscience.org/pe/hs-ets1-3-engineering-design)**:** 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. | | |
| **Science and Engineering Practices (SEPs)** | **Disciplinary Core Idea(s)** | **Crosscutting Concepts (CCCs)** |
| [Planning and Carrying Out Investigations](http://www.nap.edu/openbook.php?record_id=13165&page=59)[Constructing Explanations and Designing Solutions](http://www.nap.edu/openbook.php?record_id=13165&page=67)*Connections to Nature of Science*Scientific Investigations Use a Variety of Methods \*[Appendix H](https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20H%20-%20The%20Nature%20of%20Science%20in%20the%20Next%20Generation%20Science%20Standards%204.15.13.pdf) - ethics standards | [LS1.A: Structure and Function](http://www.nap.edu/openbook.php?record_id=13165&page=143%22)[ETS1.B: Developing Possible Solutions](http://www.nap.edu/openbook.php?record_id=13165&page=206) | [Stability and Change](http://www.nap.edu/openbook.php?record_id=13165&page=98)*Connections to Engineering, Technology, and Applications of Science*[Influence of Science, Engineering, and Technology on Society and the Natural World](http://www.nap.edu/openbook.php?record_id=13165&page=212) \*[Appendix H](https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20H%20-%20The%20Nature%20of%20Science%20in%20the%20Next%20Generation%20Science%20Standards%204.15.13.pdf) - ethics standards |

**TEACHER PREPARATION**

**Materials:**

| **Material** | **Description** | **Quantity** |
| --- | --- | --- |
| Classroom Computer | Teacher computer with projector, speakers, and internet connection to project Lesson 4 Slidedeck and videos | 1 for each teacher and co-teacher and other staff support as needed |
| Student Computers | Student computers with Excel spreadsheet software | 1 for each student, or 1 per group |
| Documents (Printed/hard copy) | *Student Handout 4.1: Brain Technology Reading*  *Student Handout 4.2: Brain Technology Worksheet*  *Student Handout 4.3: Neurotechnology Recommendation Write-up Guide* | 1 per group  1 per student  1 per student |
| Electronic Documents | Lesson 4 Slidedeck  Teacher Resource: Jamboard Version of SH4.2  Teacher Resource: Pugh Chart on Excel Spreadsheet | For teacher use  1 per group  1 per group |
| Mini-Design Challenge Supplies | Supplies for a mini-design challenge, such as a spaghetti tower ( 10 pieces of spaghetti and 4 marshmallows per tower) | Supplies per individual, pair, or small group |

**Preparation:**

1. Preview the Lesson 4 Slidedeck and add/change as needed. Pre-assign students in groups for collaborative work.
2. Make copies of *Student Handout 4.1: Brain Technology Readings,* one set per group. Upload copy to Google classroom or similar platform for remote learning students.
3. Make copies of *Student Handout 4.2: Brain Technology Worksheet*, one per student. Or assign the Jamboard version of the handout on Google classroom or similar platforms, 1 per group (see Teacher Resource: Jamboard Version of Brain Technology Worksheet).
4. Create a group copy of the Teacher Resource: Pugh Chart on Excel spreadsheet. Assign the spreadsheet to students’ Google classroom accounts or similar platforms, 1 per student.
5. Make copies of *Student Handout 4.3: Neurotechnology Recommendation Write-up Guide*. If doing hard copies, make a copy for each student. If assigning electronically, link the document to Google classroom accounts or similar platforms. This write-up is the summative for this lesson, so set a due date for the assignment.
6. Divide students into groups of three.

**PROCEDURE**

*Use the Lesson 4 Slidedeck as you progress through the lesson procedure.*

**Activity 1: What are Criteria and Constraints? (10 minutes)**

1. Introduce the engineering challenge of building a Spaghetti Tower (or an alternate engineering design mini-challenge; see [Link Engineering Educator Exchange](https://www.linkengineering.org/) for ideas). The challenge is to create the tallest Spaghetti Tower in 5 minutes using only 10 pieces of spaghetti and 4 marshmallows. (Note to Teacher: You can also change the number of spaghetti pieces and the time element to your liking).
2. After they build the tower, ask the students what were the requirements of the Tower. Explain to students that this is the **Criteria**. Then, ask the students what were the challenges or limitations they faced. Explain to students that these are the **Constraints**.

