Is there enough oxygen for fish and other aquatic animals in the stream?
Dissolved Oxygen as a measure of water quality

What is dissolved oxygen (D.O.) and why is it important to measure?

Can you imagine what would happen if you didn't have enough air to breathe? Just like people, fish and other aquatic organisms need oxygen to live. Dissolved oxygen is oxygen gas that is in the water. Unlike other water quality measures high amounts of oxygen are positive for organisms in the stream! Fish don't have lungs, like people. Instead, fish have gills that allow them to breathe in the oxygen that is in water. If there isn't enough oxygen in the water, fish and other organisms die. Trout is a type of fish that needs very high amounts of oxygen to live. That means that trout is an indicator fish. If trout are spotted in a stream, what does it mean?
(students need a box or some sort of space to put their response).

Do you remember other water quality measures and the results that trout need to make the water hospitable?
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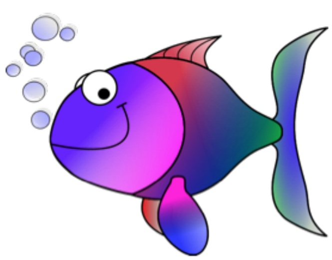
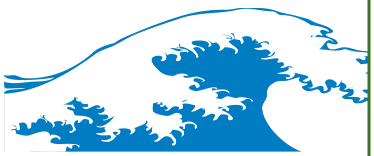
	URL: https://openclipart.org/detail/2707/happy-fish Credit: Machovka License: Public Domain

Carp, on the other hand, is a type of fish that can live in high and low oxygen levels.

What are the sources of dissolved oxygen – where does it come from?

Have you ever seen water crashing against rocks as it flows downstream? At the bottom of a waterfall, have you observed the water as it hits the water below? The crashing water below a waterfall or against rocks cause turbulence.



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Credit: johnny_automatic

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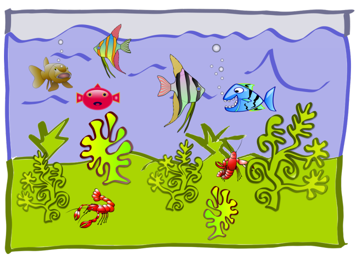
Turbulent water can capture oxygen from the air. It traps the oxygen and pulls it into the water. The atmosphere, therefore, is one source of oxygen for streams. Any fast moving water that causes turbulence can capture oxygen from the air.

Another source of oxygen in stream comes from water plants. During photosynthesis plants produce



URL: https://openclipart.org/detail/29473/underwater-world-aquarium

Credit: pfluegl

License: Public Domain

oxygen. If the plants are on the land, the oxygen goes into the air. If stream, lakes, and rivers have water plants, when these plants produce oxygen, the oxygen goes into the water.

What causes oxygen levels to drop?

The main reason oxygen levels drop is due to excess organic waste. Organic waste is any decomposing waste from an organism. When plants and animals die they become organic waste. Waste from animals and raw sewage are also organic waste. When excess algae (often due to excess nitrogen and phosphorous) dies it becomes organic waste. Bacteria decompose organic waste.

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Credit: Ana Banderchuk

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Because there is an abundance of organic waste, the bacteria population dramatically increases. Bacteria also use oxygen. If there are excess bacteria they will use up all of the oxygen. Fish and other aquatic organisms die from lack of oxygen. This results in more organic waste. The cycle starts again. The end result may be an oxygen-depleted environment that can lead to a dead zone: a place that lacks the conditions necessary for life.

Another factor that could contribute to lower oxygen levels is thermal pollution. Warm water cannot hold as much oxygen as cold water. So if the water is abnormally hot its oxygen levels may be lower.

Water Quality Standards

Just like other water quality measures there are standards that are used to represent if a fresh water body of water has enough oxygen.

Here are the water quality standards for dissolved oxygen:

Dissolved Oxygen Water Quality Standards	Dissolved Oxygen Percents
Excellent – plenty of oxygen	91-110%
Good – enough oxygen	71-91% or over 110%
Fair – not enough oxygen	51-70%
Poor – not enough oxygen	Below 50%

When you test your stream or river for dissolved oxygen, what results are you hoping to get? Can you explain why?
(students need a box or some sort of space to put their response).

Is there enough oxygen for fish and other aquatic animals in the stream?
Dissolved Oxygen as a measure of water quality

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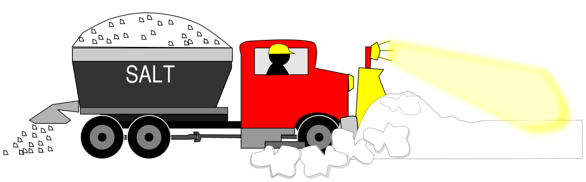
How many dissolved solids are in our stream?
Dissolved Solids as a measure of Water Quality

Why do we measure for dissolved solids of streams? Where do they come from?

People use products outside on land that can get washed into storm drains or simply run downhill during rain or snowmelt and then flow into streams, rivers, and lakes. Some of these products contain substances that dissolve. Three of the major dissolved solids that impact water quality are road salt, nitrates, and phosphates. High amounts of these can cause problems for organisms in the water.

Road Salt – What is its source and how does it Impact Water Quality?

If you live in a northern climate you probably have experienced snowy winters. In addition to snow covered roads, ice and freezing rain can cause potential safety hazards.

	URL: https://openclipart.org/detail/15567/open-road Credit: IncessantBlabber License: Public Domain

Road salt is put on surfaces - roads, sidewalks, and parking lots - to help avoid accidents and keep people safe. Organisms in lakes, rivers, and stream are freshwater organisms, not saltwater organisms. Although adding salts to slippery roads is important for safety reasons, too much salt can be a problem for freshwater organisms.

Nitrates and Phosphates – What are they and where do they come from?

Compounds that contain nitrates and phosphates can dissolve. For instance, sodium nitrate can dissolve in water. But what are they? Nitrogen and Phosphorus are both elements. In nature, nitrogen and phosphorous can be found in various compounds like like sodium nitrate and potassium phosphates. Nitrates and phosphates are essential nutrients; all organisms need them for growth and repair. However, they are only needed in very small amounts. So where are nitrates and phosphates found? Well, if all living organisms need them, then all living organisms have nitrates and phosphates. But so do products that come from them, like animal waste. All dead organisms, then, have nitrates and phosphates. Another name for dead organisms is organic waste. This includes dead animals and plants. If you live in a climate where leaves change colors and fall off trees every year you are very familiar with dead leaves!

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Dirt can hold nitrates and phosphates. So far, all of these sources are from nature. Nitrates and phosphates are essential components of the life cycle. When there is organic waste (dead plants and animals), decomposers such as bacteria break down the dead matter. During this process, nitrates and phosphates are released. On land, the nutrients go into the soil and are then used by plants for growth. In the water, water plants use nitrates and phosphates that are released from decomposition. Whether on land or in the water, animals eat plants and other animals. That's how they get nitrates and phosphates. Both the plants and animals eventually die and become organic waste and the cycle starts all over again. This cycle is important. Without it, new plants and animals would not be able to grow.!

Too many nitrates and phosphates in water, however, can cause significant problems for aquatic environments. A major source of excess nutrients (nitrates and phosphates) in waterways is fertilizer. Think about it – farmers use fertilizer to help their crops grow. People use fertilizer to have nice lawns and gardens.

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When it rains, runoff from agriculture, lawns, and home gardens that includes fertilizer can flow downhill and into various waterways, contributing excess nutrients. Dairy farms have cows that produce waste. Cow manure and manure from other animal farms can also runoff into waterways. In addition, nutrients can come from leaking septic tanks and from wastewater treatment plants. Finally, some cleaners contain phosphates. These sources – fertilizer, human waste, animal waste from farms, and cleaners – come from people and result in excess nitrates and phosphates.

What is the effect (consequence) of excess nitrates and phosphates in waterways?

When there are too many nitrates and phosphates it can lead to a disruption of the life cycle that can eventually result in a **dead zone**. Dead zones are areas in water that cannot support life. A chain-reaction cycle occurs. First, excess nitrates and phosphates in water, often from fertilizer runoff, can result in excess algae growth causing algal blooms (remember that both nitrates and phosphates are nutrients for growth). Algae have a short life span. When all the excess algae die, there is an excess amount of organic waste. Do you remember what happens to organic waste? It is decomposed, broken down, by bacteria and other decomposers. If there is an excess amount of organic waste, there is an excess food source for bacteria. The bacteria population dramatically rises. Bacteria need oxygen. These excess bacteria use up all of the oxygen. Fish and other aquatic organisms need oxygen. Without it, they die. This results in more organic waste and the cycle starts again. Eventually, the oxygen is depleted (this cycle is also known as the oxygen depletion cycle) and the area becomes a dead zone.

How do we measure dissolved solids?

There are different ways to measure the amount of dissolved solids in water. One method is to use a conductivity probe. Dissolved solids can conduct electricity. For example, when put in water, sodium chloride (salt) breaks apart into sodium and chloride and can conduct electricity. Sodium nitrate breaks down in water to sodium and nitrate and potassium phosphate breaks down in water to potassium and phosphate and can conduct electricity. Though a conductivity probe can measure the ***amount*** of dissolved solids in a lake, river, or stream, it will not identify which solids are dissolved. Qualitative observations are used to help determine which solids might be dissolved in the water. What would you look for **in** the water that might indicate the possibility of nitrates and phosphates? (Students need a box to put their response – dead, decaying leaves, water plants or other plants in the water could indicate nitrates and phosphates. Algal blooms could indicate excess nitrates and phosphates. Soap bubbles could indicate phosphates).

What **area** observations might indicate that people are using products on land that might contain phosphates and nitrates that could have entered water through run-off? (Students need a box to put their response – nice lawns and/or gardens could indicate fertilizer. Windows, cars, etc. could indicate cleaners. Farms or golf courses in the area could indicate fertilizer use.).

If you live in a northern climate, winter weather could result in snow. High readings from a conductivity probe could be the result of road salt that has entered a waterway through run-off. Road salt, Calcium chloride, can break down and conduct electricity.

In addition to conductivity probes, nitrate and phosphate kits are sometimes used.

Here are the water quality standards for different ways of measuring the amount of dissolved solids:

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Excellent – not too many dissolved solids	0-100 mg/L	0-1	0-1

Good - not too many dissolved solids	100-250 mg/L	1.1-4	1.1-3
Fair - too many dissolved solids	250-400 mg/L	4.1-9.9	3.1-5
Poor - too many dissolved solids	> 400 mg/L	> 10	> 5

Whether due to road salt, nitrates, or phosphates, too many dissolved solids are not healthy for streams and organisms that live in streams. People's actions on the land can significantly impact the amount of these dissolved solids. Are there some action steps that you can think of that people can take to minimize the amount of dissolved solids that may enter waterways? (Students need a box to put their response – use less fertilizer and road salt. Don't use fertilizer at all. Instead, cut your grass and leave it on the lawn to naturally decompose and put nitrates and phosphates back into the soil. Rake leaves away from storm drains)

Does our stream have too many nitrates, phosphates or salt?

