Feeding the World: Water Quality Overview - Middle School

Disclaimer: The charts included in this unit make one set of connections between the lessons outlined in the unit an dhte NGSS performance expectations. Other valid connections are likely; however, space and time restrictions prevent us from listing all possibilities.

This middle school unit on Water Quality exposes students to several methods and techniques of water testing as applied in community science and agriculture. The Science and Engineering Practices covered in these lessons include: **Constructing Explanations and Designing Solutions** in order to create explanations and design solutions to improve human impacts to aquatic ecosystems.

Much of this unit centers around the Nature of Science. These four aspects are closely aligned with the practices.

- Scientific Investigations Use a Variety of Methods
- Scientific Knowledge is Based on Empirical Evidence
- Scientific Knowledge is Open to Revision in Light of New Evidence
- Scientific Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

While these are more closely aligned with the Crosscutting Concepts:

- Science is a Way of Knowing
- Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Science is a Human Endeavor
- Science Addresses Questions About the Natural and Material World

Lesson 1A *How Clean is the Water?* introduces the phenomena of the unit through a big question, ***How Clean is the Water?*** then encourages students to begin to observe differences in water appearance and look for human impacts that can lead to poor water quality. Lesson 1B *Chemical and Physical Tests to Determine Water Quality* asks students to perform both chemical and physical tests to assess water quality and begin to construct explanations for the health of the aquatic system. Lesson 1C *Biotic Testing* asks students to continue investigation with macroinvertebrate testing and observation of the aquatic system to construct an explanation for stream health and begin to design solutions for water quality improvement. Lesson 1D *Water Quality Conclusion* asks student so construct and explanation for stream health and design solutions for human activities that have impacted stream health.

Water Quality testing is a set of techniques that have been developed to monitor natural water systems that may or may not have been impacted by human activities. Aquatic organisms are very susceptible to changing water conditions and have a narrow range of tolerance to the ecosystem's chemical and physical factors. Human impact has dramatically changed many aquatic ecosystems and water testing is necessary to help maintain and improve natural water systems. Students will have a chance to investigate these water testing techniques and make connections to the human activities than have affected the health of an aquatic ecosystem. Students will then help to design solutions to decrease human impact to the water systems and improve water quality.

Science and Engineering Practices

Lesson 1A: How Clean is the Water?
Constructing Explanations and Designing Solutions

Lesson 1B: Chemical and Physical Tests to Determine Water Quality
Constructing Explanations and Designing Solutions

Lesson 1C: Biotic Sampling
Constructing Explanations and Designing Solutions

Lesson 1D: Water Quality Conclusion
Constructing Explanations and Designing Solutions

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Water Quality Storyline

Phenomenon: *How clean is that water? Show the slidedeck of different aquatic ecosystems with two water samples in a jar to be passed around by students for their observation.*

Lesson/Focus Question	Overview	What should students be able to explain?	How does this add to their explanatory model?
Lesson 1A **How Clean is that Water?** *How can we monitor water quality and the conditions that allow for different animals and plants to survive in an aquatic ecosystem?*	Students brainstorm factors that can cause adverse effects on the organisms in a water system.	The interaction and dependence of nonliving and living components in an ecosystem. The factors that affect water quality.	Students will be able to describe the biological, physical and chemical characteristics that are utilized in water quality assessments.
Lesson 1B **Physical and Chemical Water Testing** *How can we analyze the abiotic components (chemical and physical tests) of the stream in order to determine the stream's overall water quality?*	Students test the chemical and physical components of a water system. .	How the chemical and physical components of the water system can help to determine water quality and the potential harm to the aquatic ecosystem.	There are various ranges of tolerance that aquatic organisms have to both physical and chemical factors in a water ecosystem. Students are able to test these components to determine a quantitative water quality assessment for consideration as they design their solution to improve the health of the aquatic ecosystem. .
Lesson 1C **Biotic Water Sampling** *How can the health of an aquatic ecosystem be determined by the macroinvertebrates present in the ecosystem*?	Students investigate the macro invertebrate diversity of a water system.	How macroinvertebrate diversity in a water system can be used to assess the health of an aquatic ecosystem.	There are macroinvertebrates that are more sensitive to water quality conditions than others which with greater tolerance. By identifying the macroinvertebrates in a water system, it is possible to assess the health of the aquatic ecosystem.
Lesson 1D **Water Quality Conclusion** *How can the health of an aquatic ecosystem be determined by the biotic and abiotic factors present in the ecosystem? How can the human impact be*	Students analyze biological, chemical, and physical water quality data to provide a water quality assessment and design a solution to improve or maintain the health of the	The water health of an aquatic ecosystem utilizing biological, physical and chemical data. How the chemical, physical, and biological factors interact to create the water quality rating assessed.	Students will be able to explain if the aquatic ecosystem is clean/healthy for aquatic life based on previously tested factors and analysis. Students will be able to design potential solutions to remediate the aquatic ecosystem based on the health of the system.

lessened to maintain or improve the water quality rating for an aquatic ecosystem?	aquatic ecosystem. .		

Water Quality Unit - Middle School

MS-ESS3: Earth and Human Activity		
Students who demonstrate understanding can: **MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.** ● *Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).*		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. ● Apply scientific principles to design an object, tool, process or system.	**ESS3.C: Human Impacts on Earth Systems** ● Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.	**Cause and Effect** ● Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.

Middle School: Water Quality Vocabulary

Lesson 1A

- **Ecosystem:** a biological community of interacting organisms and their physical environment
- **Biodiversity:** the variety of life in a particular habitat or ecosystem

Lesson 1B

- **Turbidity:** is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates
- **Dissolved Oxygen (DO):** is the amount of gaseous oxygen(O_2) dissolved in the water
- **Biological Oxygen Demand (BOD):** is the amount of dissolved oxygen needed (i.e. demanded) by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period
- **pH:** a scale used to specify how acidic or basic a water-based solution is
- **Phosphate:** a nutrient needed for plant and animal growth
- **Nitrate:** a nutrient needed for plant and animal growth to build proteins
- **Resilience:** the capacity of an ecosystem to respond to a perturbation or disturbance by resisting damage and recovering quickly

Lesson 1C

- **Riffle Zone:** zones in a stream that are shallow with fast, turbulent water running over rocks
- **Macroinvertebrate:** organisms that lack a spine and are large enough to be seen with the naked eye
- **Range of Tolerance:** an organism's ability to survive (range of tolerance) within certain abiotic conditions found in its habitat
- **Dichotomous Key:** a key that consists of a series of 2 choices that lead the user to the correct name of a given organism

Water Quality Pretest/Posttest

Choose the best answer.

