Neuroscience and Mental Illness

Companion Lesson X-STEM All Access Episode "Exploring Our Minds" by Dr. Kaf Dzirasa

Grade Band: Middle School - High School	**Topic:** Neuroscience

Brief Lesson Description: Students explore brain signals, AI emotion decoding, mental illness, and neuroethics.

Performance Expectation(s):

MS LS1-3: Use arguments supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

MS LS1-8: Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or long-term changes.

HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

HS LS1-3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

Specific Learning Outcomes:

Students will be able to:

- explore how the brain processes and interprets sensory signals.
- explore how neuroscience technology, artificial intelligence (AI), and machine learning help decode brain activity to better understand emotions and mental illness.
- investigate how treatments like transcranial magnetic stimulation (TMS), deep brain stimulation (DBS), and brain-machine interfaces (BMIs) are used to change electrical states in the brain to address mental health conditions.

Narrative / Background Information

For centuries, scientists have tried to understand the human brain—how we think, feel, and experience the world. But the brain is not like a computer—it doesn't just store and retrieve data. Instead, it interprets information, sometimes filling in gaps or making mistakes (as seen in optical illusions).

This lesson bridges neuroscience, mental health, and cutting-edge AI technology to explore how we read, interpret, and influence the brain's electrical signals. Students will:

- Experience how the brain interprets sensory information (and how it can be tricked).
- Explore how scientists use technology and AI to understand emotions and mental illness.
- Debate the ethical implications of AI-driven brain research.

This lesson assumes middle school students have the following understandings:

1. Human Body Systems & Nervous System Basics
    - The body is made up of interacting subsystems, including the nervous system.
    - Neurons are the cells that make up the brain and nervous system.
    - The brain processes sensory information from the eyes, ears, and skin.
    - The brain sends and receives electrical and chemical signals to control movement, thoughts, and emotions.
2. Energy & Waves (Basic Physics Connection)
    - Electrical signals move through wires (basic circuits) and can also move through the body (nerve signals).
    - Light and sound waves carry information to the brain, which interprets what we see and hear.
3. Introduction to Artificial Intelligence & Technology
    - AI is used to recognize patterns (e.g., facial recognition, voice assistants).
    - Scientists can record brain waves (EEG) and use computers to understand brain activity.

Scaffolding Strategy for MS:

Before the lesson, a short activity on body systems and nerves (e.g., using reaction time tests or simple neuron models) will help solidify concepts.

This lesson assumes high school students have the following understandings:

1. Neurobiology & Brain Function
    - The brain is divided into regions (frontal lobe, occipital lobe, temporal lobe, etc.), each responsible for different tasks (e.g., vision, movement, emotions).
    - Neurotransmitters (dopamine, serotonin) and their role in mental health.
    - Electrical signals travel via action potentials along neurons and synapses.
2. Electrical and Magnetic Fields (Physics Connection)
    - The brain's electrical activity can be measured with EEG (electroencephalography).
    - Magnetic fields can influence electrical signals in the brain (TMS - transcranial magnetic stimulation).
    - AI and machine learning use patterns in data to interpret brain activity.
3. Ethics & AI in Medicine

- AI can be used to predict emotions, diagnose disorders, and even influence decision-making.
- Brain-machine interfaces (BMIs) may help people with paralysis but also raise ethical concerns.
- Privacy concerns: Should companies be allowed to "read" emotions from brain scans?

Scaffolding Strategy for HS:
A pre-lesson discussion on AI in everyday life (Siri, Google Assistant, recommendation algorithms) will help students see AI's relevance before applying it to neuroscience.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Engaging in Argument from Evidence Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon. (MS-LS1-3) **Obtaining, Evaluating and Communicating Information** Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias for each publication and methods used, and describe how they are supported or not supported by evidence. (MS-LS1-8) **Planning and Carrying Out Investigations** Plan and conduct an investigation individually or collaboratively to produce data to serve as the basis for evidence and in the design: decide on types, how much and accuracy of data needed to produce reliable measurements and consider limitations on the precision of data (e.g., number of trails, cost, risk, time) and refine the design accordingly. (HS-LS1-3)	**LS1.A: Structure and Function** In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. (MS-LS1-3) **LS1.D: Information Processing** Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical) transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories. (MS-LS1-8)	**Cause and Effect** Cause and effect relationships may be used to predict phenomena in natural systems. (MS-LS1-8) **Systems and System Models** Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. (MS-LS1-3) **Stability and Change** Feedback (negative or positive) can stabilize or destabilize a system (HS-LS1-3) **Connections to Nature of Science** **Science Is a Human Endeavor** Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas. (MS-LS1-3)