Dissolved Solids as a measure of Water Quality

Why do we measure for dissolved solids of streams? Where do they come from?

People use products outside on land that can get washed into storm drains or simply run downhill during rain or snowmelt and then flow into streams, rivers, and lakes. Some of these products contain substances that dissolve. Three major dissolved solids that impact water quality are salt, nitrates, and phosphates. High amounts of these can cause problems for organisms in the water.

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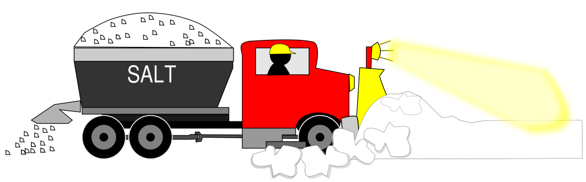	URL: https://openclipart.org/detail/15567/open-road Credit: IncessantBlabber License: Public Domain

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Nitrates and Phosphates – What are they and where do they come from?

Nitrates and Phosphates are two other substances that dissolve. But what are they? Nitrogen and Phosphorous are both elements. In nature, nitrogen and phosphorous can be found in different forms like nitrates and phosphates. Both are essential nutrients; all organisms have to have them for growth. However, they are only needed in very small amounts. So where are nitrates and phosphates found? Well, if all living organisms need them, then all living organisms have nitrates and phosphates. But so do products that come from them, like animal waste. All dead organisms, then, have nitrates and phosphates. Another name for dead organisms is organic waste. This includes dead animals and plants. If you live in a climate where leaves change colors and fall off trees every year you are very familiar with dead leaves!

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LESSON #1: Why do we want to study water quality? What questions can we ask about water quality?

Overview: This one to two-day lesson introduces students to the driving question, "*How healthy is our stream for freshwater organisms and how do our actions on land potentially impact the stream and the organisms that live in it?*" Students generate questions they have about water quality. Students are guided by the teacher, not only to think about the water and organisms in the water, but also about people and how people might impact the water quality. It includes anchoring activities that could include a video or two and a stream walk. Students brainstorm to begin to figure out, "*Why should we investigate water quality? How do people affect the water quality of streams, rivers, and lakes?"* In this first lesson a context is set for exploring the driving question (DQ). In order to answer the driving question, students will need to engage in several practices and use crosscutting concepts. The DQ is rich with science ideas. The lesson, as well as the entire unit is flexible. It depends on teacher resources. Is there a stream/river nearby? Are there water issues in the teacher's particular area?

NGSS Performance Expectation:

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

MS-LS1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Lesson Learning Performances: LP1: Students generate questions to explore how human activities related to products people use on the land, may negatively impact populations of organisms in fresh waterways. (CCC = cause and effect)

Safety Guidelines: None

Preparation: Some internet sites are provided that introduce water quality issues. However, conducting a search to find issues in your community or a nearby community will help to contextualize the unit even more and make it more interesting and meaningful to your students.

Time: One or two class periods

Materials:

- Videos related to water quality, preferably related to local issues. Some general sites provided.
- Post-it notes

INSTRUCTIONAL SEQUENCE

1. Introduction: Begin to set a context for studying water quality. (~1-2 min)

Purpose: Set a context for small group brainstorming.

Begin by asking students questions about their water use. Questions could include:

"How many of you took a shower last night or this morning before you came to school?

Did all of you brush your teeth this morning?

You're all wearing clean clothes; how did they get clean?

You ate breakfast with with clean dishes. How did they get clean?

Did any of you drink water this morning or have drinks that contain water?

*What are all the ways that you use water? (*Ask students to spend one minute with the people round them to generate a list of all the ways that they use water). *How many ways do you have on your lists? Lots!*

What do you know about water and all living organisms, including us?

Water - it's a pretty important part of our lives. We can't live without it. Plants and animals can't live without it either!"

2. Small group brainstorm: WHY should we investigate water quality of freshwater bodies of water such as rivers, lakes, and streams? Do you think people are related to water quality? If no, explain. If yes, how? (~5 min)

Purpose: Illicit student prior knowledge of water quality of freshwater lakes, rivers, streams

This activity allows students to brainstorm and share ideas. It provides you with insights into students' prior knowledge. Since everyone has some knowledge of water it empowers all students to share and begins to develop a collaborative learning environment.

Ask groups of 3-4 students to work together to generate specific ideas related to the two questions listed above. They may split a paper in half with one question on each half (see below). Encourage students to try to come up with at least three ideas for each question. Assist students that are struggling. For example, "What are some things that people might do that impact water?"

WHY should we investigate water quality of Freshwater bodies of water such as rivers, Lakes, and streams?	Do you think people are related to water quality? If no, explain. If yes, how?

Making science learning accessible to all learners:

3. Classroom Sharing: Groups sharing ideas. (~10 minutes)

Purpose: Share everyone's ideas, learn from others, identify common ideas, will lead to unit's driving question. This sharing will continue to provide you with insight into students' prior knowledge.

Going from group to group have a student share one idea that the group generated. You may want to record these ideas on the board. You can split the board into two sections: one related to WHY we should investigate water quality and the other, how are PEOPLE related to water quality. There will most likely be overlap of ideas and themes will emerge. You may ask, "How many groups had the same idea?" to get a sense of where students are at. This will be particularly useful if a group shares an idea that you know will be addressed during the unit.

4. Introductory video related to quality of freshwater creek, stream, river, or lake (3-10 minutes)

Purpose: Set a context for studying water quality of freshwater lakes, rivers, streams.

Show one or two short videos to set an interesting context. There are a few suggestions below. However, a quick search and you may find interesting videos based on water issues right in your own community. Avoid videos that "tell" students all of the answers. Rather, look for ones that pique interest.

Making science learning accessible to all learners:

A. EPA Water Quality Video - YouTube **2:15** https://www.youtube.com/watch?v=o8uVOxsl90w
B. **Urban Waters Voices:** Thirteen, 3-minute videos from different parts of the county related to local water quality. Look for one near your community. Here is the introduction from the website:

   "EAP Urban Waters Voices is a series of video interviews featuring locally led efforts to restore urban waters in communities across the United States. These videos feature local efforts and strategies to improve urban water quality while advancing local community priorities."

C. UNESCO Protecting Water Quality for People and the Environment - YouTube **8:29** https://www.youtube.com/watch?v=i5jGxO28Kw8

D. http://www.mlive.com/news/index.ssf/2015/09/michigan_water_issues.html#0

Background

All organisms need water. The earth's surface is 70-75% water, yet less than 1% (closer to 0.1%) is freshwater that is usable by people. And this water needs to be shared with other organisms that need freshwater. This idea may come up in one of the video's or during discussion during this introductory lesson. If it doesn't come up, you may want to integrate this into the way you contextualize the lesson. Earth's nicknames are "Blue Planet" and "Water Planet" because we have so much water. But pollution threatens the availability of that water.

5. Small Group: Specific Questions related to water quality and people: (~5 min)

Purpose: Students generate questions based on the initial brainstorming activities and the video(s) related to water quality of freshwater bodies of water and people. Hopefully, many of their questions will be addressed during the unit. This facilitates students to take ownership in their learning as these are student generated questions. This activity also sets the context for the next lesson. Also, when students have choice, they are more motivated to learn.

Students should work in groups, using post-it notes to write down a couple of well thought-out questions - one or two - related to ideas that were generated in the class discussion, video(s), or any new ideas. These questions should be of interest and meaningful to them and that they deem important to investigate. You can decide whether or not students put their names on the questions.

Collect the questions, but do not read them yet. Read through the questions later and group them. Once you introduce the driving question you can create a driving question board (DQB). A DQB is a bulletin board or an area on a wall where the driving question is posted. It is a visual tool to focus learners' attention, post questions that they generate, record what they have learn, and used as a reference to make connections to the driving question throughout the entire unit. If you have multiple classes you may have different parts of the room where you display their questions. Another option is to combine the various questions. Chances are good that some, and hopefully many, of the questions generated will be addressed in the unit. When this occurs, you may pull the post-it note and read it aloud to either introduce what's coming up or as you are engaged in addressing the question.

6. Stream walk or other contextualizing activity (~10-20 min)

Purpose: To show students the phenomenon under investigation and to motivate students. To introduce the driving question, "How healthy is our stream for freshwater organisms and how do our actions on land potentially impact the stream and the organisms that live in it?"

There are different options depending your access to a freshwater body of water:

1. If you have a creek or stream within quick walking distance of your classroom, walk students out to show them the waterway. Introduce the driving question, "Is our stream healthy for freshwater organisms and how do our actions on land potentially impact the stream?"
2. If you do not have a creek or stream within quick walking distance, but you have a waterway that you will be able to regularly access, pull up a picture, video, etc. of that waterway. Then introduce the driving question.

3. If you do not have a waterway that you will be able to access as a class, but have a waterway from which you will be obtaining water samples and bringing them to class, pull up a picture, video, etc. of that waterway. Then introduce the driving question.

Concluding the lesson

Regardless of what body of water you will be investigating, you will now tie together everything that was done in this introductory lesson. Refer to the brainstorming ideas and to the initial videos that introduced the lesson (if time, you may show others). Let students know that you will read through the questions they generated during class and that hopefully many of them will be answered as we, as a class, investigate the stream (or creek, etc). We will use the driving question as the guide for the entire unit and explore sub-questions - hopefully many that will spring from students questions - that will be part of the driving question.

Homework or reading: None

LESSON #2:

Lesson question: How do experts determine water quality? What can WE do to determine water quality?

Overview: In this one-day lesson, students conduct a short internet search to investigate what experts do to investigate water quality (this could be done as homework the night before). The teacher informs students of water quality measures that the class will be doing. Students discover that we will be doing many of the same water quality tests that expert scientists do! Students are asked to think about how many pieces of evidence are needed to figure out and explain the waterway phenomenon (whether is be a creek, stream, river, pond, or lake) under investigation. In the prior lesson, students were introduced to the driving question, *"How healthy is our stream for freshwater organisms and how do our actions on land potentially impact the stream and the organisms that live in it?"* They were also introduced to the specific phenomenon that they would be investigating (a local creek, etc).