1. Turbidity is the measure of the relative ____ of water.
   A. Color
   B. Sediment Content
   C. Acidity
   D. Clarity

2. Temperature can affect the level of _____ in water.
   A. Sediment
   B. Dissolved Oxygen
   C. Turbidity
   D. None of the above

3. _____ is needed by aquatic plants and animals to build protein.
   A. Phosphate
   B. Turbidity
   C. Nitrate
   D. None of the above

4. A limiting factor for freshwater plant growth is _____.
   A. Phosphate
   B. Nitrate
   C. pH
   D. None of the above

5. Macroinvertebrates that are tolerant of environmental conditions.
   A. Mayflies
   B. Leeches
   C. Fish
   D. All of the above

6. Macroinvertebrates that are intolerant of environmental conditions.
   E. Mayflies
   F. Leeches
   G. Fish
   H. All of the above

Water Quality Pretest/Posttest Answers

Choose the best answer.

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Lesson 1 Introduction - Teacher Explanation

The following four lessons, Lessons 1A-1D, are proposed to be taught as a progression in order to master the skills necessary and be successful in achieving the Performance Expectations and ultimately determine an overall water quality assessment for an aquatic ecosystem, which is the final lesson of the sequence. However, it is up to the discretion of the teacher to determine the testing needed to achieve the water quality assessment information preferred to create an explanation for the current water quality and design a solution to maintain or remediate that water quality.

Lesson 1A What is Clean Water introduces students to several slides of aquatic ecosystems. Students are asked to observe the slides and make observations that help them to determine whether or not the water is clean and defend their answers with their observations. Students are then asked to discuss what factors help to determine the water health of an aquatic ecosystem based upon their observations.

Lesson 1B Chemical and Physical Water Testing asks students to complete multiple tests (Temperature, Turbidity, DO, pH, Nitrate, and Phosphate) in order to get a quick view of the current water health of an aquatic ecosystem. Feel free to add or detract the required tests you prefer your students to complete in order to create an explanation for the current chemical and physical water health.

Lesson 1C Biotic Water Sampling asks students to conduct a macroinvertebrate screening to determine the biological range of tolerance for the chemical and physical factors in the aquatic ecosystem. Students will collect macroinvertebrate samples, identify the macroinvertebrates using a key, and calculate the range of biodiversity in the sample in order to indicate poor, good, or excellent water quality.

Lesson 1D Water Quality Conclusion asks students to compare the collected results of both the physical and chemical water testing and the macroinvertebrate testing. The chemical and physical testing provide an immediate assessment of the aquatic ecosystem, however, because many aquatic ecosystems change rapidly, these results may not provide an accurate assessment for overall health. The biotic sampling will provide help to confirm the health of the aquatic ecosystem by providing a more long term assessment due to the macroinvertebrate range of tolerance to the ecosystem's chemical and physical factors that contribute to water quality.

Lesson 1A
How Clean is the Water? - Teacher
Focus Questions: How clean is the water? How can we monitor water quality and the conditions that allow for different animals and plants to survive in an aquatic ecosystem?
Learning Target: *Students describe several factors that can affect water quality.*
Vocabulary: Biodiversity, Ecosystem

MS-ESS3: Earth and Human Activity

Performance Expectation	Connections to Activity
MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	This activity is an introduction for the students to begin visualizing the differences that can occur in aquatic ecosystems and water health.
Science & Engineering Practices	
Constructing Explanations and Designing Solutions ● Apply scientific principles to design an object, tool, process or system.	Students begin to construct an explanation by observing data to support their explantation of water health in the provided slidedeck. Students begin to design solutions to potential poor water health issues by observing external factors that might contribute to said health and determine methods to improve the aquatic ecosystem.
Disciplinary Core Ideas	
ESS3.C: Human Impacts on Earth Systems ● Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.	The slidedeck photos provide several images of aquatic ecosystems that indicate both good and poor water health. Students determine possible human interactions that could be contributing to the health of each ecosystem.
Cross Cutting Concepts	
Cause and Effect ● Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.	Human impacts have made a significant impact on aquatic ecosystems. Students will observe possible factors that have led to ecosystem decline and design possible solutions to correct this decline.

- Student handout information is indicated in light gray print. Answer keys are embedded in the student handout section.

This lesson focuses on Constructing Explanations and Designing Solutions as a means to identify some potential factors that affect the health and **biodiversity** of aquatic **ecosystems** and the corresponding conditions that allow aquatic organisms to survive. Students will make observations about photos of aquatic ecosystems and predict if the water is clean or not. Then, they will brainstorm ideas for additional factors that may affect water

health and the overall biodiversity of the aquatic ecosystem and possible ways to test for these factors. Finally, students will begin to design possible remediation strategies to maintain or improve water health.

Prior knowledge and possible observations or questions about water quality from your students:

- The color and smell of the water system.
- The diversity of plant or animal life in the water system.
- The movement and turbidity of the water system.
- The shade cover and temperature of the water system.
- Is the water polluted? What pollutants would cause harm?
- What do aquatic organisms need to survive in this body of water?
- How can we test for water quality?

Teacher Background

Natural and human activities have altered the landscape and quality of many **ecosystems** around the world, including aquatic ecosystems. There is no single measure that constitutes good water quality. Water health is defined in terms of the chemical, physical, and biological content of the water. The health of aquatic ecosystems changes with the seasons and geographic areas, even when there is no pollution present. Precipitation dissolves or entraps dust and gases in the air to reach the earth's surface and flow over and through the soil and rocks, dissolving and picking up other substances. Human activities such as mining, forestry, urbanization and agriculture have altered the landscape and quality of aquatic ecosystems. For example, industrial activities can increase concentrations of metals and toxic chemicals, increase temperature and lower dissolved oxygen in the water. Agriculture can increase the concentration of nutrients, pesticides, and suspended sediments. Urban living has increased the runoff of debris, and increased the concentrations of nutrients, pathogens, oil products, and road salts. A healthy aquatic ecosystem is one in which the water quality supports a rich and diverse community of organisms. The interrelationships between climate change, human activities, changing watershed conditions and water quality can quickly make the balance shift, causing a change in the composition of the ecosystem.

Materials:

- Slidedeck with aquatic ecosystem slides
- Water Samples
- Student Handout
- Access to a computer or other device with wifi for possible research

Teacher Preparation

1. Make copies of the student handout.
2. Load the How Clean is your Water slide deck to show your students and promote conversation about what clean water means. Promote conversation with students to share with the class or in pairs to brainstorm ideas about water quality.

