Unit Title: Energy and Matter in Aquatic Ecosystems

Subject/Target Grade: 6th grade science

Unit Summary:

This unit will introduce some of the basic concepts of ecosystem science at a 6th grade curriculum level. Students will learn how energy and matter flow and cycle within and across ecosystem boundaries. This unit incorporates and relates to several components of the current 6th grade science curriculum in use at Washington Middle School (Calumet, MI) which teach students about the concepts of energy and matter with a physical science focus. Adding an ecosystem science unit to the current curriculum will provide teachers and students with an opportunity to explore the connections between traditional physical science and life science in the natural world. This unit is designed to be taught in conjunction with the current 6th grade science curriculum so students will have some background knowledge about energy and its' forms, as well as some of the general properties of matter prior to beginning any of the lessons in this unit.

Next Generation Science Standards:

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-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

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-LS1-6: Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.]

MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. [Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.]

MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. [Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.]

MS-LS2-3: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.] [Assessment Boundary: Assessment does not include the use of chemical reactions to describe the processes.]

MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]

MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services.* [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]

Math CCSS 6th grade:
6.EE: -Represent and analyze quantitative relationships between dependent and independent variables.

6.SP: -Develop understanding of statistical variability.
-Summarize and describe distributions.

Learning Objectives: Students will be able to:

1. **Use scientific tools such as thermometers, rulers, balances, etc. to collect data in a classroom/laboratory setting**
2. **Identify the proper metric units to use when collecting scientific data on temperature, mass, length, etc.**
3. **Interpret and draw conclusions from data collected in a classroom/laboratory setting.**
4. **Describe general properties of matter.**
5. **Define energy.**
6. **Name four forms of energy.**
7. **Define "Abiotic".** (*Clarification: Students will be expected to explain that "Abiotic" refers to the* ***non-living*** *parts of an ecosystem*).
8. **Define "Biotic".** (*Clarification: Students will be expected to explain that "Biotic" refers to the* ***living*** *parts of an ecosystem*).

9. **Define "Ecosystem".** (*Clarification: Students will be expected to describe: living and non-living components of an ecosystem, and the interactions between the living and non-living components of an ecosystem*).

10. **Describe how humans fit into ecosystems.** (*Clarification: Students will be expected to explain that humans are a part of ecosystems that interact with other organisms and their environment*).

11. **Describe how ecosystem boundaries are defined for study**. (*Clarification: Students will be expected to explain that ecosystems can be studied at many different scales. I.e. Ecosystems can be as small as an aquarium or fish-bowl or as large as the entire planet depending on what factors are being studied).*

12. **Define "Photosynthesis" and describe the role it plays in the flow of energy in ecosystems.** (*Clarification: "Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis"; Next Generation Science Standards, LS1.C*).

13. **Describe what is meant by "resource availability" in an ecosystem.** (*Clarification: Students will be expected to explain that the term "resource" can refer to habitat, food/energy sources, water, etc. "Resource availability" can be used to describe the amount of, and/or access to, a particular resource.*)

14. **Develop predictive statements about how changes in resource availability (reduction, or increase) may affect the growth of organisms (cause and effect relationship).**

15. **Construct a graphical model/diagram showing the major biotic components, abiotic components, and energy-flow pathways of an ecosystem of their choice.** (*Clarification: Students will be expected to include examples of organisms found in their ecosystem, habitat features, and basic energy-flow pathways beginning with sunlight*).

16. **Define and identify dependent and independent variables in ecological data sets.**

17. **Construct graphs of the dependent and independent variables in ecological data sets.**

Table of Lessons:

1. What is an Ecosystem & Model Your Favorite Great Lakes Ecosystem
2. Tools of the Trade
3. Energy and Matter in the Environment
4. A 6th Grade Scientist's Investigation of an Aquatic Ecosystem