NGSS Performance Expectation: PE: MS-LS2-4, PE: MS-LS2-1, PE: MS-ESS3-3

Lesson Learning Performances:

LP2: Students gather, read, and communicate information from multiple sources to explore how experts determine water quality where human activities may alter the biosphere, impacting fresh waterways and their populations of organisms. (CCC- cause and effect)

Safety Guidelines: None

Time: One day

Materials: internet availability

INSTRUCTIONAL SEQUENCE

1. **Internet search** - How do experts determine water quality? (~15 min)

Purpose: To allow students to see that we will be conducting many of the same water quality tests that experts conduct. This will further motivate students because they will both be excited to do what experts do and will enhance the value and importance of water quality monitoring.

Begin by reviewing yesterday's class: You can begin class by asking students to summarize what was done in class yesterday - we generated ideas related to water quality of freshwater streams, etc. and people's relationship with water quality. You may ask students for their ideas of how we will know if our stream is healthy? Building from student suggestions introduce the following: If we're going to study water quality of our local stream, etc. ask students if it makes sense to see what experts do to determine water quality. If we know what experts do, then we can see if WE can do any of the same things to investigate our stream.

Students should spend 10 minutes searching the internet. They should access several different sites that they think should be reliable such as government sites. They may also look at sites that are from state or local water quality monitoring projects. Stress to students to investigate water quality for freshwater organisms. This search is not related to drinking water. Students should simply LIST 6-8 different ways experts test streams, rivers, etc. Students do not need to read about the tests, but simply find a couple of sites that discuss monitoring water quality of streams and write down various water quality tests, in list format. The purpose is simply to introduce students to some measures, not for students to develop any understanding of these measures. Here are search phrases that students can use:

Search phrases: 1. Water quality tests for streams, 2. river and stream water quality monitoring,

Background
This unit has students investigating pH, temperature, conductivity, oxygen, and turbidity. They will also conduct a visual survey: qualitative observations in the water, next to the water, and near the stream - the area of the mini-watershed surrounding the stream. Below are some tests/words students will find during their search and which ones are related. Following this are some other measures that are not part of this unit.
pH: acids, bases, neutral
Temperature: thermal pollution
Conductivity: salinity, phosphorous/phosphates, nitrogen/nitrates, nutrients
Oxygen: dissolved oxygen, B.O.D (biological oxygen demand), flow rate
Turbidity: secchi disks, dirt, floating particles, suspended particles, erosion
Other measures not included in this unit : metals, ammonia, hardness, toxic substances, e-coli/bacteria, benthic macro-invertebrates,

2. Class sharing of water quality measures (~10 min)

Purpose: Students share information they found during their internet search.

Bring the class back together and ask students to share what they found. Record their responses on the board. You will see that some responses are simply synonyms. For example, turbidity, floating particles, and clarity are all synonyms. Others will be related, for example, nitrogen, phosphorus, and road salt are all dissolved solids measured by conductivity, or nitrate and phosphate kits. Regardless of what is shared (even synonyms), record it on the board and ask students to record anything that is shared that is not on their list. In the end, everyone will have the same list.

3. Identifying what can be investigated during the unit. (~5 min)

Purpose: Inform students what the class can investigate. Excite and motivate students as they see that they will be conducting many of the same water quality tests as the experts.

One by one go down the list and circle items from the list that will be investigated during the unit. For example, circle pH, saying, “We will be able to test this” and/or “We have equipment to investigate this.” For items that cannot be tested, simply cross them off saying something like this: “We don’t have equipment to test this." You may circle words and let students know that some are related. In the end, there should be many items that are circled. You can step back and ask students to look at the overall board. Everyone should be able to conclude that we will be able to investigate some, if not many, of the tests that experts conduct.

This is also an opportunity to make connections with questions that students generated in the previous lesson. Some of the questions may also be related to the water quality measures that are on the driving question board (some that may be addressed and others that may not). This will allow you to let students know if the class will be investigating these questions, or if the questions are valuable, but not feasible to address in the unit.

4. How much evidence do we need to collect? - basketball analogy (~5 min)

Purpose: Provide students with a real-life, non-science, example to help them understand why we need to have several pieces of evidence in order to best answer the driving question.

Say to students, "Let's pretend for a moment that you have been asked to evaluate a basketball player who is a senior in high school to see if she is good enough to play college basketball. You go to the gym and see her standing at the free-throw line and, swish, she makes the free-throw. Do you conclude that she is college material?" Students should respond that one free-throw is not enough information to conclude that the player is strong enough to play college ball. Ask students if they observed her making 19/20 frees throws if this would be enough information. They should have a similar response. Ask students what other information they might want to obtain that would allow them to make an informed decision to fully respond to the question, "Is this girl good enough to play college basketball?". Students may suggest that they need to see if she can pass, dribble, play defense, and if she has a good shot from many areas. They may want to know if she's a team player, if she can play under pressure, and if she has a good work ethic. Based on these responses, you can help students conclude that if they want to fully understand this senior's college basketball potential, they need to obtain several pieces of evidence from which they can make a conclusion. In other words, they need to support their conclusion with evidence.

Let students know that this is the same case with science. To be able to answer the driving question, "How healthy is our stream for freshwater organisms and how do our actions on land potentially impact the stream and the organisms that live in it?" we will need to collect several pieces of evidence. The stream is a complex system (systems and systems modeling in an important crosscutting concept). We will be conducting several tests (also called measures) over the course of the next couple of weeks. As we collect data, we will build and test models to explain our understanding of the water we are studying. We will expand our models as we obtain more evidence to see if our models accurately portray the water quality of the phenomenon.

This is an opportunity to introduce quantitative and qualitative data. Quantitative data is data obtained, usually using an instrument, to measure something, and obtaining a number. Qualitative data is data obtained using our senses (except taste) where we write a rich description using words.

5. Introducing the first water quality measure - pH (5-10 min)

Purpose: Assess student prior knowledge of pH. Introduce the homework reading.

Remind students that one of the water quality measures they found when exploring what experts do to determine water quality is pH. Inform students that the first water quality measure that we will use to investigate the stream (or whatever water phenomenon that you are investigating) will be pH. Ask students, when they hear the term "pH" what do they think of? You may have students first share with a partner (one minute) and then share as a class. Let students simply share their ideas until all ideas are shared. Some students may share they they test for pH in their fish tanks. Other students have seen testing at a swimming pool that could be pH. Some students may say pH is related to acids and to stomach indigestion. Whatever students say, let them know that pH is an important water quality measure for freshwater.

Show students a pH probe (or pH paper, or whatever you are using to measure pH). Let students know that this is an instrument that we will use to test pH. A pH probe will provide us with a number (quantitative evidence) - the pH of the stream. Ask students if that is enough information. Help students realize that before we can test for pH in the stream, we need to have an understanding of what pH measures and why pH is important for freshwater organisms. The probe (or pH paper) only provides us with a number. Stress that *we* are the ones who need to figure out *what* the number means for organisms, and try to figure out *why* the stream has that pH level.

pH demo: How healthy does Elodea appear in water with various pH levels? (currently not in curriculum - possibility to add)

Concluding the lesson (~5 min)

Quickly summarize today's lesson. We investigated what the experts do to determine water quality. We found out that we will be able to conduct many of the same tests that experts do. We decided it's important to conduct several different types of tests in order to get a more complete picture of the stream, which is a complex system. Our first water quality test will be pH. We have some ideas about pH, but need to learn more, particularly why is it important for freshwater organisms and what causes pH levels in various waterways to change.

This sets the context for the homework.

Homework: pH Student Reader

Depending on the reading level of your students, you can also do the reading as a close read in class.

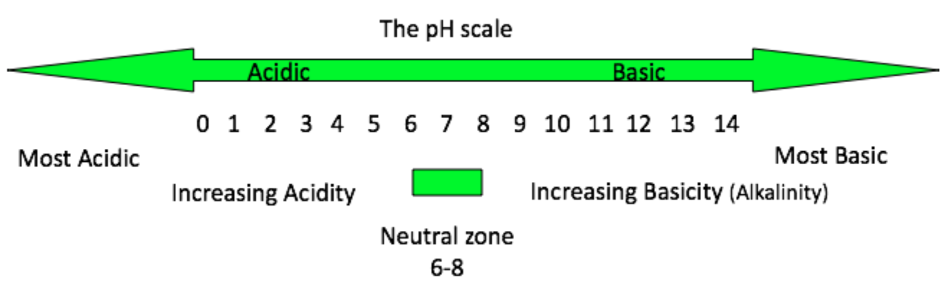
For homework, students will complete a short reading that includes a few questions. Let students know that this reading introduces them to the importance of pH for freshwater organisms. They should carefully study the chart that is part of the reading. A couple of the questions require students to use the chart.

The reading will lead to a three-day lesson on pH. The reading should take the average student around 10-15 minutes to complete. Tomorrow's lesson will begin with a discussion of this reading. The reading follows:

Is the stream acidic, basic, or neutral? pH as a measure of Water Quality

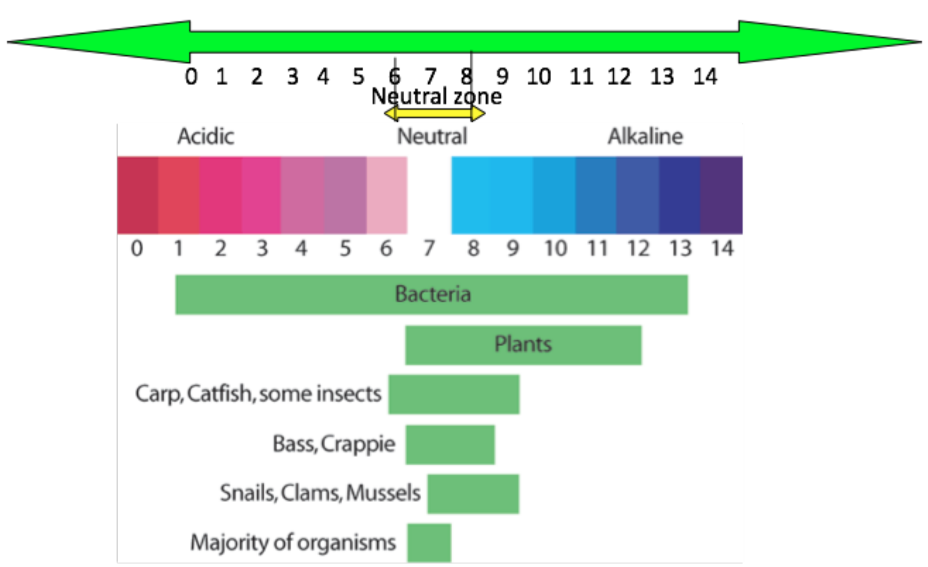
What does pH measure?

pH is a water quality measure that determines if a stream, river, or any body of water is acidic, basic, or neutral. Look at the pH scale below and you'll see that it runs from a value of zero, which is very acidic, to 14, which is very basic. Right in the middle is 7, which is neutral.