Student Handout

1. What are some visible indicators of a healthy water ecosystem?
Possible answers: *high biodiversity, clear water, no smell, low aquatic plant growth, no visible pollutants, etc.*

2. What are some ways in which aquatic ecosystems have been impacted due to human activity.
Possible answers: *waterway diversion, wetland fill, dam construction, overfishing, invasive species, canopy removal, pollution, sediment overload, pollution, etc.*

3. How can we assess the health of an aquatic ecosystem? What can we test for?
Possible answers: *Turbidity, temperature, pH, nutrients (N, P), smell, coliform bacteria, dissolved oxygen (DO), biological oxygen demand (BOD)*

4. What are some ways that humans can improve the health of an aquatic ecosystem?
Possible answers: *Repair riparian zones, increase biodiversity along aquatic ecosystems, decrease runoff from suburban and rural zones,*

Differentiation
Other ways to connect with students with various needs:

- **Local Community:** Students may investigate local aquatic ecosystems to predict the health of the system and observe possible causes for that health assessment.
- **Students with special needs (language/reading/auditory/visual):** Students may investigate real aquatic ecosystems instead of the photos from the provided slidedeck to discuss possible water health. Teachers can also create copies of the slides to pass out to the students so that they can write on the slides as they identify the potential harm and possible remediation to that harm on that slide.
- **Extra support:** Volunteer Stream Monitoring, A Methods Manual: https://www.epa.gov/sites/production/files/2015-06/documents/stream.pdf, Nebraska Department for Environmental Quality, Stream Monitoring: http://deq.ne.gov/NDEQProg.nsf/OnWeb/SBMP
- **Extensions:** Students can observe real time data in Nebraska through USGS: https://nrtwq.usgs.gov/ne/ Students can help to solve real water problems within their community. Take part in organizations such as Give Water a Hand: https://erc.cals.wisc.edu/gwah/

Rubric for Assessment

Skill	Developing	Satisfactory	Exemplary
Constructing Explanations	Student can give an example of a human impact that can disrupt the health of an aquatic ecosystem.	Student can give an example of a human impact that can cause disruption to the health of an aquatic ecosystem and explain how this impact can lead to future harm.	Student can give an example of a human impact to an aquatic ecosystem, explain how this impact can lead to additional harm and create a possible solution to alter the course of future harm.

Rubric for Self Assessment

Skill	Yes	No
I can explain what a healthy aquatic ecosystem is.		
I can describe both biotic and abiotic components that can lead to aquatic ecosystem imbalances.		
I can describe possible ways that the health of a disrupted aquatic ecosystem can be improved.		

Slide 1

Prompt: How clean is this water?

- What are some factors that help you to determine the health of this aquatic ecosystem?
- Do you see any human impact to this ecosystem?

Slide 2

Prompt: How clean is this water?

- What are some factors that help you to determine the health of this aquatic ecosystem?
- Do you see any potential human impact to this ecosystem?
- How is this photo different from the first photo?
- How is this photo similar to the first photo?

Slide 3

Prompt: How clean is this water?

- What are some factors that help you to determine the health of this aquatic ecosystem?
- Do you see any potential human impact to this ecosystem?
- How is this photo different from the first two photos?
- How is this photo similar to the first two photos?

Slide 4

Prompt: How clean is this water?

- What are some factors that help you to determine the health of this aquatic ecosystem?
- Do you see any potential human impact to this ecosystem?
- How is this photo different from the first three photos?
- How is this photo similar to the first three photos?

Slide 5

Prompt: How clean is this water?

- What are some factors that help you to determine the health of this water?
- Do you see any potential human impact to this water?
- How is this photo different from the first four photos?
- How is this photo similar to the first four photos?

Lesson 1B
Chemical and Physical Tests to Determine Water Quality - Teacher
Focus Questions: *How can we analyze the abiotic components (chemical and physical tests) of the stream in order to determine the stream's overall water quality?*
Learning Target: *Students describe how DO (dissolved oxygen), BOD (biological oxygen demand), Phosphate, Nitrate, Temperature, pH, and turbidity can impact water quality and aquatic life.*
Vocabulary: Resilience, Temperature, Turbidity, Dissolved Oxygen (DO), pH, Phosphate, Nitrate

This activity is adapted from:
Earth Force, LaMotte Low Cost Water Monitoring Kit and procedures.
And can be found here:
https://earthforce.org/GMGREEN/wp-content/uploads/2016/03/Low-Cost-Water-Monitoring-Kit-Manual.pdf

MS-ESS3: Earth and Human Activity

Performance Expectation	**Connections to Activity**
MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	This activity provides the chemical and physical data needed to help construct and explanation for the current water quality and .
Science & Engineering Practices	
Constructing Explanations and Designing Solutions ● Apply scientific principles to design an object, tool, process or system.	Students begin to construct an explanation by gathering chemical and physical data to support their explanation of the current water health in the aquatic ecosystem.. Students begin to design solutions to improve the water quality of the provided sample based upon their calculated chemical and physical data.
Disciplinary Core Ideas	
ESS3.C: Human Impacts on Earth Systems ● Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.	The chemical and physical testing will provide data that will indicate the health of the aquatic ecosystem. Students will analyze these factors to determine if they are the result of human interaction with the aquatic ecosystem.
Cross Cutting Concepts	
Cause and Effect ● Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.	Human impacts have made a significant impact on aquatic ecosystems. Students will test for factors that have led to ecosystem decline and design possible solutions to correct this decline.

- Student handout information is indicated in light gray print. Answer keys are embedded in the student handout section.

This lesson focuses on Constructing Explanations and Designing Solutions as a means to identify the factors that affect the health of aquatic ecosystems and the corresponding conditions that allow aquatic organisms to survive. Students will collect data on the chemical and physical health of a water sample and create a water health explanation for that sample. Students can then utilize the collected data to create solutions to either maintain or improve the health of the aquatic ecosystem.

Prior Knowledge

Students should have a good understanding of ecosystems and the complex interactions that occur within ecosystems. A freshwater aquatic ecosystem is an ecosystem that exists in a body of water with a salinity of less than 0.05 percent. It consists of a community of aquatic organisms living interactively with their abiotic environment. Ecosystems with a higher biodiversity tend to be more stable with greater **resilience** in the face of disruption to the ecosystem. Students will need to gain an understanding of how **pH**, **Dissolved Oxygen**, **Temperature**, **Turbidity** and nutrients such as **Nitrate** and **Phosphate** interact with the ecosystem to maintain or cause disturbance within the ecosystem.

Teacher Background:

Temperature is very important to water quality. Temperature affects the amount of dissolved oxygen (DO) in the water, the rate of photosynthesis by aquatic plants, and the sensitivity of organisms to toxic wastes, parasites and disease.