*Adaptation*:

* *Students can watch the Spaghetti Tower or make them do it at home for homework the day prior. Link to video about the Spaghetti Tower Challenge -* [*https://www.youtube.com/watch?v=P9ccF56Vj1s*](https://www.youtube.com/watch?v=P9ccF56Vj1s)
* *Homework Idea/Supplement Material after lesson: Read “Criteria vs. Constraints” by Rocketlit.com.* [*https://www.rocketlit.com/\_media/pdfs/articles/free/3801\_science-article\_criteria-vs-constraints.pdf*](https://www.rocketlit.com/_media/pdfs/articles/free/3801_science-article_criteria-vs-constraints.pdf)

**Activity 2: BCI and Jigsaw (15 minutes)**

1. Explain to students what BCIs are, and the different ways that neurotechnology has helped patients improve their quality of life. See the Lesson 4 Slidedeck.
2. Introduce the three neurotechnologies used to address seizures in DRE patients. (At this point, students have a working knowledge about seizures and drug resistant epilepsy).
3. In their small group of three, give students a copy of *Student Handout 4.1: Brain Technology Reading*. Have students do a jigsaw reading in their small group about the brain devices used for seizure treatment.
4. As the students read, have them fill out *Student Handout 4.2: Brain Technology Worksheet,* which will guide them in describing the purpose of the treatment, the mechanics of the neurotechnology (how it works), and the advantages and the disadvantages of the technology. Also have students reflect on the constraints of the technology, especially for use in children.
5. Have students share the main ideas of each technology to other members of their small group.

*Adaptation*:

* *For students who are working online/remotely, give them the electronic copies of the student handouts. See Teacher Resource: Jamboard Version of SH4.2 as an alternative to Student Handout 4.2 that may work well for remote learning.*
* *While students are reading the text, you can use an annotation protocol, or have students color code the text (ex: highlight in yellow the advantages, blue the disadvantages, etc.).*

**Activity 3: The Pugh Chart (15 minutes)**

1. As a class or in small groups, elicit different criteria that patients should consider when deciding on what kind of neurotechnology would be best to use for DRE.
2. Have students self-reflect on these criteria by ranking their top three. Students may or may not share this reflection to the class/group.
3. Using Teacher Resource: Pugh Chart on Excel Spreadsheet, show the students the Pugh Chart which has the criteria identified on the Y-axis of the table, and the three neurotechnologies on the X-axis of the table. With a scale from 0 to 4, have students score each neurotechnology for each identified criteria. (You may want to demonstrate/show how to manipulate the Pugh Chart as you are explaining this part of the activity). It is important to emphasize that the students need to agree as a group on each of the scores for each criteria.
4. The neurotechnology option that has the highest total score is the best suited for the problem.

**Activity 4: Recommended Neurotechnology for Child Patient with DRE (15 minutes)**

1. Tell the students that they need to write a recommendation letter to the parents of the child DRE patient based on their knowledge of brain technology treatments and their Pugh Chart matrix.
2. Go over *Student Handout 4.3: Neurotechnology Recommendation Write-up Guide* for the write-up with the students. Set up a deadline for submission.

*Adaptation:*

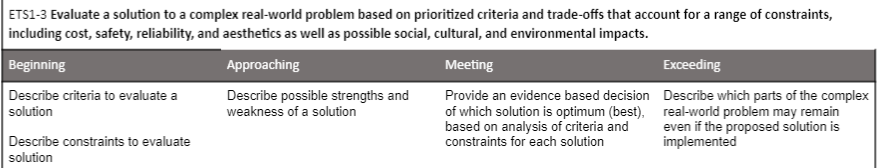
* *This can be assigned for homework. Set a due date for students to submit their work.*
* *Instead of writing their explanation, students can also take a video of themselves explaining their recommendation. Students can also schedule a 1:1 oral defense with the teacher in lieu of the written explanation. Students can record their videos on their smartphone or use* [*www.screencastify.com*](http://www.screencastify.com) *or FlipGrid.*
* *For students who are artistically inclined, they can create a storyboard or infographics to present their explanation. A good, easy to use platform is* [*www.canva.com*](http://www.canva.com)