Possible Preconceptions/Misconceptions:

1. **If something is in your brain, you can control it.** Reality: Much of brain activity happens *subconsciously*, meaning people don't have full control over thoughts, emotions, and even actions. This is why mental illness and neurological disorders exist.
2. **If AI can read emotions and thoughts from brain activity, it means we can reliably and accurately diagnose or treat mental illness.** Reality: AI can analyze patterns, but emotions and mental health conditions are complex. Brain scans alone do not diagnose mental illness—doctors need to consider many factors.
3. **Mental illness is just a weakness or personal failing**. This connotation occurs because the term refers to the intangible mind. The assumption is that if there's no visible, physical problem, then the issue must be contained within the person's personality or willpower. Reality: Mental illnesses are biological, psychological, and environmental in nature. They involve changes in brain chemistry and structure and are not simply about lacking strength of character.
4. **Mental illness can be cured if you just try hard enough.** Reality: While treatments (medication, therapy, brain stimulation) can help, there is no simple "cure." Deep Brain Stimulation (DBS) or Transcranial Magnetic Stimulation (TMS) may also help some people but these treatments come with risks and ethical concerns (e.g., personality changes, autonomy, and consent). Managing mental health is often a long-term and complex process.
5. **If AI predicts someone's emotions or mental health risk, we should trust it completely.** Reality: AI predictions are not perfect—they depend on incomplete data, and false positives/negatives can be harmful (e.g., mislabeling someone as "depressed" when they aren't).
6. **AI is neutral and always fair.** Reality: AI is trained on human-created data, which means it can inherit biases (e.g., racial, gender, or socioeconomic bias in mental health diagnosis).

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

Purpose: Capture students' curiosity by showing how the brain interprets information—and how sometimes it gets things wrong.

Objective:

- Demonstrate that the brain does not always interpret sensory information correctly.
- Show that AI and technology can "read" and even influence how we think.

Optical Illusion Activity

1. Show students the *Edward Adelson Checkerboard* optical illusion, either digitally or on paper, and ask:
    - What do you notice about the two labeled squares? (A & B)
    - Would you believe that they are the same color? (show the 2nd page, the illusion revealed, only after they have had time to explore the illusion)
    - ***Why do you think our brains sometimes "fill in" missing information?***
    - ***If our brain can be tricked by illusions, how do we really know what's real?***
2. Explain how the brain interprets visual signals, sometimes filling in missing information or making incorrect assumptions based on patterns.
    - Video to explain: Brain Tricks - This Is How Your Brain Works
3. **Key takeaways**: The brain doesn't just record what we see—it interprets information. The brain works with electrical signals, but it's not perfect—it can be tricked or influenced.

Connection to Mental Health & AI

1. Transition the conversation to how the brain interprets emotions and mental states—and how scientists use AI and machine learning to decode those interpretations.
2. Discussion Questions:
   What if we could use computers to 'read' what someone is feeling just by looking at their brain activity?
   What if a computer could predict your thoughts before you say them?
   What if technology [like AI, transcranial magnetic stimulation (TMS), deep brain stimulation (DBS), and brain-machine interfaces (BMIs) etc.] could help people with depression, PTSD, or paralysis by analyzing and altering their brain's electrical activity?

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:

Purpose: Investigate how the brain functions and how AI and machine learning can be used to decode emotions and illuminate mental illness from brain activity, and how treatments like TMS and DBS alter electrical states in the brain.