Turbidity is the measure of the relative clarity of water. Turbid water is caused by suspended and colloidal matter such as clay, silt, organic and inorganic matter, and microscopic organisms. Turbidity should not be confused with color, since darkly colored water can still be clear but not turbid. Turbid may be the result of soil erosion, urban runoff, algal blooms, and bottom sediment disturbances.

pH is a measurement of the acidic or basic quality of water. The pH scale ranges from a value of 0 (very acidic) to 14 (very basic), with 7 being neutral. The pH of natural water is usually between 6.5 and 8.2. Most aquatic organisms are adapted to a specific pH level and may die if the pH of the water changes even slightly. pH can be affected by industrial waste, urban and agricultural runoff, or drainage from mining operations.

Dissolved Oxygen (DO) is important to the health of aquatic ecosystems. All aquatic animals need oxygen to survive. Natural waters will consistently high dissolved oxygen levels are most likely healthy and stable environments, and are capable of supporting a high biodiversity of organisms. Natural and human induced changes to the aquatic ecosystem can affect the availability of DO. Dissolved Oxygen % Saturation is an important measurement of water quality. Cold water can hold more DO than warm water. High levels of bacteria or large amount so decaying material can cause the % Saturation to decrease. This can cause large fluctuations in DO levels throughout the day, which can affect the ability of plants and animals to survive.

Nitrate is a nutrient needed by all aquatic plants and animals to build protein. The decomposition of dead organisms and the excretions of living animals release nitrate into the aquatic ecosystem. Excess nutrients like nitrate increase plant growth and decay, promote bacterial decomposition and consequently decrease the amount of DO available in the water. Sewage is the main source of excess nitrates added to natural waters, while fertilizer from urban and agricultural runoff also contribute to high levels of nitrate.

Phosphate is a nutrient needed for plant and animal growth. It is a limiting factor in aquatic plant growth. High levels of phosphates can lead to overgrowth of plants, increased bacterial activity and decreased DO levels.

Materials

- LaMotte Low Cost Water Monitoring Kit.
- BOD bottle or Quart Jar with lid
- Water Sample from local water system

Teacher Preparation

1. If possible, conduct these tests on site at the aquatic ecosystem to be tested. If this is not possible, record the temperature and Dissolved Oxygen results for your students later for the most accurate results.
2. Print off the accompanying student handout.
3. Determine the tests that your students will conduct for this lesson. The following tests will provide your students with the ability to predict overall water health: Temperature, pH, Turbidity, Dissolved Oxygen, Nitrate, and Phosphate.
4. Collect water samples for the students to test in a sterile, wide mouthed jar or container that has a cap. The container should be filled completely with your water sample and capped to prevent the loss of dissolved gases. Test each sample as soon as possible or within one hour of collection.
    - *Biological Oxygen Demand (BOD) bottles will allow you to extend your water testing time frame.*
    - *When possible, perform the Temperature and Dissolved Oxygen (DO) at the monitoring site immediately after collecting the water sample.*
    a. Remove the cap of the sampling container.
    b. Wear protective gloves. Rinse the bottle 2-3 times with the stream water (or other water source).
    c. Hold the container near the bottom and plunge it (opening downward) below the water surface.
    d. Turn the submerged container into the current and away from you.
    e. Allow the water to flow into the container for 30 seconds.
    f. Cap the full container while it is still submerged. Remove it from the river completely.
5. The turbidity test is meant to be conducted in the LaMotte Low Cost Water Monitoring Kit container. If possible, adhere the Secchi disk icon sticker to the container on the bottom 8-24 hours before testing slightly off center.
6. Prepare 1 water sample for each student testing group and a Lamotte Low Cost Water Monitoring kit to conduct the tests. Students will need the colored indicator cards to record the test results.
7. Determine if you want the students to conduct all of the following tests, or allow the students to determine the tests they feel are necessary to conduct in order to determine the health of the aquatic ecosystem.
8. Remind students to carefully dispose of all reacted test samples by carefully flushing them down the drain with excess water. ** While in the field, reacted samples can be poured together into a waste container for later disposal.*

Student Handout

Students will conduct water quality tests on the following factors and rank their results in order to indicate the water quality of their sample: Temperature, Turbidity, pH, Dissolved Oxygen, Nitrate, and Phosphate.

Reflection

Create an explanation for the current water health of the water sample. Look at the recorded information above. Reflect on the following questions while creating your explanation.

1. How did your water sample results compare? Did the tests indicate a similar rating? How are they similar or different?.

Answers will vary. Students will compare their test data in the ranking chart. Students will be able to determine if the sample is poor, fair, good or excellent water quality based upon the ranking results.

2. Did any test stand out? For example, did any test show different results than the rest? If so, why do you think this test was different?
Answers will vary. Students should support their answer with data.

3. How do the water quality tests interact with one another or potentially change throughout the year? For example, temperature has a direct impact on the % Saturation of Dissolved Oxygen. How could the local climate impact the biodiversity of the aquatic ecosystem if the % Saturation changes?
Answers will vary. Students should conduct research on each test to support their explanation.

4. What tests, if any, demonstrate that the health of the aquatic ecosystem could be improved? What are some ways that humans can remediate their impact to improve water quality?
Answers will vary. Students should conduct research on each form of remediation to support their explanation.

Differentiation
Other ways to connect with students with various needs:

- **Local Community:** Students may investigate local aquatic ecosystems to test the physical and chemical properties of the ecosystem and observe possible causes for that health assessment. Students can hear a presentation from a local water quality district or agronomy to learn more about chemical testing.
- **Students with special needs (language/reading/auditory/visual):** Students that perform better with visual aids can read directly from the LaMotte Water Monitoring Kit: https://earthforce.org/GMGREEN/wp-content/uploads/2016/03/Low-Cost-Water-Monitoring-Kit-Manual.pdf. Students that do not perform well in groups may perform testing on their own. Students may create connections between the tested materials through graphic organizers.
- **Extra support:** Volunteer Stream Monitoring, A Methods Manual: https://www.epa.gov/sites/production/files/2015-06/documents/stream.pdf. Earth Force: www.earthforce.org/GMGREEN Nebraska Department for Environmental Quality, Stream Monitoring: http://deq.ne.gov/NDEQProg.nsf/OnWeb/SBMP
- **Extensions:** Students can observe real time data in Nebraska through USGS: https://nrtwq.usgs.gov/ne/. Students can help to solve real water problems within their community. Take part in organizations such as Give Water a Hand: https://erc.cals.wisc.edu/gwah/.

Rubric for Assessment

Skill	Developing	Satisfactory	Exemplary
Constructing Explanations	Student can conduct the chemical and physical water quality tests.	Student can create an explanation for the data that resulted from the chemical and physical water quality tests.	Student can create an explanation for the data that resulted from the chemical and physical water quality tests and design some forms of remediation for negative test results.

Rubric for Self Assessment

Skill	Yes	No
I can conduct chemical and physical water quality testing.		
I can describe the abiotic tests that I conducted that can lead to aquatic ecosystem imbalances.		
I can describe possible ways that the health of a disrupted aquatic ecosystem can be improved.		

