Toxins in an Ecosystem

Companion Lesson to X-STEM All Access Episode "One-on-One with the Classy Chemist"

Grade/ Grade Band: Middle School-High School	**Topic:** Cycling of Matter through ecosystems–Bioaccumulation	

Brief Lesson Description:
Students will explore how matter in the form of a toxin cycles through an ecosystem. They will use data collected from a kinesthetic simulation and a virtual simulation to create a model explaining why the toxin accumulates at higher concentrations the further it moves through the food chain.

Performance Expectation(s):
NGSS MS LS 2-3: Develop a model to describe the cycling of matter and the flow of energy among living and nonliving parts of an ecosystem.

NGSS HS LS 2-2: Use Mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems on different scales.

Specific Learning Outcomes:
Students will be able to :
-Define what a toxin is and how it travels through an ecosystem.
-Develop a model that explains how toxins relative amounts increase as it moves from producers to consumers that includes living and nonliving components of an ecosystem.

Narrative / Background Information

Prior Student Knowledge:
Prior to this lesson, students should have content knowledge of how energy is transferred through a food chain and food web. They should also understand that as energy moves through the chain, the number of organisms decreases to support their energy needs.

Science & Engineering Practices:	Disciplinary Core Ideas:	Crosscutting Concepts:
Develop and Using Models: Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop a model to describe phenomena. (MS-LS2-3) **Using Mathematics and Computational Thinking:** Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena or design solutions to support and revise explanations. (HS-LS2-2)	**LS 2.B:** Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3) **LS2.C:** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2)	**Energy and Matter:** The transfer of energy can be tracked as energy flows through a natural system. (MS-LS2-3) **Scale, Proportion, and Quantity:** Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. (HS-LS2-2)

Possible Preconceptions/Misconceptions:
-Students may think that food webs are simplistic like food chains. However, food webs show complex relationships about how energy is transferred through an ecosystem. There are multiple pathways rather than one simple progression.
-Students may think that organisms that are higher in a food web eat everything below them. However, this is inaccurate because higher organisms eat some, not all, other organisms in the food web.
-Students may think that predator and prey populations are similar in size. However, the higher in the food web an organism is found, the smaller the population generally is.

LESSON PLAN – 5-E Model (Suggested Timing: Day 1 (Engage and Explore); Day 2 (Explain, Elaborate, Evaluate)

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

1. Teacher will explain that "Chemistry is a branch of science that is fundamental to studying many different topics in the natural world. Today we are going to explore how Chemistry is used to help keep humans safe. We are going to watch the video "One on One with the Classy Chemist" to learn a little bit more."
2. Show video: One on One with the Classy Chemist
3. After watching the video, have students discuss the following prompts with a shoulder partner:
    a. *Dr. Daniels works hard to develop tools to help remove what from the environment?*
    b. *Why is the speaker's work important to keeping people safe?*
    c. *If you could ask this speaker any question, what would you ask?*
4. Accessing Background knowledge:
    a. "Toxins are chemicals that cause disease when they are present in an organism, sometimes at even the smallest concentration (amount). As a table group, *create a list of toxins you think humans might be exposed to in either the environment or their jobs."*
    b. Provide 5 minutes for students to generate a list. Then have them share a a class to compile a list of common toxins
5. Set purpose for remaining lesson: " Dr. Daniels' work is focused on keeping humans safe from the environment or in their jobs by removing toxins. But what happens when toxins remain? We are going to explore what happens to Toxins as they move through the food chain in an ecosystem."

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

Prior to starting the explore section of this lesson, you will need to gather the following materials for a class of 30:
300 Cotton Balls
1 Permanent Marker
Twenty (20) 3 oz cups (Small bathroom cups)--Label each cup primary consumer and/or small fish/shellfish
Eight (8) 5 oz cups (Large bathroom cups)--Label each cup secondary consumer and/or large fish
Two (2) 12 oz cups (Plastic punch cups)
Timer
Area marked off with masking tape that holds all students (Suggested size: 12 ft x 12 ft if available)

Using the Google Slides, (Link to Google Slides) you will conduct a kinesthetic simulation with students to see how a toxin travels through an ecosystem.

Slide 1 Script:
Today we are going to consider how matter moves through an ecosystem. We will be thinking about an aquatic (water) ecosystem located in the Japanese city of Minamata. This ecosystem is found in a saltwater sea near an island in the Yatsushiro Sea. The area is often the site of commercial fishing and the wildlife that is caught is eaten by locals. Our ecosystem is represented by the area taped off on the floor. You will each be one organism in this ecosystem.