**STUDENT ASSESSMENT**

**Assessment Opportunities:**

* **Formative Assessment:** The formative assessment will include the student worksheet or Jamboard document, as well as the self-reflection for the criteria. Throughout the group work, the teacher will also ask questions and check in with individual students.
* **Summative Assessment:** The summative assessment is the recommendation that the students will write/give to the family and medical team of the child with DRE. The write-up should include the reason for the recommendation based on the description of the device and the scores on the Pugh Chart.

**Scoring Guide:** Here is a rubric to assess student learning for the summative assessment. This is a district-made rubric from Highline Public Schools in Washington.



**Extension Activities to Build on Student Interest and Expertise:**

If students are interested in learning more, here are some resources:

**What is a BCI?**

* BrainWorks Video on [BCIs](https://www.youtube.com/watch?v=cBPQu80pwfU)
* Read “Chapter 2: Brain-Computer Interfaces” of the interactive e-book, [*Exploring Neuroscience and Neurotechnologies at Home*](https://uw.pressbooks.pub/yspreach2020/)
* [Articles and activities list](https://centerforneurotech.uw.edu/education-resources-teachers/neuroprosthetics-brain-computer-interfaces) from the Center for Neurotechnology

**Interesting Neurotechnology Examples and Experiments**

* Meet Milo, the Brain Controlled Wheelchair [Video & Article](https://montreal.ctvnews.ca/meet-milo-a-mind-controlled-mcgill-created-automated-wheelchair-1.4398696)
* [Build Your Own Cyborg Hand](https://backyardbrains.com/experiments/DIYNeuroprosthetic), an engineering challenge from Backyard Brains
* Explore the News and Research sections of the [Center for Neurotechnology website](https://centerforneurotech.uw.edu/), as well as the [Center’s YouTube channel](https://www.youtube.com/user/CSNEERC).

**Careers in Neuroscience and Neurotechnology**

* Read “Chapter 5: College and Career Pathways” of the interactive e-book, [*Exploring Neuroscience and Neurotechnologies at Home*](https://uw.pressbooks.pub/yspreach2020/)
* [Careers info](https://centerforneurotech.uw.edu/education-resources-teachers/exploring-engineering-careers) from the Center for Neurotechnology
* This Neuroscience for Kids [webpage](https://faculty.washington.edu/chudler/chjob.html) itemizes the different jobs in the field of neuroscience and neurotechnology.
* [Women in Neuroscience](https://faculty.washington.edu/chudler/win.html)

**TEACHER BACKGROUND & RESOURCES**

**Background Information:**

* This lesson is part of a bigger unit on homeostasis and feedback with a focus on epilepsy. The teacher can follow the science modeling pedagogy from [Ambitious Science Teaching](https://ambitiousscienceteaching.org/), which starts with giving students a real-world puzzling phenomena, which for this unit is the use of brain computer interfaces for epilepsy.
* It would be helpful to read the Gapless Scientific Explanation, which is available in the Unit Overview document for this curriculum unit. There are resources linked throughout this document for the teacher’s background information.

**Citations:**

* Neuroscience for Kids website. <https://faculty.washington.edu/chudler/neurok.html>
* Vagus Nerve Stimulation, Mayo Clinic <https://www.mayoclinic.org/tests-procedures/vagus-nerve-stimulation/about/pac-20384565>
* Responsive Neurostimulation, University of Pittsburgh Medical Center <https://www.neurosurgery.pitt.edu/centers/epilepsy/responsive-neurostimulation>
* Laser Ablation Surgery for Epilepsy Brain Tumors, Seattle Children’s Hospital <https://www.seattlechildrens.org/clinics/neurosciences/services/laser-ablation-surgery-epilepsy-brain-tumors/>