How the Brain Interprets Signals

1. Mini-Lecture with Brain Model or Diagram:
    - Explain how the brain receives signals from sensory organs (vision, hearing, touch) and processes them in different regions (e.g., the occipital lobe for vision, temporal lobe for sound).
    - Introduce neural pathways and how electrical and chemical signals are transmitted between neurons.
2. Hands-On Neural Signal Simulation:
    a. Have students act as neurons, passing a "signal" (e.g., a handful of cotton balls or other small soft objects) to show how the brain communicates. Neurons communicate using two types of signals: electrical and chemical signals.
        - Place several small balls (representing neurotransmitters) in the axon terminals of each "neuron."
        - Tap the first "neuron" to activate the signal, explaining that this represents sensory input, like seeing a falling vase.
        - The first neuron "fires" an action potential (students can act this out with a movement, like wiggling their arms like they are doing the wave).
        - The axon terminals (left hand) release neurotransmitter balls into the synapse, and the next neuron's dendrites collect them.
        - Receiving a Signal: Dendrites (right hand) receive a chemical signal from another neuron.
        - Triggering an Action Potential: If the chemical signal is strong enough, it changes the neuron's electrical state. If it reaches a certain threshold (enough neurotransmitter balls accumulate in the right hand of the neuron), an electrical signal (action potential) is triggered.
        - Sending the Signal: The action potential travels down the axon to the axon terminal.
        - Passing the Message: The axon terminal releases neurotransmitters (chemical messengers) across the synapse (the gap between neurons).
        - Continuing the Chain: If enough neurotransmitters are received by the next neuron, the process repeats, allowing signals to travel through the nervous system.
        - Action potentials follow an "all or nothing" rule. If the signal is strong enough to reach the threshold, a full action potential occurs and travels down the axon. There are no weak or strong action potentials—it's always a complete response or nothing at all. This helps prevent information loss during neuron communication.

b. Demonstrate how signals can slow down or misfire in conditions like depression, PTSD, or schizophrenia. (Many psychiatric disorders have been related to disturbances in synaptogenesis and subsequent plasticity.)

Teacher notes: *Neurotransmitters do not travel in the neuron. When enough neurotransmitters are attached to receptors and the necessary activation threshold is reached in the neuron, an electrical signal called an action potential is sent down the axon until it reaches the axon terminal, causing the release of neurotransmitters. Dendrites do not absorb neurotransmitters. These attach to receptors and then drop off, with some of them later on being recycled back into the neuron's action terminals.*

AI & Emotional Decoding

1. Students explore how scientists use EEG and fMRI data to train AI to recognize emotions based on brain activity. Example: AI can detect fear, happiness, or stress by analyzing brain wave patterns.
    - Possible videos to illustrate the points: EEG, The computer is learning to read your mind (note: this video is at least 6 years old and therefore advances have been made, however, it is a good representation of the challenges when using technology)
    - Interactive Simulation (if available): Students try an EEG-based brainwave game or use an online tool that demonstrates AI-driven emotional recognition.

Brain-Machine Interfaces & Mental Health Treatments

1. Introduce brain-computer interfaces (BCI) and discuss their potential applications for people with paralysis, depression, or anxiety.
    a. Video *Mind-reading computers turn brain activity into speech*
2. Introduce Transcranial Magnetic Stimulation (TMS) and Deep Brain Stimulation (DBS) as ways to treat mental illnesses by altering electrical activity in the brain.
3. Show a video explaining how TMS helps people with depression by stimulating specific brain regions.
4. Have students discuss how these treatments differ from traditional medication-based treatments.

Discussion Questions:

How does AI help scientists analyze brain activity?
How do brain-machine interfaces work, and what are their potential uses?
How can changing the brain's electrical state impact mental health?

EXPLAIN:

Purpose: Help students make connections between brain activity, mental health, and the role of AI and technology in neuroscience.

1. Introduction to the Video: Begin by informing students that they'll watch a video titled "Exploring Our Minds," which explores how artificial intelligence can interpret human thoughts and emotions by analyzing brain signals.
2. Guided Viewing: Provide students with a set of focus questions to consider while watching the video. These questions could include:
    a. What technologies are used to capture brain activity?
    b. How does AI process the data from these technologies to interpret emotions?
    c. What are the potential applications and ethical considerations of this technology?
3. Post-Viewing Discussion: After the video, engage the students in a discussion based on the focus questions. Encourage them to share their thoughts and insights, fostering a deeper understanding of the content.
4. Clarification of Concepts: Address any misconceptions or questions that arise during the discussion. Emphasize key points such as:
    a. The role of EEG and fMRI in detecting electrical and blood flow changes in the brain.
    b. How AI algorithms analyze patterns in brain activity to correlate with specific emotions.
    c. The importance of ethical considerations, including privacy and consent, in the use of such technologies.
5. Connecting to Prior Knowledge: Relate the video's content to previous lessons or activities, such as the Hands-On Neural Signal Simulation, to reinforce learning and demonstrate real-world applications.

ELABORATE: Applications and Extensions:

Purpose: Apply knowledge by designing AI-based mental health tools and debating ethical concerns.

Design a Mental Health AI Assistant

1. In groups, students design an AI system that can help people track their mental health based on brain activity.
2. They must include:
    - How it detects emotional changes
    - How it provides recommendations or interventions
    - How they would protect user privacy
3. Groups present their designs to the class.