Lesson Title- Brief Description	**Learning Objectives**	**NGSS Addressed**	**Materials**
Tools of the Trade	• Accurately measure water temperature (°C) using a thermometer • Accurately measure water temperature (°C) using a digital temperature probe • Accurately measure Dissolved Oxygen content in water using a digital probe • Accurately measure the pH of: Distilled water, Vinegar, and Milk of magnesia • Accurately measure the length (mm) of an object with a ruler • Accurately measure the mass of an object with a triple-beam balance		• *Tools of the Trade* Student handout • Thermometers: Red Spirit filled, dual scale (*Fahrenheit & Celsius*). 10-12 depending on class/group size • Digital temperature probe: e.g. Vernier LabQuest®2 • Dissolved Oxygen probe: e.g. Vernier Dissolved Oxygen Probe DO-BTA • pH Test strips: e.g. Hydrion Spectral MICRO ESSENTIAL pH Strips. One pack (*100 strips*) • Distilled water: • White vinegar: (*or any suitable weak acid*) • Milk of magnesia: (*or any suitable base*) • Rulers: Metric and Imperial units. 10-12 depending on class size • Balance(s): e.g. Ohaus Triple Beam • Calibration Weights: Will need to have a variety of masses available (*e.g. 1g, 2g, 5g, 20g, 50g, 100g*)
What is an Ecosystem & Model Your Favorite Great Lakes Ecosystem	• Define an ecosystem (Clarification: Students will be expected to describe: living and non-living components of an ecosystem, and the interactions between the living and non-living components of an ecosystem). • Define "Abiotic". (Clarification: Students will be expected to explain that "Abiotic" refers to the non-living parts of an ecosystem). • Define "Biotic". (Clarification: Students will be expected to explain that "Biotic" refers to the living parts of an ecosystem).	**MS-LS1-6:** Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.]	• *What is an Ecosystem*? PowerPoint • *What is an Ecosystem*? • Student notes handout (to be completed by students during PowerPoint slideshow) • *Model Your Favorite Great Lakes Ecosystem* Student handout with rubric • Computer(s): with Microsoft PowerPoint (or similar) software • Poster Template.pptx • Example ecosystem posters

	• Describe how ecosystem boundaries are defined for study (Clarification: Students will be expected to explain that ecosystems can be studied at many different scales. I.e. Ecosystems can be as small as an aquarium or fish-bowl or as large as the entire planet depending on what factors are being studied). • Describe four (4) types of ecosystems found in the Great Lakes region. • Describe how humans fit into ecosystems (Clarification: Students will be expected to explain that humans are a part of ecosystems that interact with other organisms and their environment). • Construct a graphical model/diagram showing the major biotic components, abiotic components, and energy-flow pathways of an ecosystem of their choice. (*Clarification: Students will be expected to include examples of organisms found in their ecosystem, habitat features, and basic energy-flow paths beginning with sunlight*).	**MS-LS2-3:** Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.] [Assessment Boundary: Assessment does not include the use of chemical reactions to describe the processes.]	
Energy and Matter in the Environment	• Define "Photosynthesis" and describe the role it plays in the flow of energy in ecosystems. (Clarification: "Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis"; Next Generation Science Standards, LS1.C). • Describe general properties of matter. • Define energy. • Name four forms of energy.	**MS-LS1-6:** Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.]	• *Energy and Matter in the Environment* Microsoft PowerPoint presentation • *Energy and Matter in the Environment* Student handout • Thermometers: Red Spirit filled, dual scale (*Fahrenheit & Celsius*). 10-12 depending on class/group size • Digital temperature probe: e.g. Vernier LabQuest®2 • Calorimeters: e.g. Ward's Science Economy Calorimeter 5-6 depending on class/group size • Dried plant material • Dried insects: e.g. freeze dried crickets, etc. • Matches or lighters

A 6th Grade Scientist's Investigation of an Aquatic Ecosystem	• Identify dependent and independent ecological variables • Apply the scientific method to develop and write a scientific hypothesis about an aquatic ecosystem including one dependent variable and one independent variable • Write a clear set of procedures for collecting data needed to test their hypothesis • Use scientific tools such as thermometers, rulers, balances, etc. to collect data in a classroom and in an outdoor setting • Construct graphs and tables to display ecological data • Interpret ecological data and explain whether the data they collected support or refute their hypothesis	**MS-LS2-1:** Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. [Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.] **MS-LS2-2:** Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. [Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.] **MS-LS2-5:** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.* [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]	• Student activity packet containing: - *Developing a Scientific Hypothesis* - *Designing an Investigation of an Aquatic Ecosystem* - *Interpreting Your Data, What Have We Learned* • Wading Boots: e.g. knee-high rubber boots, hip waders, chest waders • Thermometers: Red Spirit filled, dual scale (Fahrenheit & Celsius). 10-12 depending on class/group size • Digital temperature probe: e.g. Vernier LabQuest□2 • Dissolved Oxygen probe: e.g. Vernier Dissolved Oxygen Probe DO-BTA • pH Test strips: e.g. Hydrion Spectral MICRO ESSENTIAL pH Strips. One pack (100 strips) • Rulers: Metric and Imperial units. 10-12 depending on class size • Balance(s): e.g. Ohaus Triple Beam • Aquatic Dip-nets: e.g. Frabill Smelt/Shrimp/Shad Net (or any similar net with maximum mesh size of 3/8", and minimum handle length of 48"). 4-5 minimum depending on group size • Beach Seine: e.g. Douglas Nylon Minnow Seine (4' X 20' X ¼" mesh). One per group • Bucket(s): Five gallon bucket(s) to hold water and aquatic organisms collected during field activity

Safety Considerations:

1) Tools of the Trade:
- Broken Glass (*thermometers and/or glassware*)
- Spills (*water, acid, base, etc.)*