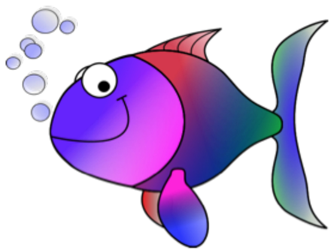


Credit: Ann M. Novak

What is the pH range that is the best for freshwater organisms - the pH range that is the best for the majority of organisms? To find out, look at the chart below. Read the types of organisms and line them up with the pH scale. (students need a small box to put their response).



Do you see that the majority of freshwater organisms need a pH between 6.5 and 7.5? This is the best pH range for freshwater organisms and would be considered excellent water quality for pH. Examples of organisms that need this pH range in order to live include trout, mayfly nymphs, stonefly nymphs, and caddisfly larvae.

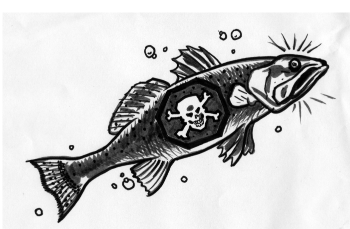
	URL: https://openclipart.org/detail/2707/happy-fish Credit: Machovka License: Public Domain

Many other organisms can live in a pH range that falls between 6–8 on the pH scale. This is called the *neutral zone* for freshwater organisms. It's a pretty healthy pH for water and would be considered *good* water quality, even though 6.5-7.5 is the best. Look back at the pH scale. Do you see that 6-8 is labeled as the neutral zone? When we test the water quality of a river or stream (or any freshwater body) we hope that the pH is either excellent (pH between 6.5-7.5) or good (pH between 6.0-6.5 or 7.6-8).

What happens when the water's pH becomes more acidic or basic? Write down your guess.

(small box for student response here)

If something causes a stream to become either too acidic or too basic, the organisms that need a more neutral pH will die. The water is no longer healthy for them. For example, trout, mayfly nymphs and stonefly nymphs need a pH range between 6.5-7.5. Bass and Crappie would also die; they need a pH between 6-8.5. Remember, most organisms need neutral pH.

	URL:https://www.flickr.com/photos/apeshot/9019017468/in/photolist-eJYPFb-79gJse-aVyxQn-6FChTi-5gUXSk-89G1qK-786A7r-idfDxA-duTeka-djVJWa-dLco5X-eVE6TL-cSHspN-p7NhiT-jUVget-orK2ad-4hTJau-owdbiX-ovgPia-a484nX-7EeeEQ-owXki6-z32oUp-7qknZ3-2VuU7z-otkGM9-owhuMq-ocadJf-9i2xth-ow4HHZ-oeUoWb-4pny3Q-tf1NWw-83FdwQ-8fiA77-4hTKdE-9AFQ1k-ba75qK-93bkEi-a3m5Gj-daNBR9-GUMJHC-afbq3p-ry5k5p-9DNCxB-nVazPY-hyRZat-dvgtDC-oy6Gjn-re3kVo

	Credit: scottapeshot License: Common Domain

Look back at the pH chart. What organism can live in the largest range of pH? What is the pH range? What other types of organisms also have a large pH range? What is the range? (students need a box to put their response).

Reading the chart, you should see that bacteria can survive in a pH range from 1-13. This is a huge range - bacteria are very hearty organisms! Plants can live in a pH range between about 6-12 or 13.

What *causes* pH to become acidic or basic?

People use products on land and do various activities outside that can end up causing a stream to change its pH. How can this happen? If someone puts fertilizer on their lawn, when it rains, the fertilizer can get picked up with the rain and then be carried by the rain downhill into the nearest water. If someone has a car wash, the car wash soap

	URL: https://www.flickr.com/photos/3dproducts/5104359338/in/photolist-8M4bcu-ar4Ykg-9V7ekS-d4CgyN-dJ3S4d-dJ3uim-9nPuGD-7jm8q6-dw9F9K-aRkXF-648it6-8xnhCS-av4YeU-4q2ZsJ-8xnhTW-4PiGAb-8MTBqW-8xjfCa-8xjgpP-5LUKb-dSNxzc-8xnhWo-97FyE5-8xjfGB-6Tsq6p-dCpgSu-f6V19K-hmQrgS-hmPZET-n5x53-bnBcUc-7jm87i-6y3UPg-46DtMs-hmQ6Ur-dTj4aR-5TYTVM-nU9XHw-bE9mQ4-brF8pV-bFfKiq-5EbUCa-gAMeMt-5zbdDf-cBFB-5pY6rv-9dabjK-6RBu8u-9eoBzC-DjHe3 Credit: Tunch Goren License: Creative Commons

will run downhill and into a storm drain. Did you know that storm drains are connected underground to pipes that flow directly into streams, rivers and lakes? LOTS of people use fertilizer and wash their cars.

	*Credit*: Ann M. Novak

People use lots of other of products outside: soaps, windshield wiper fluid, antifreeze. We wash our driveways with a garden hose using tap water or we water our lawns with a sprinkler system. Tap water is water that is treated with chemicals to make it safe for people to drink. Those chemicals in tap water, along with products people use outside on the land can have an acidic or basic pH.

	URL https://www.flickr.com/photos/internetsense/6789942482/in/photolist-bm1ekQ-ko99eF-sfGzmD-rhALF7-8vXWh5-cECbDN-7MpiJc-6E7A3t-57rq4a-fYMHcC-cEBYu5-8tSC8V-cR1PgN-bmh5pq-kePxUa-7uRBgj-dS6SX4-eCqRjy-bHcoy6-aNXZat-pA19J4-asochM-mcwE8w-5FR9Cj-aeB3s-qSMmdr-9HUtnU-qEspMT-jCPVAZ-EYjRQA-o1g3wc-auxF8E-dCTVN3-3QHo7g-4EwDvF-dHH5Hc-kCLxSL-6ovygv-8ZeAsj-6U6QvC-e9fcaK-mkwzJe-bnDndu-7ZDUUS-inBW4W-5ePojr-7byNSC-6vXzj3-pFwwMu-soEZd7 Credit: Philip Wison License: Creative Commons

If they run-off the land, either through storm drains or downhill on land, they can enter various waterways and change the pH. This can happen even if we live far away from a body of water. Many farmers also use fertilizer and pesticides that can run off into water. So do many people who take care of golf courses. Acid rain can also change the pH of water. Pollution from automobiles and coal-burning power plants can enter the air and interact with moisture and oxygen to form acid rain. The acid rain can enter the streams and lake and change the pH to be more acidic. All of these, use of fertilizer, car washes, and acid rain, and lot of other activities people do outside can cause the pH of freshwater to become either acidic or basic.

Water Quality Standards

Remember earlier that we said 6.5-7.5 pH range is excellent and that just below or just above these numbers in the neutral zone are good? A group of scientists got together and developed National Water Quality Standards for freshwater lakes, rivers, and streams (Stapp, & Mitchell, 1995). They used four categories for all water quality test results. They are *excellent, good, fair, or poor.* If a water quality test falls into the *excellent* or *good* range for water quality standards, the stream is considered healthy for freshwater organisms with *excellent* being better than *good*. If, on the other hand, the test results match up with *fair* or *poor* water quality, the stream has problems related to supporting freshwater organisms with *poor* being the most problematic.

Here are the pH water quality standards:

pH Water Quality Standards	pH Range
Excellent - neutral	6.5-7.5
Good - neutral zone	6.0-6.4 or 7.6-8.0
Fair - too acidic/basic	5.5-5.9 or 8.1-8.5
Poor - too acidic/basic	Below 5.5 or Above 8.5

When you test your stream or river for pH, what results are you hoping to get? Can you explain why? Can you include some examples of organisms and pH ranges they need in your response? (students need a box to put their response).

LESSON #3

Lesson questions: Is the stream acidic, basic, or neutral? What does pH measure and what is the best pH for freshwater organisms? What happens to organisms if the pH is too acidic or basic? Are products that people use on land acidic, basic, or neutral?

Overview: In the last lesson, students explored how experts determine water quality as well as determined that the class could conduct many of the same water quality tests as experts. In this lesson, students explore the first water quality measure – pH. They are introduced to what pH measures and a pH chart that includes the pH ranges needed for various freshwater organisms to survive. With teacher support, students plan and carry out an investigation, collecting and analyzing data as they test the pH of various everyday substances that people use on land in large quantities. Discussion of how these products can get into the water and change the water's pH (causes), the possible impact on the stream's pH (consequences/effects), the the effects on fish population and other organisms' population are included. Once students test these everyday substances they then test the pH of their stream. They now will have insight into whether or not the stream is healthy for freshwater organisms based on pH and possible causes of what may have caused the pH to be acidic or basic, should there results fall out of the neutral zone for pH.

Lesson Learning Performances:

- Students plan and carry out an investigation to test pH of everyday substances that people use on land that can get into waterways in large quantities.
- Students collect and analyze data to explore the relationship between the pH of the stream and the quality of the water for various populations of organisms.
- Students construct an argument to infer which specific substances might account for the pH levels of in the water and how human activity impacts those levels.

Safety Guidelines: Students will be testing everyday substances, some of which will be acidic or basic. They should wear goggles. Students should be careful to avoid falling into the water when testing the pH of their waterway.

Preparation:

Time: 3 days

Materials:

For the teacher	groups	individuals
pH powerpoint	pH probe, pH paper, or pH kit Products in tennis cans Bottles of distilled water for cleaning the probes	pH student reader data table for investigation Goggles pH chart Data table for all water quality tests

INSTRUCTIONAL SEQUENCE: Day 1

Background

Here are elements of the DCI that are introduced in this lesson. Other water quality tests also address some of these DCI's.

- People unknowingly use products outside that can impact the pH of streams, making them unconducive for populations of freshwater organisms.
- Human activities alter the biosphere and may negatively impact populations of organisms.
- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors

Everyone lives in a watershed, the land area that directs the flow of water to creeks, streams, river, etc.. When people use products on land, to wash their cars, fertilize their lawns, clean their windows, decks, or trash cans, these products get picked up by rainwater or snowmelt and travel downhill to a storm drain or simply run downhill and then to the nearest creek, stream or river. These products are untreated and pollute the water because they can change the water's pH. Sprinkler systems, or cleaning driveways with tap water from the hose produces runoff that may change the pH of streams; the pH of treated drinking water is not an appropriate pH for aquatic organisms. All of these human activities on the land may not only impact pH, but many other water quality measures. The result can be devastating for freshwater organisms.