Lesson 1C
Biotic Sampling - Teacher
Focus Questions: How can the health of an aquatic ecosystem be determined by the macroinvertebrates present in the ecosystem?
Learning Target: *Students identify macroinvertebrates and rate the health of an aquatic ecosystem.*
Vocabulary: Riffle Zone, Range of Tolerance, Dichotomous Key

MS-ESS3: Earth and Human Activity

Performance Expectation	**Connections to Activity**
MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	This activity is a macroinvertebrate assessment for an aquatic ecosystem that will enable the students to analyze the taxonomic groups that live in the habitat annually.
Science & Engineering Practices	
Constructing Explanations and Designing Solutions ● Apply scientific principles to design an object, tool, process or system.	Students begin to construct an explanation by gathering macroinvertebrate taxonomic data to support their explanation of the water health of an aquatic ecosystem. Students continue to design solutions to improve the health of the aquatic ecosystem based upon their observations of the site and taxonomic data collected.
Disciplinary Core Ideas	
ESS3.C: Human Impacts on Earth Systems ● Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.	The macroinvertebrate testing will provide data to indicate the health of the aquatic ecosystem. Students will determine if the data supports human impact in the aquatic ecosystem.
Cross Cutting Concepts	
Cause and Effect ● Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.	Humans have made a significant impact on aquatic ecosystems. Students will test for the biotic data that demonstrate the water health of the ecosystem and design possible solutions to correct the decline.

- Student handout information is indicated in light gray print. Answer keys are embedded in the student handout section.

This lesson focuses on Constructing Explanations and Designing Solutions as a means to identify biotic indicators that help to determine the health of an aquatic ecosystem and the corresponding conditions that allow aquatic organisms to survive. Students will collect data on aquatic macroinvertebrates of an aquatic ecosystem

and create a water health explanation for the ecosystem. Students can utilize the collected data to create solutions to either maintain or improve the health of the aquatic ecosystem.

Prior Knowledge

Students should have prior knowledge about the kick-seining method used to collect macroinvertebrates from aquatic ecosystems. There are several video tutorials available, here is a short video that demonstrates how the kick technique should be performed: https://www.youtube.com/watch?v=MHt56nhqgFk Students will need to be familiar with a macroinvertebrate **dichotomous key** such as the Stroud Water Research Center Key found here: https://3jgs2o4a02n22u73bi2gnd3l-wpengine.netdna-ssl.com/wp-content/uploads/MacroKey_Complete.pdf Students can also use the photo identification key located here: https://stroudcenter.org/macros/gallery/

Teacher Background

Macroinvertebrates are animals without a backbone that can be seen with the naked eye. These bottom-dwelling animals include crustaceans and worms, but most are aquatic insects. Macroinvertebrates form permanent, relatively immobile stream communities that can be easily collected in large numbers for observation. They occupy all stream habitats and display a wide range of functional feeding preferences. They are important to the ecosystem and inhabit the middle of the aquatic food web as a major source of food for fish and other aquatic and terrestrial animals. Macroinvertebrates are a good indication of changing water conditions because they demonstrate both acute and chronic reactions to environmental changes in the aquatic habitat.

The kick seine technique is a useful way to measure the macroinvertebrate diversity of an aquatic ecosystem. Macroinvertebrate taxa can tolerate varying levels of water quality conditions. Some macroinvertebrates groups can only tolerate excellent water quality, whereas other groups have a different **range of tolerance** for environmental conditions. Field sampling should be done when the water is warm and macroinvertebrates are active, usually between the end of May through the end of September. The best areas to locate macroinvertebrates are in areas of high oxygen concentration such as **riffle zones** or rapids in the benthic zone. Students will find that macroinvertebrates may cling to the bottom on rocks and humus and will need to be wiped and kicked into the net for collection.

Materials

- Kick Seine net
- White bucket, tub, or ice cube tray (to place organisms in for identification)
- Macroinvertebrate Dichotomous Key
- Closed toe shoes
- Suggested Materials: Aqua Bugs App by the Izaak Walton League

Teacher Preparation

1. Prepare students by watching the kick seining video (https://www.youtube.com/watch?v=MHt56nhqgFk) with the class to learn the kick seining technique that will be used in this investigation.
2. Prepare copies of both the student handouts as well as the macroinvertebrate dichotomous keys.
3. Help students to select roles for their group: 2 people will hold the net, and the remaining 2+ participants will be kickers to move macroinvertebrates into the net.
4. It is a good idea to practice macroinvertebrate testing in the classroom. This can be done by passing out pictures of macroinvertebrates for student practice. You can also create a fake stream on the floor in your classroom to practice the kick seine technique and identification.
5. Students must have closed toed shoes to enter the stream. Students may wear plastic gloves if they are concerned about touching live organisms.
6. Take hand wipes or hand sanitizer for students to clean up after macroinvertebrate testing if a bathroom/sink is not available.

Student Handout

1. How did the stream appear to your group? Healthy or not healthy? Did the stream have an odor or a layer of oil on its surface? Did you notice anything that stood out as unusual? Write details about the stream below.
Possible answers: *Students should observe the layout of the stream and write down their observations. Answers will vary.*

2. How did your water sample results compare? Did you have organisms from more than one index group? What was your index rating?
Possible answers: *Students should record and explain their group index data. Answers will vary.*

3. If your stream was Excellent Water Quality or less, what are some factors that could be leading up to the rating? Could human impact have changed stream conditions and lessened the water quality rating? How?
Possible answers: *Students should explain how their group index data could be maintained or improved. Answers will vary.*

Differentiation

Other ways to connect with students with various needs:

- **Local Community:** Students may investigate local aquatic ecosystems to conduct macroinvertebrate testing of the ecosystem and observe possible causes for that health assessment.
- **Students with special needs (language/reading/auditory/visual):** Students in cooperative groups can rotate tasks and utilize all students' strengths.
- **Extra support:** Volunteer Stream Monitoring, A Methods Manual: https://www.epa.gov/sites/production/files/2015-06/documents/stream.pdf. Nebraska Department of Environmental Quality, Stream Monitoring: http://deq.ne.gov/NDEQProg.nsf/OnWeb/SBMP
- **Extensions:** Students can observe real time data in Nebraska through USGS: https://nrtwq.usgs.gov/ne/. Students can help to solve real water problems within their community. Take part in organizations such as Give Water a Hand: https://erc.cals.wisc.edu/gwah/.

Rubric for Assessment

Skill	Developing	Satisfactory	Exemplary
Constructing Explanations	Student can help conduct macroinvertebrate kick seine testing and identify local benthic macroinvertebrates.	Student can create an explanation for the data that resulted from the macroinvertebrate kick seine water quality testing.	Student can create an explanation for the data that resulted from the that resulted from the macroinvertebrate kick seine water quality testing and design some forms of remediation for any negative test results.