Slide 2 Script:
The primary producer in this ecosystem is phytoplankton. We will represent these producers by using cotton balls. (Spread the cotton balls across the simulation area). Question: *Where do the producers get their energy and nutrients?*

Next, there are primary consumers (small shellfish and fish) that eat the phytoplankton–these are primary consumers. Twenty of you will represent these. (Hand out the 3 oz cups to each of these students) Question: *Where do these primary consumers get their energy and nutrients?*

Next, there are secondary consumers (large fish) that eat small shellfish and fish. Eight of you will represent these organisms. (Hand out the 5 oz cups to each of these students) Questions: *Where do these secondary consumers get their energy and nutrients?*

Finally, there are tertiary consumers (Humans) that can eat either small shellfish/small fish or large fish. Two of you will represent these organisms. (Hand out the 12 oz cups to each of these students). Question: *Where do these tertiary consumers get their energy and nutrients?*

Turn and talk to a shoulder partner: *Why do we have fewer organisms as we go up the food chain in the ecosystem?* Give students time to share and then discuss student ideas as a class.

Slide 3 Script:
Near Minamata there are several chemical plants that release waste into the sea. One of the chemicals that is released into the environment is Methyl Mercury. Methylmercury is a toxin that causes imparied neurological (brain) development in humans. This can affect how people pay attention, remember information, learn new information, their language, and their motor skills like walking. Humans can be impacted at even low levels of exposure. The World Health Organization (WHO) has named Mercury one of the ten most dangerous chemicals in the world.

In our simulation we will represent mercury with a colored dot on the phytoplankton (cotton balls) as they absorb the chemical from the water.

Slide 4 Script:
We are going to do a simulation today to see how the Mercury that was released into the bay affects the organisms in the area. The small fish/shellfish will have 15 seconds to eat as much phytoplankton as they can. Then the large fish will have 15 seconds to eat as many of these as they can. Finally, the humans will have 15 seconds to eat as many small fish/large fish as they can. When you eat an organism, you will put all of its cotton balls into your cup. When your cup is full, your organism is full and cannot eat any more! At the end of each 15 second section, we will collect data to see how much mercury each organism consumed.

Slide 5 Directions:
Have students complete the simulation. At the end of each 15 seconds, have students count how much mercury (colored dots) they have in their cup. Collect data on the class data table on the Google Slide. (Note: It is helpful to take the google slides out of the present mode at this point and type in the data to the table. Then, when all data is collected, have students return supplies to the teacher and return to their seats.

Slide 6 Directions:
With your table group, look at the data we collected. As a group, answer the following 2 questions:

1. *What happens to the amount of mercury that is consumed by each type of organism? What evidence from the table did you use to draw this conclusion?*
2. *If higher amounts of mercury have larger effects on organisms, which organism in this ecosystem is most affected by the mercury pollution? How do you know?*

EXPLAIN: Concepts Explained and Vocabulary Defined:
Teachers will explain:
"This simulation showed us what happens when mercury moves through the food chain. This process is called Bioaccumlation. We will now use a new simulation to learn about the science of bioaccumulation and how it moves through another aquatic ecosystem. As you complete the simulation, you will complete a graphic organizer that explains the science of this phenomena. You will record information in both words and pictures on your organizer"

Teacher should hand out the graphic organizer and have students go to
https://www.sciencelearn.org.nz/image_maps/119-bioaccumulation-in-the-sea

Students should complete the graphic organizer as they go through the simulation.
Link to Graphic Organizer: https://docs.google.com/document/d/16zpcBF9tQGZJ4uDLmDzBsBEVK0h5_QG47h7eItJOPFw/edit?usp=sharing

Vocabulary: Toxin, bioacculumation, producer, consumer, scavenger, food web, primary, secondary, tertiary

ELABORATE: Applications and Extensions:
Teacher will explain that "Today we have used two different models to explore how a toxin (mercury) moves through an aquatic ecosystem. In the first simulation we learned about how the amount of Mercury found in organisms increases as it travels through the food web. In the second simulation, we learned about the process of bioaccumulation in consumers. Now, as a group, your task is to create a scientific model that shows how mercury moves throughout an aquatic food web"

Ask groups to begin by creating a checklist as a class of what information/ideas they feel should be included in the scientific model. Then, provide each group with paper/markers to create their model.

As students work through their model, teachers should work around the room and ask probing questions to help students consider what they are creating. Some possible probing questions for this model might include:
-How will you show how matter flows through the ecosystem?
-How will you show how energy flows through the ecosystem?
-How might you show the amount of matter as it goes higher in the food web?
-How might the results of our fist model (the cotton ball simulation) look across the food web instead of the food chain that we modeled?