Overall then, there is one cause related to humans impacting the pH of streams: products people use outside that can get into the water. There is overall one effect or consequence of water that is too acidic or basic: aquatic organisms die.

Optional: You may describe non-point and point source pollution. Non-point source pollution is a result of run-off where the source is not easily identified. Acid rain is also non-point in that the emissions from factories that contributed to the acid rain could be hundreds of miles from from the rain. Point source pollution, on the other hand is easily identified because a pipe connects the source directly to the waterway. Examples are factories and wastewater treatment plants. Sometimes factories dump chemicals directly into waterways through discharge pipes that can change the pH. Be careful, however, that students do not confuse discharge pipes from storm drains as point-source pollutants. If students traveled up a storm drain pipe they would end up at a storm drain somewhere outside.

1. After Reading: Probing for understanding (~20 min)

Purpose: To assist students to begin to understand the relationship between the pH of the stream and the quality of the water for various populations of organisms. Discuss main ideas about pH and its importance for water quality and how people's actions on land can impact the pH of waterways. A powerpoint is included that highlights important ideas. A suggestion is to use it *after* discussing pH ideas.

For homework, students completed a reading that introduced them to the importance of pH for freshwater organisms. Discuss the reading, probing students' understanding that should include the following:

a. We test pH to see if a stream is acidic, basic, or neutral.

Background Knowledge. You may want to include a discussion of characteristics of acids and bases. It is suggested that this discussion come *after* the pH lab. That will allow students to have experience with common products that are acidic, basic, or neutral.
Both acids and bases have the ability to corrode (they burn, "eat way", wear away material, they sting). Acids can taste sour (Direct students to never taste in a science classroom), have a pH less than 7 and contain Hydrogen ions (H+).
Bases can taste bitter, have a pH greater than 7, contain Hydroxide ions (OH-), and can feel slippery. Bases are also referred to as alkalines.
Acids and bases react to neutralize and form salts and water.

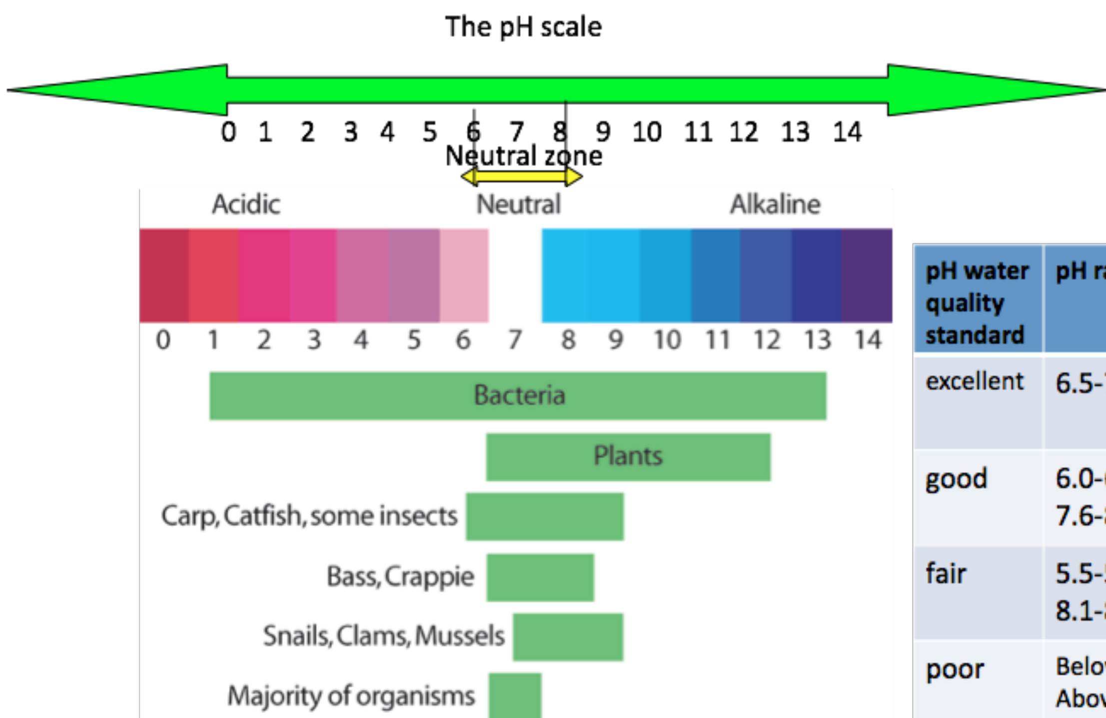
b. Even though 7 is neutral, 6-8 is considered the neutral zone for freshwater aquatic organisms. For water quality, numbers above 8 are basic. Numbers below 6 are acidic.
c. The largest variety of freshwater organisms need neutral pH, living in a very small pH range (6.5-7.5). The neutral zone, for freshwater is pH between 6-8 and many organisms can live within this range. Ask students questions about the chart to ensure that they understand how to use the chart. The chart is shown below.
d. As the stream becomes acidic or basic, organisms begin to die.
e. Bacteria can live in a pH range from 1-13.
f. When people use products outside on the land, those products can be acidic or basic and can run downhill (runoff) through storm drains or simply downhill and end up in waterways and change the pH.
g. Factories and car emissions can produce acid rain that can enter into waterways through precipitation and change the pH.
h. Riparian buffers are areas of vegetation near the banks of waterways. These plants, shrubs and trees can help slow run-off so the water soaks into the ground. The vegetation absorbs pollutants so they do not get into waterways. So a buffer acts as protection.

A suggestion to help students understand buffers by using the analogy of football helmets, shin guards, and mouth guards. These help protect athletes from injury. However, if an impact is to strong, athletes can still get injured.

i. Some waterways that contain a limestone bed, which is basic, protect themselves from acid rain with natural buffering ability that neutralizes acids. They help a waterway maintain a neutral pH. Unfortunately, people's actions on land can go over the limit of what a stream's buffer can handle.

The pH scale is a logarithmic scale based on 10's. Each number is 10 times more powerful than the number before. If you wish to explain this scale to your students, more time will be needed. It is introduced in the pH powerpoint.

Range of pH that different organisms can tolerate



pH water quality standard	pH range
excellent	6.5-7.5
good	6.0-6.4 7.6-8.0
fair	5.5-5.9 8.1-8.5
poor	Below 5.5 Above 8.5

Next, review water quality standards with your students:

Water Quality Standards: Water quality experts developed water quality standards using the terms excellent, good, fair, and poor. These are qualitative measures of water quality across all tests; whether you are measuring for pH or other water quality tests, the four qualitative terms are used. Excellent and good indicate that the stream is in the neutral range and healthy, with excellent being better than good. Fair and poor indicate that pH is too acidic or basic meaning the results are problematic for aquatic organisms, with poor being worse than fair. Excellent and good standards mean that for that water quality test the results are positive. Fair and poor results indicate that problems.

Here are the pH standards:

pH Water Quality Standards	pH Range
Excellent - neutral	6.5-7.5
Good - neutral zone	6.0-6.4 or 7.6-8.0
Fair - too acidic/basic	5.5-5.9 or 8.1-8.5
Poor - too acidic/basic	Below 5.5 or Above 8.5

Various tools are available for collecting pH data. Show students the tools they will be using to collect pH data.

pH tools and other water quality testing options:
Scientific probes, pH paper, or pH kits can be used to measure pH. Two companies, Pasco Scientific, https://www.**pasco**.com, and Vernier www.**vernier**.com/ sell a variety of probes that may be used throughout this curriculum. Probes are now wireless and data can be sent to cell phones, tablets, or computers. pH paper may also be used and may be obtained from various companies that supply science equipment and chemicals. pH kits, along with a variety of kits for other water quality testing, may be obtained from companies such as Hach, https://www.hach.com or LaMotte, http://www.lamotte.com/en/education/water-monitoring/5870-01.html

2. Plan in-class investigation (~25 min)

Purpose: Assist students to conceptualize and plan an in-class investigation to test the pH of everyday substances used outside.

Ask students - If they were to go outside today and test the pH of the water, would they be able to know what the results meant for the water quality and organisms? Students should be able to connect the pH number they would obtain to both the pH chart and to the pH water quality standards. For example, if the pH was 7.3 the largest variety of organisms would be able to live in the stream because based on pH, the stream would be excellent according to water quality standards. On the other hand, if the stream's pH was 8.7 only plants and bacteria could live in the water with a poor water quality standard.

Students should know WHAT the pH results mean for organisms, but ask them if they would know WHY they got those results? What might be the reason for the results? What could be done, in class, that would provide students with some insights that would allow them to infer why the stream's pH might be acidic or basic?

The goal is to assist students to figure out that they can test everyday products that people use outside that could get into the stream in large amounts. Students are not used to conceptualizing and designing their own investigations so this is not easy for them. They will need guidance and support. Nudge students to think about the reading. Hopefully, a student will suggest to test products. If not, you can suggest, "What do you think about testing the pH of everyday substances used outdoors?"

Brainstorm a list of possible products. Let students know that in order to test for pH, products must be in solution (in water). Some products are already in solution like windex. Other products, like fertilizer, will need to be put in water. Students may suggest dirt. Although found in nature, dirt can enter streams because of human activity such as during construction when dirt can runoff into waterways. Or if people cut down trees, roots no longer hold the soil so loose dirt could enter a waterway.

> Substances used for the pH investigation will be used again, in Lesson 6, for an investigation involving dissolved solids (the conductivity water quality test).
>
> To test pH, products must be in solution. Students may suggest products that do not dissolve. For now, that's fine. These products will be discussed during the lesson on turbidity (suspended particles).
> Here are common products:
> Fertilizer (test more that one as different fertilizers can have different pH's), windex, road salt, windshield wiper fluid, antifreeze, dish soap (people often use to wash trash cans), car wash soap, vinegar (people clean windows), road salt, dirt, tap water, murphy oil soap (used to clean people's decks). Collect rainwater if you can (acid rain?). Also test tap water (people hose off driveways, have sprinkler systems, and mix products with tap water).
> Think about testing products that are advertised as earth friendly.
> Avoid dangerous chemicals like insecticides. Avoid car oil - it does not have a pH and it ruins the pH probe.

Once you have generated a list of products ask students about their ideas of how to set up the investigation. Students can generate ideas of how to set up an investigation as well as the procedure for conducting the experiment. One potential guide sheet is included - Link to: pH Lab set-up and experimental procedure. Discussion should include keeping everything the same (controlling variables) except for the product that will be tested.