Rubric for Self Assessment

Skill	Yes	No
I can identify macroinvertebrates.		
I can use the collected taxa data to determine a water quality rating of poor, fair, good, or excellent.		
I can use the collected data and assessment to describe possible ways that the health of a disrupted aquatic ecosystem can be improved.		

Lesson 1D
Water Quality Conclusion - Teacher
Focus Questions: How can the health of an aquatic ecosystem be determined by the biotic and abiotic factors present in the ecosystem? How can the human impact be lessened to maintain or improve the water quality rating for an aquatic ecosystem?
Learning Target: *Students analyze biotic and abiotic data from lessons 1B and 1C to create an explanation for the health of an aquatic ecosystem. Students design solutions for aquatic ecosystem maintenance and/or restoration.*

MS-ESS3: Earth and Human Activity

Performance Expectation	**Connections to Activity**
MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	This activity uses data collected from lessons 1B and 1C to design a method to minimize human impact on an aquatic ecosystem.
Science & Engineering Practices	
Constructing Explanations and Designing Solutions ● Apply scientific principles to design an object, tool, process or system.	Students construct an explanation using biotic and abiotic data to support their explanation of the water health of an aquatic ecosystem. Students design solutions to improve the health of the aquatic ecosystem by minimizing the human impact on the aquatic ecosystem.
Disciplinary Core Ideas	
ESS3.C: Human Impacts on Earth Systems ● Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.	Students will determine if the data supports that human impact has impacted the quality of life in the aquatic ecosystem tested.
Cross Cutting Concepts	
Cause and Effect ● Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.	Students will analyze biotic and abiotic data to determine if the water quality assessment is causal or correlational with human impact.

- Student handout information is indicated in light gray print. Answer keys are embedded in the student handout section.

This lesson focuses on Constructing Explanations and Designing Solutions as a means to identify the biotic and abiotic indicators that help to determine the health of an aquatic ecosystem and the corresponding conditions that allow aquatic organisms to survive. Students will analyze collected data from lessons 1B and 1C to

construct an explanation for the water quality of the ecosystem. Students can then design solutions to either maintain or improve the health of the aquatic ecosystem. This lesson is designed to follow lessons 1A - 1C.

Materials

- Student Handout Lesson 1B data
- Student Handout Lesson 1C data
- Student Handout Lesson 1D

Student Handout

2. Construct an explanation for the current water quality of the aquatic ecosystem from the collected data and your observations. Use the collected data from above and include any human activities that may have led to the water quality assessment.

Possible answers: *Answers will vary*

3. Design a solution to improve any human impact at the aquatic ecosystem testing site. Be sure to address how this solution will maintain or improve the current water quality assessment.

Possible answers: *Answers will vary*

Differentiation

Other ways to connect with students with various needs:

- **Local Community:** Students may investigate local aquatic ecosystems to conduct testing of the ecosystem and observe human activities that have impacted the testing site.
- **Students with special needs (language/reading/auditory/visual):** Students in cooperative groups can rotate tasks and utilize all students' strengths. Students can design an alternative solution by creating a model of their design solution.
- **Extra support:** Volunteer Stream Monitoring, A Methods Manual: https://www.epa.gov/sites/production/files/2015-06/documents/stream.pdf. Nebraska Department of Environmental Quality, Stream Monitoring: http://deq.ne.gov/NDEQProg.nsf/OnWeb/SBMP
- **Extensions:** Students can observe real time data in Nebraska through USGS: https://nrtwq.usgs.gov/ne/. Students can help to solve real water problems within their community. Take part in organizations such as Give Water a Hand: https://erc.cals.wisc.edu/gwah/.

Rubric for Assessment

Skill	Developing	Satisfactory	Exemplary
Constructing an Explanation of Water Quality	Student can conduct water quality testing and calculate water quality ratings.	Student can calculate water quality ratings and identify the human activities that impact the water quality of the aquatic system.	Student can calculate water quality ratings, identify human activities that may impact the aquatic ecosystem and create connections between human impact and environmental conditions.
Designing Solutions to Human Impact	Student can identify human activities that may impact the water quality of the test site.	Student can identify human activities that impact the health of the testing site and outline some possible steps to improve the water quality of the testing site.	Student can identify human activities that impact the health of the testing site and create a solution to improve the water quality. The solution must explain how the proposed actions will improve the water quality.

Rubric for Self Assessment

Skill	Description	Yes	No
Identifying Human Impact	I identified human activities that created an impact upon the tested aquatic ecosystem.		
Constructing Explanations	I constructed an explanation for the current water health of the tested aquatic ecosystem.		
Designing Solutions	I helped to design a solution to improve the water quality of the aquatic ecosystem and counteract the human impact on that system.		

Lesson 1A
How Clean is the Water?

Focus Questions: *What is clean water? How can we monitor water quality and the conditions that allow for different animals and plants to survive?*
Vocabulary: Ecosystem, Biodiversity

Background:
Human activities have altered the landscape and quality of many **ecosystems** around the world, including aquatic ecosystems. Many aquatic ecosystems have been impacted by climate change, pollution, population and habitat changes. A healthy aquatic ecosystem is one in which the water quality supports a high **biodiversity** of organisms. For this to happen, the biotic and abiotic components of the ecosystem must be in balance with one another. The interrelationships between human activities, changing watershed conditions and water quality can quickly make the balance shift, causing a change in the composition of the ecosystem. What are some ways that abiotic and biotic factors can change an aquatic ecosystem?

1. What are some visible indicators of a healthy water ecosystem?

2. What are some ways in which aquatic ecosystems have been impacted due to human activity.

3. How can we assess the health of an aquatic ecosystem? What can we test for?

4. What are some ways that humans can improve the health of an aquatic ecosystem?

Self Assessment

Skill	Yes	No
I can explain what a healthy aquatic ecosystem is.		
I can describe both biotic and abiotic components that can lead to aquatic ecosystem imbalances.		
I can describe possible ways that the health of a disrupted aquatic ecosystem can be improved.		

Lesson 1B
Chemical and Physical Tests to Determine Water Quality

Focus Questions: *How can we analyze the abiotic components (chemical and physical tests) of the stream in order to determine the stream's overall water quality?*
Vocabulary: Resilience, Temperature, Turbidity, Dissolved Oxygen (DO), pH, Phosphate, Nitrate

Background:

A freshwater aquatic ecosystem is an ecosystem that exists in a body of water with a salinity of less than 0.05 percent. It consists of a community of aquatic organisms living interactively with their abiotic environment. Ecosystems with a higher biodiversity tend to be more stable with greater **resilience** in the face of disruption to the ecosystem. The following factors may impact the health of an aquatic ecosystem.