If you are unfamiliar with creating scientific models with students, visit https://thewonderofscience.com/developing-and-using-models or https://stemteachingtools.org/brief/8 to learn more.

EVALUATE:

Formative Monitoring (Questioning / Discussion):
Embedded Questions and Class discussion throughout the lesson. These questions can be found in *italics*.
You can also gather evidence of understanding by looking at their initial models created during the elaborate section of the lesson.

Summative Assessment (Quiz / Project / Report):
After students complete their models, have students present their model to the class. This presentation can be used as the assessment of this lesson. A student/group that is proficient should include the following information:
-Explanation of mercury moving through the ecosystem is clear.
-A complete understanding is shown that includes how more mercury accumulates at higher levels of the food web.
-The relationships between organisms in the food web are shown clearly.

After all groups have presented, help them to name components that are similar across models and discuss those that are different. This should lead to group discussion to determine what next steps in learning are for the class.

Elaborate Further / Reflect: Enrichment:
Students who are interested can conduct independent research on common toxins found in water and present their impact on humans to their classmates. Possible topics include:
-Lead (Flint Water Crisis)
-Mercury (Minamata Disease in Japan)
-E Coli in drinking water

SOCIAL EMOTIONAL LEARNING ACTIVITY

Direction Instruction:
In the X-STEM episode "One on One with the Classy Chemist", Dr. Daniels talks about how she overcame obstacles including not being admitted to graduate school in psychology or neuroscience. She was able to overcome this obstacle to become a PhD chemist. To help you learn to consider how to overcome challenges, we will learn a new strategy called the "WOOP"method.

Teachers will explain that the WOOP method stands for:
W: "Wish"--What is the goal/wish that you want to achieve?
O: "Outcome"--What will it look like/feel like if this goal is achieved? Be as specific as possible.
O: "Obstacle"--What obstacles might you encounter trying to achieve this goal? Brainstorm as many as you can.
P: "Plan"--Create a plan for what positive behavior you will do if you encounter this obstacle. "If __X__ happens, then I will ___Y___"

The teacher will then provide an example of how this acronym can support students in planning for obstacles they encounter as they pursue goals.

W: My goal is to earn an A in chemistry class.
O: I will achieve A's on my assignments and tests in this course. I will understand the material that is being taught in class. I will feel proud of my learning.
O: Receiving a poor grade on a test/assignment, not understanding material that is taught, missing class due to an illness.
P: If I receive a poor grade on a test/assignment, then I will change how I study for the next exam.
If I receive a poor grade on a test/assignment, I will ask the teacher to meet with me to reteach the material.
If I do not understand the material that is being taught, I will find a study partner on my volleyball team to help me understand.
If I miss class due to an illness, I will go work with my chemistry teacher during our schools access period

Guided Practice:
Provide each group of students with a graphic organizer -or- a white board. Have them complete the WOOP method for one (or more of the following goal statements:

- I will improve my time running the mile in PE Class.
- I will meet new friends in a club I am participating in.
- I will be accepted into a college when I graduate.

As a group, have them complete the WOOP method to plan for what they will do if they encounter obstacles. Then, have them share their ideas with another group. The group that listens to the presentation should provide feedback using the following sentence stems:

- One thing you did well was ________ because ___________.
- Another way you could deal with this obstacle is _________________ because ________________.

Individual Practice:
Have students complete the WOOP method for a goal/wish of their own. Have them share with a partner for feedback.

For additional resources on the WOOP method, visit https://characterlab.org/activities/woop-for-classrooms/

INTERDISCIPLINARY CONNECTIONS/IDEAS
Career and Technical Education: Dr. Daniels work as an industrial hygienist is to identify potential toxins that various workers will encounter during their job and create materials/methods for these workers to come home safely to their families. Collaborate with CTE students/teachers to consider what types of unique toxins they might encounter in their CTE courses and what safety measures are in place to protect them. **Language Arts:** Dr. Daniels work as an industrial hygienist is to identify potential toxins that various workers will encounter during their job and create materials/methods for these workers to come home safely to their families. Have students conduct a research project into what types of toxins are most commonly found in careers they wish to pursue. Have students create an infographic to explain the toxins and how humans can be protected from them in the workplace. **Social Studies:** Dr. Daniels work as an environment chemist focuses on cleaning toxins out of water. This work is governed by the Environmental Protection Agency in the United States. Research how regulations keep humans safe in your local community and share with your class.

Materials Required for This Lesson/Activity	
Quantity	**Description**
300	Cotton Balls
1	Permanent Marker
20	3 oz cups
8	5 oz cups
2	12 oz cups
1	Roll of Masking Tape

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