> Options
> Students can work in small groups to generate ideas. You can discuss ideas as a whole class. Small groups will extend the lesson. Regardless of your approach, everything needs to be controlled except for the product. In the end you should settle on one lab set-up and procedure.

> Date Recording Options. Option 1. You may want students to create a "sloppy copy" data table with partners. You can ask students what should go into the data table or simply let partner draw their ideas and then have a few students draw their tables on the board. The class can critique the tables and then

pull the best ideas together to create a final version. Not only do students want columns for the substances and the results, they should also include a column for predictions. Additionally, both prediction and result columns should be subdivided into a space for a number and for the matching text. For example, if a student predicts a product has a pH of 12, that would be a strong base. This will provide students with experience in using the pH scale to better understand how it works. If completed in class, it will extend the lesson. Option 2: You may students to generate ideas of what should go into a data table during class and then have students complete a data table for homework. Option 3: You can supply students with a data table - included below and with this link:

You will need to conduct the investigation:

Labelled containers: If you have beakers great, but clean tennis cans work well. If putting in water, use distilled water. Same amount of water (500 mL). Same amount of product. Ask students how much product to mix with the water. Students may suggest a couple of tablespoons, a cup, ½ cup etc. Try to come to consensus. If you teach several classes you can make a couple of batches where 2 or 3 classes share. A picture of a set up may be found in Day 2 of the lesson.

Concluding the lesson (~5 min)

This concludes day one of a three-day lesson. Ask students to summarize today's lesson. We explored pH and its importance to water quality. We've now designed an investigation to test the pH of everyday products that people use on the land. Once we test the pH of our stream, knowing the pH of everyday products can help us to figure out why our stream has a certain pH.

Let students know that you will be setting up the materials for the investigation that will take place next class.

Homework: The homework depends on your approach to the data table. You may want students to create a nice data table for homework. A data table for the investigation is provided.

INSTRUCTIONAL SEQUENCE: Day 2

1. Investigating the pH of everyday substances (~30 min)

Purpose: Gain insight into the pH of everyday products that could impact water quality

Begin by reviewing yesterday's class: You can begin by asking students to summarize what was done In class yesterday - we started to investigate pH and designed an investigation to test the pH of many products. We know that products people use on lands can runoff into waterways.

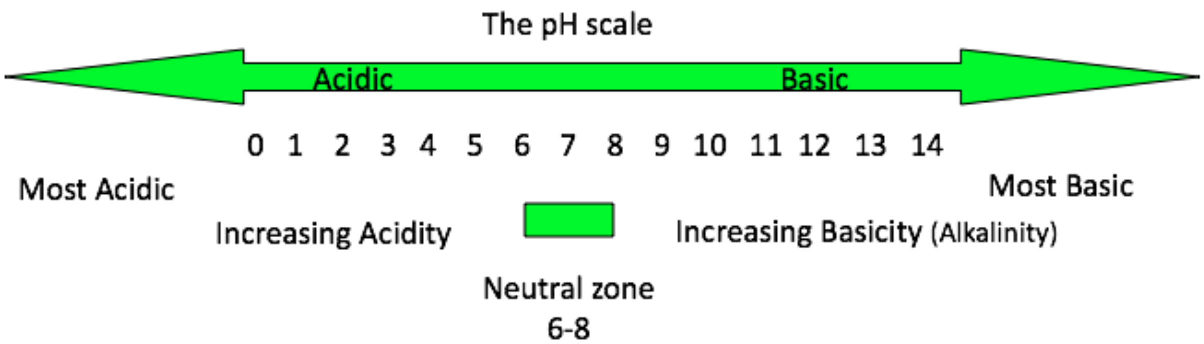
Let students know that, based on yesterday's planning, you have put various products in tennis cans for testing (see picture). Discuss the testing procedure with students. Have a list of all of the products on the board.

Tips:
1. 500 mL of the various products are placed in labelled tennis cans. The tennis cans are then placed in cup holders from fast food restaurants. This helps to avoid spillage.
2. A container of three or four products may be placed at each table, along with a spray bottle of distilled water for cleaning off the probes for use between each substance. This is to avoid contamination.
3. If students are using pH paper, they may simply dispose of each slip after one use in a container placed on the table.
4. You can decide if students will test only the products at their table and then share results or if student groups will move from table to table to test all of the products.
Credit: Ann M. Novak

Pass out data tables for each student. A data table is included below. If students created their own data tables for homework ask students to take out their tables. Ask students to write the names of the products in the far left column. Discuss the table with students pointing out that there are columns for both predictions and results. These are subdivided into boxes for numbers and text. Explain to students that they should use the pH scale that is at the top of the data table to help them as they predict the pH of the substances. They should record their predictions, both the number (ie 8.5) and the text (ie) weak base in the appropriate boxes. Students should both predict and record their numbers to the nearest tenth.

Are everyday products people use outside acidic, basic, or neutral?

We know that products we use on land can run downhill into storm drains or down a hill and end up in streams. If we test the pH of everyday products it can help us to understand why we might get the pH results when we go out to the stream to test for pH. Fill in each box. Use the pH scale provided to help you with your predictions and results. An example is provided.



pH Data

Substance	Prediction # acid, base, neutral	Results Trial 1	Results Trial 2	Results Trial 3	Result Ave	Result: Acid, base, neutral
Antifreeze	2 strongly acidic	8.9	9.1	9.1	9.0	Weakly basic

Students groups will now test the products. Ensure that each student wears goggles. Group sizes will depend on your equipment. Smaller groups will allow all students to test. They should take turns. Be sure to stress to students that they need to rinse the probe between products. They should test each three times to ensure the results are consistent. They may record the average or the most consistent number.

2. Engaging in sense-making: sharing and discussing pH results (~15 min)

Purpose: Students gain insight into the relationships between what products people use on land the their potential impact on water quality. Students share data to look for discrepancies and patterns in the data.

It is important to share the data. First, it allows the class to see if the data is consistent. If one group's numbers are continually different from others than you may need to check that probe. Next, it allows students to identify patterns. One important pattern for students to identify is that most cleaning products are basic. Some fertilizers are acidic, while others are more neutral or basic.

Encourage students to discuss the various products that they tested. Ask students if there are products that could negatively impact a stream's pH if they were to get into the waterway in large quantities? Students should use the chart from the pH Student Reader. For example, Murphy Oil soap has a pH that is around 10. Ask students, if a stream has a pH of 10, what are some examples of organisms that would die? What pH range do these organisms need? Snails, clams, and mussels need a pH between 7-9 so they could not live in a stream if the pH was 10. Bacteria and many plants could live. Bacteria can live in a pH between 1-13 and plants live in pH ranges from 6-12. Tap water's pH is often basic because of the chemicals put in to kill bacteria. If students have sprinkler systems or use their hoses to clean their driveways, this water gets into streams via storm drains and runoff.

Ask students if there are choices of products that could be used that would not have a negative impact on a stream's pH?

> Teaching extension: This is an opportunity for you to ask students to generate ideas of action steps that they and others can take to decrease the possibility of unintentionally contributing acidic or basic pollutants. Ideas include taking your car to a professional car wash. Here, soapy water goes down drains to the local water treatment plant instead of running downhill into storm drains that connect to waterways. If washing your own car, wash it on grass so it slowly seeps through the ground where the ground can naturally absorb the chemicals. When washing trash cans or a deck, choose earth friendly products. Decreasing the use of fossil fuels would also help prevent the formation of acid rain.

Concluding the lesson: This concludes day two of a three-day lesson. Let students know that they should now be able to test their stream water and understand what the pH numbers that they obtain mean: whether the stream is acidic, basic, or neutral and what types of organisms can live there and what types cannot according to water quality standards - understanding the relationship between the pH of the stream and the quality of the water for various populations of organisms. They now also have some insight into possible products that people use on land that might account for the readings that they obtain. For example, if their stream's pH is 9, they can rule out the substances that they tested that were acidic. This will assist students to see the relationship between products people use on land and the impact on a waterway's pH.

Understanding the idea of relationships, how one variable affects another variable (how the two variables are related) is key in developing models. Introducing the idea of relationships here will begin to lay the foundation for student work in future lessons where they create models of the stream.

Let students know that tomorrow we will test the pH of the stream (or whatever phenomenon you are using). If going outside, remind students to dress appropriately for the weather.

Homework: Students will write a prediction about the pH of the stream. (~5 min)

Predictions will include four parts:

- A pH number along with the corresponding text (ie. I predict the stream will have a pH of 8.5 which is basic).
- The standard for their prediction (Excellent, good, fair, or poor)
- A statement about the types of organisms that can live (all, many, some, very few) that matches the standard
- At least one reason for their prediction.

Here's an example:

I predict the stream will have a pH of 5.3 which is acidic. This is poor according to water quality standards so very few organisms can live in it. I'm predicting this because we tested fertilizer in class and it had a pH of 4.2 and I think lots of people are using fertilizer around here because I see nice lawns.

You will decide if students will write their prediction in a notebook, on paper, or using a computer.

<u>INSTRUCTIONAL SEQUENCE: Day 3 (and potentially 4)</u>

1. Investigating the pH of the stream (~30-45 min)

Purpose: Collect the first piece of water quality data - pH.

Begin by asking students to share their predictions. Another option is to collect data first and then share predictions. Provide students with instructions for data collection. Below is one possible data table for students to use.

Recording the weather is important because rainwater can pick up pollutants and carry them to waterways either through storm drains or simply by running downhill.

pH of the stream	Observations of substances or conditions that could impact the stream's pH
Trial 1 _____ Trial 2 _____ Trial 3 _____ Average __________	<u>In the water</u>: <u>Near the water</u>: <u>Recent Weather</u>:

<u>Groups</u>:
Based on your phenomenon, equipment, and student population, you will need to decide how to group students. Ideally, student groups are 3-4 students and each group has its own stream section where it will collect data for each water quality test.

<u>Data collection options</u>: If your stream is nearby and you can collect data in one class period that is ideal. Students should test three times to ensure accuracy. They could also test in different locations within their stream section. If needed, water samples from a stream could be brought into class.

2. Engaging in sense-making: Sharing and discussing pH results (~5-15 min)

Purpose: Students share data to look for discrepancies and patterns in the data.

You may want student groups to write their results on the board. If there is an outlier, this group may want to re-test. There could be other plausible factors that influence student results based the location of where they tested in relation to the land.

Students may work in groups to focus on these questions:

- According to your results is the stream acidic, basic, or neutral?
- How healthy is the water's pH for organisms?
- What water quality standard do your results convey (excellent, good, fair, or poor) for pH?
- What types of organisms could and could not live in the stream based on your results? Use the pH chart to assist you.