Debate: Should We Use AI to Read and Change the Brain?

1. Divide students into groups arguing for and against the use of AI, BMIs, and electrical treatments in psychiatry.
    a. Key points to consider:
        - Potential benefits (better treatment, improved quality of life)
        - Risks (privacy invasion, ethical concerns)
2. Students present their arguments, and the class votes on whether AI in mental health should have limits.

EVALUATE:

Formative Monitoring (Questioning / Discussion):
Questions in bold, italics can be used to check student understanding throughout the lesson. Additionally, student presentations in the explore section and case study handouts in the elaborate section can be used to monitor student progress.

Summative Assessment (Quiz / Project / Report):
Score the Mental Health AI Assistant project using this rubric

Reflect using these two questions:
What is one technology you learned about today that could change mental health treatment?
Would you use a brain-machine interface if it could improve your quality of life? Why or why not?

Elaborate Further / Reflect: Enrichment:
Activity adapted from the Center for Sensorimotor Neural Engineering's Introduction to Neural Engineering & Ethical Implications-A Curriculum Unit for Grades 6-12 STEM Classes
Purpose: What happened in the past that will help students understand how the current innovations in neural engineering came to be.
Activity: Exploring the History of Neural Engineering: Students will create a timeline of events related to neural engineering from the topics of research/ethics, anatomy and physiology, prosthetics, and technology.

1. Create a timeline on the board/wall
2. Make copies of the Timeline Cards. The cards should be printed double-sided on cardstock using a different color for each topic. A full set of cards is enough for about 16 students in groups of 4.
3. Each group receives cards from one category: Ethics of Research, Anatomy & Physiology, Prosthetics, or Technology. Each card describes a historical event with a date on one side and no date on the other. Do not look at the date side!
4. Shuffle the cards and deal them evenly. Players do not look at or flip their cards.
5. If there is an uneven number of cards, place extra card(s) date side up in the middle. Otherwise, each player adds one card date side up to start the timeline.
6. How to Play:
    a. Arrange the cards in the middle from oldest (left) to newest (right).
    b. The first player places their top card where they think it fits in the timeline.
    c. Flip the card to check:
    d. If correct, leave it date side up.
    e. If incorrect, move it to the right spot and earn one point.
    f. Play continues clockwise until all cards are placed.

Discussion questions:
Based on the timeline activity, how have advancements in neural engineering improved our ability to restore or enhance movement and sensation?
What challenges do scientists still need to overcome in developing future neuroprosthetic technologies?
As neuroprosthetics become more advanced, what ethical concerns should we consider? For example, who should have access to these technologies, and how might they impact personal identity or human enhancement beyond medical necessity?

SOCIAL EMOTIONAL LEARNING ACTIVITY

CASEL Competency Addressed: Self-Awareness, Social Awareness, and Responsible Decision Making
Purpose:

1. **Ethical Dilemmas in Neuroprosthetics**
    a. Scenario Discussion: Present a real or hypothetical case where a neuroprosthetic device enhances human capabilities beyond normal function (e.g., brain implants for faster learning, robotic limbs stronger than human arms).
    b. Think-Pair-Share- Ask students:
        - Should these technologies be available to everyone or only those with medical needs?
        - How might these advancements create social or economic inequalities?
2. **Empathy Walk Activity**
    a. Assign students different roles (e.g., a person with a disability, a scientist, a policymaker, an athlete considering enhancement).
    b. Each student reflects on how they might feel about neuroprosthetics from their assigned perspective.
    c. Facilitate a class discussion on how different viewpoints shape ethical decisions.
3. **Personal Reflection Journal**
    a. Students write a short reflection on:
        - If I had access to a neuroprosthetic device, how would I use it?
        - How do I define "fairness" when it comes to who gets access to advanced technology?

Materials Required for This Lesson/Activity	
Quantity	**Description**
1 per class	Computer with Projector and Internet Access
1 per group	Computer with Internet Access for Research
1 per student	Copies of rubrics as found in the Evaluate section
1 per pair	Color copies of the Edward Adelson Checkerboard Illusion and illusion revealed (on cardstock if available)
20 pieces	Small soft objects for use in the Hands-On Neural Signal Simulation
***optional** for elaborate further section: 1 set of 20 timeline cards per group (2-4 players)	1 set of 20 timeline cards color coded to the categories: Ethics of Research, Anatomy & Physiology, Prosthetics, or Technology.

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