Temperature is very important to water quality. Temperature affects the amount of dissolved oxygen (DO) in the water, the rate of photosynthesis by aquatic plants, and the sensitivity of organisms to toxic wastes, parasites and disease.

Turbidity is the measure of the relative clarity of water. Turbid water is caused by suspended and colloidal matter such as clay, silt, organic and inorganic matter, and microscopic organisms. Turbidity should not be confused with color, since darkly colored water can still be clear but not turbid. Turbid may be the result of soil erosion, urban runoff, algal blooms, and bottom sediment disturbances.

pH is a measurement of the acidic or basic quality of water. The pH scale ranges from a value of 0 (very acidic) to 14 (very basic), with 7 being neutral. The pH of natural water is usually between 6.5 and 8.2. Most aquatic organisms are adapted to a specific pH level and may die if the pH of the water changes even slightly. pH can be affected by industrial waste, urban and agricultural runoff, or drainage from mining operations.

Dissolved Oxygen (DO) is important to the health of aquatic ecosystems. All aquatic animals need oxygen to survive. Natural waters will consistently high dissolved oxygen levels are most likely healthy and stable environments, and are capable of supporting a high biodiversity of organisms. Natural and human induced changes to the aquatic ecosystem can affect the availability of DO. Dissolved Oxygen % Saturation is an important measurement of water quality. Cold water can hold more DO than warm water. High levels of bacteria or large amount so decaying material can cause the % Saturation to decrease. This can cause large fluctuations in DO levels throughout the day, which can affect the ability of plants and animals to survive.

Nitrate is a nutrient needed by all aquatic plants and animals to build protein. The decomposition of dead organisms and the excretions of living animals release nitrate into the aquatic ecosystem. Excess nutrients like nitrate increase plant growth and decay, promote bacterial decomposition and consequently decrease the amount of DO available in the water. Sewage is the main source of excess nitrates added to natural waters, while fertilizer from urban and agricultural runoff also contribute to high levels of nitrate.

Phosphate is a nutrient needed for plant and animal growth. It is a limiting factor in aquatic plant growth. High levels of phosphates can lead to overgrowth of plants, increased bacterial activity and decreased DO levels.

Procedure
Temperature

1. Wear protective gloves. Place the thermometer 4 inches below the surface of the water for one minute. Record the temperature as degrees Celsius.

Temperature	°C

Turbidity

1. Fill the turbidity jar (white water quality monitoring kit) to the turbidity fill line located on the outside kit label.
2. Hold the Turbidity Chart on the top edge of the jar. Looking down into the jar, compare the appearance of the secchi disk icon in the jar to the chart. Record the results in JTU.

Turbidity	JTU

pH

1. Fill the test tube (0106) to the 10 mL line with the water sample.
2. Add on pH Wide Range TesTab (64459A).
3. Cap and mix by inverting until the tablet has disintegrated. Bits of material may remain in the sample.
4. Compare the color of the sample to the pH color chart. Record the result at pH.

pH	

Dissolved Oxygen (DO)

1. Record the temperature of the water sample from above.
2. Submerge the small tube (0125) in the water sample. Carefully remove the tube from the water sample, keeping the tube full to the top.
3. Drop 2 Dissolved Oxygen TesTabs (3976A) into the tube. Water will overflow when tablets are added.
4. Screw the cap on the tube. More water will overflow as the cap is tightened. Make sure no air bubbles are present in the sample.
5. Mix by inverting the tube over and over until the tablets have disintegrated. This will take about 4 minutes.
6. Wait 5 more minutes for the color to develop.
7. Compare the color of the sample to the Dissolved Oxygen color chart. Record the result as ppm DO.
8. Locate the temperature of the water sample of the % Saturation chart on the next page. Locate the DO result of the water sample at the top of the chart. The % Saturation of the water sample is where the Temperature row and the DO column intersect.

% Saturation

Temperature °C	Dissolved Oxygen		
	0 ppm	4 ppm	8 ppm
2	0	29	58
4	0	31	61
6	0	32	64
8	0	34	68
10	0	35	71
12	0	37	74
14	0	39	78
16	0	41	81
18	0	42	84
20	0	44	88
22	0	46	92
24	0	48	95
26	0	49	99
28	0	51	102
30	0	53	106

Dissolved Oxygen (DO) Test

Temperature		ppm DO		% Saturation	

Nitrate

1. Fill the test tube (0106) to the 5 mL line with the water sample.
2. Add one Nitrate Wide Range CTA TesTab (3703A). Immediately slide the test tube into the Protective Sleeve (0106-FP). **If testing indoors, there is no need to use the protective sleeve which protects the reaction from UV light.*
3. Cap and mix by inverting for 2 minutes to disintegrate the tablet. Bits of material may remain in the sample.
4. Wait 5 minutes for the red color to develop. Remove the tube from the Protective Sleeve.
5. Compare the color of the sample to the Nitrate color chart. Record the result as ppm Nitrate.

Nitrate	ppm

Phosphate

1. Fill the test tube (0106) to the 10 mL line with the water sample.
2. Add one Phosphate TesTab (5422A).
3. Cap and mix by inverting until the tablet has disintegrated. Bits of material may remain in the sample.
4. Wait 5 minutes for the blue color to develop.
    - *Note: If the sample does not develop a blue color (sample is colorless), record the result as 0 ppm.*
5. Compare the color of the sample to the Phosphate color chart. Record the result as ppm Phosphate.

Phosphate	ppm

Ranking Test Results:

1. Compare the data collected for each test with the ranking chart below. Record the scores in the final column.

Test Factor	Result	Rank	Score
Temperature	°C	N/A	N/A
Turbidity	0 JTU >0 to 40 JTU >40 to 100 JTU >100 JTU	4 (excellent) 3 (good) 2 (fair) 1 (poor)	
pH	4 5 6 7 8 9 10	1 (poor) 1 (poor) 3 (good) 4 (excellent) 3 (good) 1 (poor() 1 (poor)	
Dissolved Oxygen (DO)	91-110% 71-90% 51-70% <50%	4 (excellent) 3 (good) 2 (fair) 1 (poor)	
Nitrate	5 ppm 20 ppm 40 pm	2 (fair) 1 (poor) 1 (poor)	
Phosphate	1 ppm 2 ppm 4 ppm	4 (excellent) 3 (good) 2 (fair)	

Reflection

Create an explanation for the current water health of the water sample. Look at the recorded information above. Reflect on the following questions while creating your explanation.

1. How did your water sample results compare? Did the tests indicate a similar rating? How are they similar or different?.