3) Energy and Matter in the Environment:
- Broken Glass (*thermometers and/or glassware*)
- Burns (*When using calorimeter*)

4) A 6th Grade Scientists Investigation of an Aquatic Ecosystem:
- Broken Glass (*thermometers and/or glassware*)
- Spills (*water, acid, base, etc.)*
- Inclement weather (*outdoor activity*)
- Wildlife encounters (*outdoor activity*)
- Water safety (*outdoor activity*)

Evaluation Plan:

Formative Assessment Tools:

1. *Tools of the Trade*
- Students work in small groups to complete a series of laboratory exercises learning how to safely and properly use a variety of scientific equipment

2. *What is an Ecosystem & Model Your Favorite Great Lakes Ecosystem*
- During the lecture students will ask and be asked various questions about ecosystems
- Students will complete a worksheet following the lecture
- Students will write a short paragraph about humans position in ecosystems
- Students select a Great Lakes region ecosystem to research
- Students explore the kinds of biotic and abiotic components found in the ecosystem of their choosing
- Students create a deliverable product of their research using technology

3. *Energy and Matter in the Environment*
- Students work in small groups to complete a laboratory exercise exploring how combustion releases energy from organic matter in the form of heat
- Students learn how calorimeters are used to determine the amount of energy stored in organic matter
- Students will complete a note worksheet during the lecture

4. *A 6th Grade Scientist's Investigation of an Aquatic Ecosystem*
- Students follow the principles of the scientific method to design an investigation based on what they want to learn about a local aquatic ecosystem
- Students create a testable hypothesis and set of procedures to guide their investigation
- Students identify independent and dependent ecological variables
- Students interpret the findings of their study

Summative Assessment Tools:

1. *Tools of the Trade*
- Complete a lab worksheet demonstrating the proper use of a variety of scientific equipment

2. *What is an Ecosystem & Model Your Favorite Great Lakes Ecosystem*
- Students create a deliverable product of their research in the form of a large format poster
- Students will present a 1-2 minute discussion explaining the content of their poster to an audience of their teachers, parents, and/or classmates

3. *Energy and Matter in the Environment*

- Complete a lab worksheet demonstrating their understanding of how energy is stored in organic matter and released during combustion and expand this concept to the transfer of energy in ecosystems.

4. *A 6th Grade Scientist's Investigation of an Aquatic Ecosystem*

- Students analyze and interpret the findings of their study to prepare a short (1-2 paragraph) report summarizing the findings of their investigation
- Students will create graphs and/or tables to visually display their data as part of their summary report

Resources (websites):

- **National Oceanic and Atmospheric Administration Great Lakes Environmental Research Laboratory**
  This site provides information covering the entire Great Lakes basin including ecological and economic descriptions of the basin as a whole, threats to the Great Lakes, and profiles of each lake with food web diagrams.

- **Great Lakes Ecological Protection and Restoration, U.S. Environmental Protection Agency**
  This site provides links to reports describing threats, protection, and restoration measures for several Great Lakes ecosystems.

- **Michigan Department of Natural Resources**
  This site provides detailed descriptions of the 76 natural community types found in the State of Michigan.

- **Hyperphysics Calorimetry**
  This site provides a brief description of the principles of food calorimetry as well as an online tool for performing calorimetry calculations.

- **Food Calorimetry, Carolina Biological Supply**
  This site provides a detailed food calorimetry activity and link for purchasing calorimeter equipment.

- **Vernier Software and Technology**
  This site provides information and pricing for digital probes available from Vernier.

- **Michigan Technological University, Aquatic Ecology**
  This site provides information about some of the Aquatic Ecology research that is being conducted by scientists at Michigan Technological University.

- **Wildlife Supply Company**
  This site carries a variety of tools and equipment for conducting aquatic research.

How this material relates to my graduate research

The addition of an ecosystem-based unit such as this will help students to "bridge the gap" between the traditional physical sciences and life sciences by incorporating aspects of both disciplines into the lessons. This unit is intended to complement the curriculum currently in use in my partner

teacher's classroom. The connections between resource availability, physical habitat, and fish communities provide an excellent avenue for middle school students to begin to explore some of the basic aspects of ecosystem science such as the flow of energy and cycling of matter in aquatic systems.

As a doctoral student in the department of Biological Sciences at Michigan Technological University my graduate research focuses on exploring the interactions between aquatic organisms and their environment. My dissertation research is part of a larger project involving scientists from Michigan Technological University and The Little River Band of Ottawa Indians investigating the potential for re-establishing a native fish species into a watershed from which it was extirpated over a century ago. Specifically, I am interested in determining how resource availability (i.e. food) and habitat conditions structure and regulate fish communities in freshwater ecosystems. Much of the focus of my current research involves studying the energetic trade-offs faced by fish species that feed on drifting invertebrates in flowing water in order to estimate the carrying capacity of those species.