This may be followed up with a class discussion.

A comprehensive data table is provided for students to record data from the of the water quality tests that they conduct during the project. Students may now fill in the information about pH in that table.

Water Quality Test Results

How Healthy is our stream for freshwater organisms?
How do our actions on land potentially impact the water?

Organize your results from all of the water quality tests into one data table below. Notice the far right column labeled *Observations*. Record any information that you may have observed in or near the water that might help you determine what caused the results you obtained for that test.

Name of Water Quality Test	Results	Water Quality Standard	Observations
pH			

Concluding the lesson: (3-5 min) This concludes the three-day lesson on pH. Let students know that pH is the first water quality measure. Connect pH to the Driving Question Board. This may include the overall results (acidic, basic, or neutral as well as an overall number). Check to see if any of the student questions were addressed with this lesson. You may add other ideas to the DQB.

Connect to the driving question, "*How healthy is our stream for freshwater organisms and how do our actions on land potentially impact the stream and the organisms that live in it?"* Ask students if they feel confident to answer the driving question and make overall conclusions about the stream's health for supporting organisms. Relate this back to the basketball analogy. Was seeing that the person was a good free-throw shooter enough evidence to make a claim that she could succeed as a college basketball player?

The stream phenomenon is a complex system. pH is only one measure of the quality of the water. We want to gather more evidence. We will now look at a second measure of water quality related to temperature to see if the water's temperature is suitable for organisms.

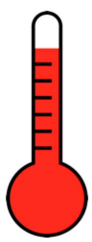
Homework: Students will complete the student reader, "Is the stream too warm for freshwater organisms?" Students apply their understanding at the end of the reader by completing questions related to thermal pollution. You may decide to have students wait to complete these questions until after you have discussed thermal pollution in class. The reading follows:

"Is the stream too warm for freshwater organisms?

Temperature as a measure of Water Quality

Why do we measure temperature of streams?

We are all familiar with temperature. Temperature tells us how hot or cold something is. The temperature of a stream or river can change. If you live in a northern climate, the water's temperature will be different in the summer than it will be in the winter - that's normal. At the same time of year, the temperature of rivers and streams in the south, like in Florida or Texas, will be different than temperatures in rivers and streams in the north, like in Michigan or Alaska - that's normal too. Climate and the seasons naturally affect the temperature of the water.

	URL: https://openclipart.org/detail/218124/thermometer Credit: Bartovan License: Public Domain

When we measure for temperature we are trying to determine if the temperature is **abnormally warm** - we're looking for an abnormal temperature increase. For example, we would expect the temperature of waters in Canada to be cool in the winter. If we measure temperature of a river and find it to be hot we would be surprised. We might think, "something isn't right here" and need to investigate further.
An abnormal temperature increase is called **thermal pollution**. It is a very different type of pollution than what we usually think of, because a change in temperature isn't "stuff" that got into the water causing it to be polluted, but rather a transfer of energy into the water that caused an unusual change in temperature..

How do we measure for thermal pollution?

When experts test for thermal pollution, they take a temperature reading at two different locations that are a mile apart. They then subtract to obtain a temperature difference. They look to the water quality standards for temperature differences to see if there is thermal pollution.

Here are the water quality standards for temperature differences, or thermal pollution:

Thermal pollution Water Quality Standards	Temperature differences degrees Celsius
Excellent - no thermal pollution	0-2^0 Celsius change
Good - no thermal pollution	2.1-5^0 Celsius change
Fair - thermal pollution	5.1-10^0 Celsius change
Poor - thermal pollution	above 10^0 Celsius change

What are the causes of Thermal Pollution?

Think about this:

> It's a hot summer day and you want to go swimming. You throw on your suit, grab a towel, and jump into your car and an adult takes you to the pool. You were in such a hurry that you didn't put anything on your feet. Now, you get to the pool and pull into the parking lot and park. You leap from the car and, "Ouch! Ouch! Ouch!" Your feet are burning up because the parking lot is SO hot! You rush to the grass and "whew! - that feels so much better!" - the grass feels cool.

There are four causes of thermal pollution. One cause of thermal pollution is **hot surfaces**. Human-made parking lots, roads, even rooftops heat up when it's hot outside. If it rains, the rainwater hits these hot surfaces. The rainwater now also becomes hot. Do you remember where rainwater goes? It goes downhill to the nearest storm drain. Do you also remember where the water in storm drains go? It flows into nearby creeks, streams, rivers and lakes. This now **hot** rainwater then flows into the water and heats it up, causing thermal pollution, an abnormal temperature increase.

URL: https://openclipart.org/detail/15567/open-road

Credit: IncessantBlabber

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A second cause of thermal pollution is from factories that produce products we use everyday, other industries, and power plants. They pull in water from a river or lake and use it to cool their machinery. The water warms up as it cools the hot machines. If this hot water is then discharged back into the river or lake then it warms up, causing thermal pollution.

	URL: https://openclipart.org/detail/23962/factory Credit: Anonymous License: Public Domain

A third cause of thermal pollution is soil erosion or other macro particles that are in the stream. Erosion can be caused when people cut down trees because the roots hold soil in place and without the roots allowing for this stability, erosion can occur. It can be caused during construction

	URL: https://openclipart.org/detail/210414/misc-proto-dirt-pile Credit: Glitch License: Public Domain

when people dig holes in the ground and loose dirt is put in piles. Poor farming practices can result in loose dirt; all of this loose dirt can be carried into rivers and streams when it rains. Whether from cutting down trees, construction, or from farming, soil that runs into water causes the water to become muddy (turbid). Dark water captures more heat from the sun and the water heats up. This can be a huge problem in the summer when the sun feel so hot. These dark particles absorb the energy from the sun.

A fourth cause of thermal pollution occurs when people cut down trees along a riverbank or pond. Trees help to shade the river from the sun. Without the trees to provide shade the sun shines directly on the water and it warms up.

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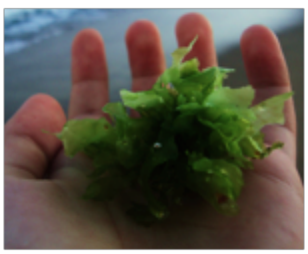
What are the effects (consequences) of Thermal Pollution?

Water temperature is very important for the health of a stream or river. There is a negative relationship between thermal pollution and water quality for freshwater organisms. Fish and other aquatic organisms live in certain temperature ranges. If water is too warm they die. For example, trout and stonefly nymphs need cool temperatures. Organisms' dying is one of four consequences of thermal pollution.

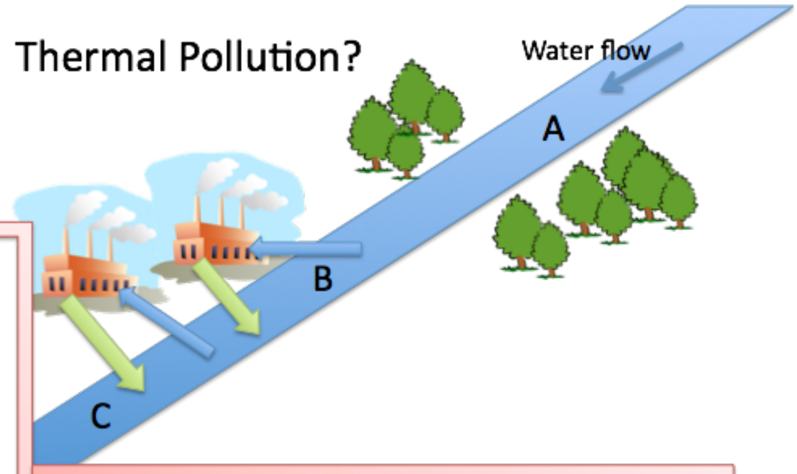
	URL: https://openclipart.org/detail/173960/fish Credit: acvarium. License: Public Domain

A second consequence of thermal pollution is that warm water can promote an algal bloom. Warm water increases the rate of plant growth and plants, like algae, can thrive. When these plants die they

	URL: https://www.flickr.com/photos/-oiboi/6675894731/in/photolist-baVGVi-bW81yL-8mXPXG-q4rqTM-okR53B-mh6dq-524K9Q-xUAhTc-9WGo3P-aeEYXU-bKMkcg-v3nVr-aj7ocA-9ksVH9-5bePRy-nKqJs9-qu7XG-2j76aA-52NtW3-3Mpx5o-4qAHYh-og7VMz-GcEcD-PmYMf-8EQfkd-9Z9QvD-gyoCY-jBocn7-qK5CNB-2t7Fnc-mcjwFm-6Kx9JN-dVoFmM-CuE4x-76Kxgp-8Dzofi-jBnaGd-86xEQg-aDJ5jX-6o3DvX-acZzua-xLTzY-8d187E-9kmCSa-WYsf3-j16hj-bjMPe1-qr16y5-5YL3dY-ogHn16 Credit: Ana Banderchuk License: Common Domain

are decomposed by bacterium. The bacteria use up the oxygen. Third, warm water cannot hold as much oxygen as cold water so a third consequence of thermal pollution is the potential for less oxygen. Finally, thermal pollution can weaken fish and insects and make them more vulnerable to disease and toxic waste.

Use the picture, the thermal pollution standards, and causes of thermal pollution to help you answer the following questions.



At Point A of a stream the temperature reading is 11.8 degrees Celsius. At Point B, father down the stream, the temperature reading is 12.8 degrees Celsius. What can you say about the water quality at Point B based on the temperature test? How do you know? What might be the reason for these results? Show all of your work.

At Point B of a stream the temperature reading is 12.8 degrees Celsius. At Point C, farther down the stream the temperature reading is 20.2 degrees Celsius. What can you say about the water quality at Point C based on the temperature test? How do you know? What might be the reason for these results? Show all of your work.

At Point A of a stream the temperature reading is 11.8 degrees Celsius. At Point B, father down the stream, the temperature reading is 12.8 degrees Celsius. What can you say about the water quality at Point B based on the temperature test? How do you know? What might be the reason for these results? Show all of your work.

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At Point B of a stream the temperature reading is 12.8 degrees Celsius. At Point C, farther down the stream the temperature reading is 20.2 degrees Celsius. What can you say about the water quality at Point C based on the temperature test? How do you know? What might be the reason for these results? Show all of your work.

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LESSON #4:

lesson question: Is our stream too warm for freshwater organisms?

