Grade Level 4-12
Lesson Length 1 class period

Lesson Summary: Students use a matching card game to explore and write about how they learn.

Standards Alignment

Next Generation Science Standards

- 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.
- 4-LS1-2. Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.
- MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
- MS-LS1-3. Use argument 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 storage as memories.
- HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.
- **Framework for K-12 Science Education**: Science & Engineering Practices 1,2,3,4,5,6,8

Objectives—Students will

- assess how they learn best.
- discuss why they learned better in one situation vs another.
- apply this reasoning to their own learning in and out of school.

 SEPA (Science Education Partnership Award) Supported by the National Center for Research Resources, a part of the National Institutes of Health. rev00-221102

Assessment Options (Evaluate)

Ask students to:

- write a reflection in their notebooks on how they learn best and why.
- write a reflection in their notebooks on how they maximize their own decisions and choose their own actions when studying.
- explain how practicing a musical instrument, foreign language, or routine improves the efficiency of neural pathways.
- turn in lab sheets or write a lab report.

Materials

- 1 deck of playing cards for every 6 students
  Sort cards such that each group of 2 students gets 9 pairs of cards matched for face value (two 2s, two Jacks, etc.) A pair of Jokers is needed for the third set. Color doesn't matter.

- notebooks for data recording and graphing
- timer app on phones or stopwatches

Procedures

Engage

Ask students to generate a list of procedures regarding how they learn best.

What do they have to do to really learn something? Since the VAK (visual-auditory-kinesthetic) learning styles are *myths* (see Scientific American article or just google 'VAK neuromyth'), do not accept answers such as, "I am a visual learner." We need all of our senses, decision making abilities and associated appropriate movements to learn.

Develop Questions

Sort this list into actions that are passive (e.g. listening to the teacher) vs active (e.g. doing the homework problems). Lead class to develop the following experimental questions.

How do I learn best?

- By watching and/or listening to others and doing what others do
- By trying to do it myself and figuring out how

Then have class make a prediction regarding which option might be best.
This dichotomy can be tested in the following experiment which is a modification of the card game Concentration.

Explore

Procedures

- Objective: Individuals make as many card pairs as possible. Each student's data is independent.
- Work in groups of 2: one person is the timer; one person is the watcher. Both students record their own data.

Rules for *Concentration 2 Ways*

- All games have a study phase and a test phase.
- The study phase lasts 2 minutes. Use the timer on a phone.
  Other directions for the study phase vary between Games A & B.
- The test phase is untimed.
- Shuffle 9 pairs of cards and place them face down in a 3 x 6 array.
- In all games, turn over 2 cards at a time, see them, and turn them back to face down.
- Turn over cards as many times as needed within the 2-minute study phase.
- The timer must not give the watcher hints of any kind, verbal or non-verbal.
- In the test phase, the watcher tries to find pairs by turning over 2 cards.
    - If they match, remove those cards and place them in the pair pile.
    - If they don't match, place the cards in the error pile.
- Score and record the number of matching pairs remembered and the number of error pairs.
- Take turns playing each game, switching who is the watcher. For players 1 & 2 and games A & B, use play order 1A, 2B, 1B, 2A or 2B, 1A, 2A, 1B.

Game A

Study phase: The watcher watches as the timer partner turns over the card pairs in any order (random or sequential) for 2 minutes.

The turner should systematically go through all cards. The turner should not intentionally uncover pairs they see at the same time. Then the watcher goes on to the test phase, trying to find as many pairs as possible.

Game B

Study phase: The same person (the watcher) studies and tests. The watcher turns over card pairs in any order for 2 minutes.

During the study phase, the watcher can turn over any pair of cards they want, unmatched or matched, as they choose. Then the watcher goes on to the test phase, trying to find as many pairs as possible.

 SEPA (Science Education Partnership Award) Supported by the National Center for Research Resources, a part of the National Institutes of Health. rev00-221102

Explain

Pool all the class data for numbers of correct and incorrect pairs for both games.
Compute averages and/or plot frequency histograms.

A # correct	B# correct	A # errors	B # errors
Follow partner	Control on own	Follow partner	Control on own

Discuss the data.

- What does the aggregated class data say? Under which conditions were more pairs formed?
- What were the differences in Game A and Game B?
- Why was Game A harder?
- What actions did each student take in Game B that made it more successful? Are all of these necessary?
- Have students offer interpretations of why this outcome was found. List these on the board. Which interpretations best explain the data?
- Did the outcome match students' predictions? Why or why not?
- How is making pairs in Concentration like learning?
- What does this outcome mean for each students' own learning?
- What strategies should students follow when studying?
- What does this mean for what students should be doing in class?