2. Did any test stand out? For example, did any test show different results than the rest? If so, why do you think this test was different?

3. How do the water quality tests interact with one another or potentially change throughout the year? For example, temperature has a direct impact on the % Saturation of Dissolved Oxygen. How could the local climate impact the biodiversity of the aquatic ecosystem if the % Saturation changes?

4. What tests, if any, demonstrate that the health of the aquatic ecosystem could be improved? What are some ways that humans can remediate their impact to improve water quality?

Rubric for Self Assessment

Skill	Yes	No
I can conduct chemical and physical water quality testing.		
I can describe the abiotic tests that I conducted that can lead to aquatic ecosystem imbalances.		
I can describe possible ways that the health of a disrupted aquatic ecosystem can be improved.		

Lesson 1C
Biotic Sampling
Focus Questions: How can the health of an aquatic ecosystem be determined by the macroinvertebrates present in the ecosystem?
Vocabulary: Riffle Zone, Range of Tolerance, Dichotomous Key

Background

Macroinvertebrates are animals without a backbone that can be seen with the naked eye. These bottom-dwelling animals include crustaceans and worms but most are aquatic insects. Macroinvertebrates form permanent, relatively immobile stream communities that can be easily collected in large numbers for observation. They occupy all stream habitats and display a wide range of functional feeding preferences. They are important to the ecosystem and inhabit the middle of the aquatic food web as a major source of food for fish and other aquatic and terrestrial animals. Macroinvertebrates are a good indication of changing water conditions because they demonstrate both acute and chronic reactions to environmental changes in the aquatic habitat.

The kick seine technique is a useful way to measure the macroinvertebrate diversity of an aquatic ecosystem. Macroinvertebrate taxa can tolerate varying levels of water quality conditions. Some macroinvertebrates groups can only tolerate excellent water quality, whereas other groups have a different **range of tolerance** for environmental conditions. Field sampling should be done when the water is warm and macroinvertebrates are active, usually between the end of May through the end of September. The best areas to locate macroinvertebrates are in areas of high oxygen concentration such as **riffle zones** or rapids in the benthic zone. Students will find that macroinvertebrates may cling to the bottom on rocks and humus and will need to be wiped and kicked into the net for collection.

Procedure

1. Watch the kick seining video with the class to learn the kick seining technique that will be used in this investigation.
2. Select roles for the members in your group, 2 people will hold the net, and the remaining 2+ participants will be kickers to move macroinvertebrates into the net.
3. Locate a shallow riffle zone to kick seine.
4. Set the poles at a 45 degree angle downstream from the riffle zone.
5. Kicker move upstream of the net and kick the bottom zone vigorously to stir up organisms and allow them to flow downstream into the net.
6. Kickers pick up rocks and other benthic materials and carefully wipe them in the water then place them back on the bottom moving downstream into the net.
7. Net holders carefully lean the net back and scoop up the bottom of the net to capture the macroinvertebrates and take them to the shore for identification.
8. Using tweezers or your fingers carefully pick up each organism and place them into a tub or ice cube tray filled with stream water for identification.
9. Use the dichotomous key, water quality Aqua Bugs App, or similar identification tool to identify the organisms collected.
10. Check off the taxa collected on the chart below to create a water quality rating for the stream.
11. Follow the directions on the chart to determine the water quality rating for macroinvertebrate testing.

Biotic Sampling

Sensitive	**Somewhat Sensitive**	**Tolerant**
☐ Caddisfly ☐ Hellgramite ☐ Mayfly Larvae ☐ Gilled Snails ☐ Rifle Beetle Adult ☐ Stonefly Larvae ☐ Water Penny Larvae	☐ Beetle Larvae ☐ Clams ☐ Crane Fly Larvae ☐ Crayfish ☐ Damselfly Larvae ☐ Dragonfly Larvae ☐ Scuds ☐ Sowbugs ☐ Fishfly Larvae ☐ Alderfly Larvae ☐ Watersnipe Larvae	☐ Aquatic Worms ☐ Blackfly Larvae ☐ Leeches ☐ Midge Larvae ☐ Lunged Snails
Boxes checked x 3 = _____ index value	**Boxes checked x 2 = _____ index value**	**Boxes checked x 1 = _____ index value**
Water Quality Rating Total Index Value = _____	**Excellent (> 22)**	**Fair (11-16)**
	Good (17-22)	**Poor (<11)**

Reflection

Create an explanation for the current water health of the water sample above. Look at the recorded information above. Reflect on the following questions while creating your explanation.

1. How did the stream appear to your group? Healthy or not healthy? Did the stream have an odor or a layer of oil on its surface? Did you notice anything that stood out as unusual? Write details about the stream below.

2. How did your water sample results compare? Did you have organisms from more than one index group? What was your index rating?

3. If your stream was less than Excellent Water Quality, what are some factors that could be leading up to the rating? Could human impact have changed stream conditions and lessened the water quality rating? How?

Self Assessment

Skill	Yes	No
I can identify macroinvertebrates.		
I can use the collected taxa data to determine a water quality rating of poor, fair, good, or excellent.		
I can use the collected data and assessment to describe possible ways that the health of a disrupted aquatic ecosystem can be improved.		

Lesson 1D
Water Quality Conclusion
Focus Questions: How can the health of an aquatic ecosystem be determined by the biotic and abiotic factors present in the ecosystem? How can the human impact be lessened to maintain or improve the water quality rating for an aquatic ecosystem?

Procedure
1. Fill in the results of the biotic and abiotic group test results from Lessons 1B and 1C below for your use.

Water Ranking Test Results (Lesson 1B)

Test Factor						
Score	**Temperature**	**Turbidity**	**pH**	**DO**	**Nitrate**	**Phosphate**
	N/A					

Biotic Sampling (Lesson 1C)

Sensitive	**Somewhat Sensitive**	**Tolerant**
Boxes checked x 3 = _____ index value	**Boxes checked x 2 = _____ index value**	**Boxes checked x 1 = _____ index value**
Water Quality Rating Total Index Value = _____	**Excellent (> 22)**	**Fair (11-16)**
	Good (17-22)	**Poor (<11)**

2. Construct an explanation for the current water quality of the aquatic ecosystem from the collected data and your observations. Use the collected data from above and include any human activities that may have led to the water quality assessment.

3. Design a solution to improve the human impact at the aquatic ecosystem testing site. Be sure to address how this solution will maintain or improve the current water quality assessment.

Self Assessment

Skill	Description	Yes	No
Identifying Human Impact	I identified human activities that created an impact upon the tested aquatic ecosystem.		
Constructing Explanations	I constructed an explanation for the current water health of the tested aquatic ecosystem.		
Designing Solutions	I helped to design a solution to improve the water quality of the aquatic ecosystem and counteract the human impact on that system.		