Expand

Discuss the experimental design.

- What were the controls in this experiment? *Each student was their own control. Why?*
- Why did the instructions include the game playing order: 1A, 2B, 1B, 2A or 2B, 1A, 2A, 1B?
- If the class didn't follow this order but always played Game A first and then Game B, how might that effect the data and its interpretation?
- If the class didn't follow this order, but player 1 did both games before player 2 did both games, how might that effect the data and its interpretation?
- What procedures could have been improved in this experiment? Why?

Discuss what is motivating to students about coursework and why.

Discuss agency. Do students have to know they are exerting their own agency to benefit from doing so? Did students think about their different roles in studying to find pairs in Games A and B?

Discuss decision making. What steps go into making a decision? Do we make all decisions the same way? How do we know which decisions are best? Does making a decision also involve evaluating its outcome? What decisions do students make in school?

Discuss the testing effect or retrieval practice. Wikipedia has a reasonable explanation of the testing effect. Note that when studying by self-testing, forcing themselves to make a choice and correct it, students are exerting their agency to learn the material. When studying for the chapter test, this means students must stop rereading, ask themselves (or each other) hard questions, and evaluate their answers. Spacing the study times over multiple days and regularly getting plenty of sleep will also help consolidate their learning.

Background

When students exert their own agency and actively explore the content to be learned, they learn better than when they watch or listen to someone else. Being actively involved and exerting agency is motivating. The brain circuits that compute motivation involve the reward circuit.

All decisions use the reward circuit to calculate the value of the choices – whether deciding what flavor of ice cream to buy or whether to get a job, the same circuit is involved. Learning school content requires students to make decisions about what to pay attention to and what to practice. Exerting agency, choosing to spend one's energy and attention on a project, raises the value of that project. Thus the reward circuit's value calculation is involved. Passively watching or listening to someone else do the project does not usually engage the reward circuit. In a social situation, the reward circuit is activated by the rewards generated from the social interactions. Curiosity also activates the reward circuit, as this represents internal motivation. All of these behaviors add a little more to the reward circuit calculations as it sums up the overall value for a decision or action.

When playing Game B, students had to choose which cards to turn over. They had to actively move their hands to do so, spending both mental and physical energy to learn where the pairs were. Both choosing and moving increased students' motivation to learn, i.e. increased their agency. The increased motivation resulted in increased attention to card positions. Not surprisingly, they remembered more pairs when they chose which cards to turn over and compared what they saw with what they remembered from previous cards. Even though this experiment only probed short-term memory, increased agency improves learning and memory on longer time scales as well.

Another curious aspect of the reward circuit is that its calculations are not on an absolute scale, but rather on a relative scale. The overall reward circuit calculates greater than or less than expected value. Getting an answer right on a test that one was uncertain about produces a positive 'reward prediction error' – a term used for surprise. Getting an answer wrong that one thought one knew produces a negative 'reward prediction error' – a term used for disappointment. Surprise or disappointment can be used to motivate correcting one's understanding. Getting an answer correct when one knew it was correct produces a 'reward prediction error' of zero, so this result is not reinforced further. Exerting agency effectively produces an expectation in the reward circuit calculations that can be compared to the outcome to motivate learning.

For more on the reward circuit, see the explanation in Motivation: Why You Do the Things You Do at Brainfacts.org.

A less detailed explanation is provided by **The Reward Circuit** series of short videos from the NIH:

- Version without drugs: The Reward Circuit: How the Brain Responds to Natural Rewards and Drugs
- Version with drugs of addiction: The Reward Circuit: How the Brain Responds to Methamphetamine

  Street drugs chemically activate the reward circuit to a greater extent than the rewards one gets from accomplishing a natural task successfully. Street drugs produce intense responses that hijack the reward circuit (and motivation) because they make natural rewards seem too small by comparison. Biochemically, street drugs distort the reward circuit calculations.

This lesson was inspired by the following scientific papers:

Murty VP, DuBrow S, Davachi L: The simple act of choosing influences declarative memory. *J Neurosci* 2015, 35:6255–64.

Voss JL, Gonsalves BD, Federmeier KD, Tranel D, Cohen NJ: Hippocampal brain-network coordination during volitional exploratory behavior enhances learning. *Nat Neurosci* 2011, 14:115–120.