Overview: In the previous lesson, students explored pH, the first water quality measure. In this two-day lesson, students explore thermal pollution, a second water quality measure of a stream's health. Through a student reader and class discussion, they are introduced to thermal pollution, what the temperature test measures, and the causes and consequences of thermal pollution. Students then test the water quality of their stream and have insight into whether or not the stream has thermal pollution and is healthy for freshwater organisms based on the temperature water quality measure. They end the lesson having two pieces of evidence, pH and temperature differences to begin to decide the overall health of the stream to support aquatic organisms.

Learning Performances: LP4: Students collect and analyze data to explore how human activities on the land may negatively impact populations of organisms.

- Students collect and analyze data to explore the relationship between the temperature of the stream and the quality of the water for various populations of organisms.

Safety Guidelines: Students should be careful to avoid falling into the water.

Preparation:

Time: 2-3 days

Materials: temperature probes or thermometers

INSTRUCTIONAL SEQUENCE Day one:

1. After Reading: Probing for understanding. (~30 min)

Purpose: To assist students to explore the relationship between the temperature of the stream and the quality of the water for various populations of organisms. Discuss main ideas about thermal pollution and its importance for water quality and how people's actions on land can cause thermal pollution of waterways.

Background
Prior Knowledge: By middle school students should understand that temperature is a measure of how hot or cold something is. They should be familiar with a thermometer.
Here are elements of the DCI that are introduced in this lesson.

- Human activities have caused thermal pollution of waterways, significantly altered the biosphere, sometimes damaging or destroying stream habitats.
- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.

Thermal pollution is an abnormal temperature increase. It is a very different type of pollutant in

that it is not “stuff” that gets into waterways but rather a transfer of energy that results in a temperature increase.
There are four Causes of Thermal Pollution that are related to people. Each is discussed in the Student Reader. They include, 1. hot surfaces, 2, macro particles, like soil, that absorb heat if in water, 3, factories that dump hot water, and 4, cutting tree that provide shade to waterways.

In addition to the four causes of thermal pollution discussed in the student reader it is important to discuss the weather and season with your students. In cold climates, it can be very sunny with no chance of thermal pollution because it is too cold for surfaces to heat up or particles in water to heat up. So while the conditions of surfaces and particles are potential causes for students to note, students also need to be aware of weather as a crucial condition as well.

There are four Consequences of Thermal Pollution, also articulated in the student reader. They include 1. Fish dying, 2. Algal blooms, 3. Potential for less oxygen, and 4. Weaken organisms that are more vulnerable.

The reading introduces students to what temperature, as a water quality test, measures and the causes of thermal pollution and consequences to organisms and the ecosystem. Through discourse, ask students what the temperature test measures (thermal pollution) and what is meant by thermal pollution. It is important for students to understand that we are not interested in the specific temperature of a waterway, but rather the temperature difference between two locations. Reinforce what is in the reading. Stress that thermal pollution is an abnormal temperature increase (not decrease), that of course water temperature increases during the summer and decreases during the winter - this is normal. That of course waterways in Florida will be warmer than waterways in Michigan or Alaska - this is normal. Thermal pollution means that the stream suddenly becomes abnormally hot. It is a very different type of pollution because it isn’t “stuff” like students are used to thinking about when it comes to pollution.

Use the reading to ask students to discuss the four causes of thermal pollution. Follow this with the four consequences of thermal pollution. You may want students to be in small groups or conduct this as a class discussion.

Teaching extension: This is an opportunity for you to ask students to generate ideas of action steps that they and others can take to decrease the possibility of thermal pollution.

Optional activity: Heating various surfaces to measuring temperature - not in unit at the present time

2. Measuring thermal pollution and thermal pollution standards (~10 min)

Purpose: Show students how to measure temperature and calculate for thermal pollution. Introduce students to water quality standards for thermal pollution.

Water Quality Standards: Just as with pH, water quality experts developed water quality standards using the terms excellent, good, fair, and poor to identify if fresh waterways have thermal pollution. The standards reflect recording temperature at two different locations that are not close to each other and subtracting to get a temperature difference. Excellent and good indicate that the stream has no thermal pollution, with excellent being better than good. These temperature differences are the result of natural occurrences such as differences in stream depth or shade versus sun. Fair and poor indicate thermal pollution meaning the results are problematic for aquatic organisms, with poor being worse than fair.

Here are the standards for Thermal Pollution:

Temperature Water Quality Standards (in Celsius change)	Temperature difference
Excellent - no thermal pollution	0-2^0
Good - no thermal pollution	2.1-5^0
Fair - thermal pollution	5.1-9.9^0
Poor - thermal pollution	Above 10^0

Provide students with practice calculating temperature differences. For example, tell students that temperature data is collected at Point A with a reading of 13.8$^{0.}$ Point B has a temperature of 12.2^0. Ask students what the results mean in terms of the temperature water quality test? How do they know? What do the results mean for freshwater organisms?

Students should subtract 12.2^0 from 13.8^0 to get a 1.6^0 temperature difference. Since this falls in the 0-2^0 temperature change category it means that there is no thermal pollution, with an excellent water quality standard, and that according to the temperature test, the water quality is excellent for freshwater organisms.

The student reader includes two examples at the end for students to complete. If they haven't completed them yet, have students complete these. Students could complete them with partners. Discuss responses.

Teaching tip: It is easy for students to confuse the actual temperature, 12.2^0 in this case, with a temperature difference. Providing students with multiple examples will help them to understand.

Let students know that experts measure the temperature at two different locations, separated by one mile, and subtract to get the temperature difference. They then use the standards to determine whether or not there is thermal pollution.

Chances are good that you will not be able to measure one mile apart. You will need to determine what students will use as their comparison. For example, inform students that they will measure the temperature in the stream at the same location that they measured pH. They will then go to a spot further away and measure again for their comparison. This can be completed at another group's section that is farthest away or another point that you predetermine.

Data may be collected using a temperature probe or a thermometer.

Concluding the lesson: This concludes day one of the two-day lesson. Let students know that they should now be able to test their stream water and understand what the temperature differences that they calculate mean - whether the stream has thermal pollution or not - and its implications for stream life. They also have some insight into the four causes of thermal pollution and should think about whether or not any of these potential causes could impact our stream. This will assist students to see the relationship between people's land use practices, thermal pollution, and the impact on a waterway's temperature. They should assist students to understanding the relationship between the temperature differences of the stream and the quality of the water for various populations of organisms.

Emphasizing relationships is key in developing models. Continuing to build on it here will assist students in the next lesson and future lessons where they create models of the stream.

Let students know that tomorrow we will test for thermal pollution of the stream (or whatever phenomenon you are using). If going outside, remind students to dress appropriately for the weather.

Homework: Students will write a prediction about thermal pollution of the stream. (~5 min)

Predictions will include four parts:

- A temperature difference number along with the corresponding text (ie. I predict the stream will have thermal pollution with temperature differences of 7^0 Celsius).
- The standard for their prediction (Excellent, good, fair, or poor)
- A statement about the types of organisms that can live (all, many, some, very few) that matches the standard
- At least one reason for their prediction.

Here's an example:

I predict the stream will have thermal pollution with temperature differences of 7^0 Celsius. This is fair according to water quality standards so very few organisms can live in it. I'm predicting this because I see lots of sidewalks and roofs and I know these heat up when it's warm outside.

You will decide if students will write their prediction in a notebook, on paper, or using a computer.

INSTRUCTIONAL SEQUENCE: Day 2

1. Investigating temperature differences of the stream - measuring for thermal pollution (~30-45 min)

Purpose: Collect the second piece of water quality data - temperature differences.

Begin by asking students to share their predictions. Another option is to collect data first and then share predictions. Provide students with instructions for data collection. Below is one possible data table for students to use. The same student groups should collect data at the same locations

Temperature difference of the stream			Observations that could impact the stream's temperature
Stream Temp	farther downstream	Difference between (subtract the two)	In the water:
Trial 1 _____	Trial 1 _____	___________	
Trial 2 _____	Trial 2 _____	___________	Near the water:
Trial 3 _____	Trial 3 _____	___________	
	Average	___________	

Groups:
Based on your phenomenon, equipment, and student population, you will need to decide how to group students. Ideally, student groups are 3-4 students and each group has its own stream section where it will collect data for each water quality test.

Data collection options: If your stream is nearby and you can collect data in one class period that is ideal. This water quality test isn't conducive to bringing in samples from a stream because the water samples will end up at room temperature, Students should test three times to ensure accuracy. They could also test in different locations within their stream section.

INSTRUCTIONAL SEQUENCE: Day 3

1. Engaging in sense-making: sharing and discussing temperature difference results (~5-15 min)

Purpose: Students share data to look for discrepancies and patterns in the data.

You may want student groups to write their results on the board. You have two options.

- Option one: Students could report actual temperatures across the entire stream, writing them in order on the board. The class can then look at all of the actual data and see the highest and lowest numbers, subtract, to obtain the largest temperature difference of the entire tested area.
- Option two: Student write their temperature differences on the board and these can be compared.

If there is an outlier, this group may want to re-test. There could be other plausible factors that influence student results based the location of where they tested in relation to the land.

Discuss the results, in small groups first if you like, and then as a class.

Students may work in groups to focus on these questions:

- According to your results is the stream thermally polluted?
    - If yes, what might be the cause?
    - If no, are there potential causes, but at this time they are not impacting the stream?
- Based on the stream's temperature test, is it healthy for organisms.
- What water quality standard do your results convey (excellent, good, fair, or poor) for pH?

This may be followed up with a class discussion.

Potential causes of thermal pollution may exist even though students results show no thermal pollution. For example, there are many surfaces in watersheds: roads, parking lots, sidewalks, roofs, etc. These surfaces can heat up. The weather will be an important factor in contributing to thermal pollution. If it's hot weather surfaces heat up. If it's not hot though, these many surfaces won't be hot. Particles in water also heat up, but if it's been cool weather, these particles will not heat up. Another factor is rain. Even if it's been hot, if there hasn't been any rain hitting those hot surfaces and then running into storm drains then the water will not be affected. Sometime a potential cause can be ruled out because it doesn't exist. For example, if you do not have a factory located on your stream or creek, then you can always rule out factories dumping hot water as one of the causes, should your waterway have thermal pollution.

Students may now fill in the temperature results into the comprehensive data table.

Water Quality Test Results
How Healthy is our stream for freshwater organisms?
How do our actions on land potentially impact the water?

Organize your results from all of the water quality tests into one data table below. Notice the far right column labeled *Observations*. Record any information that you may have observed in or near the water that might help you determine what caused the results you obtained for that test.

Name of Water Quality Test	Results	Water Quality Standard	Observations
pH			
Temperature Difference			

Concluding the lesson: (3-5 min).

Connect the temperature test to the Driving Question Board. This may include the question for the lesson: *Is our stream too warm for freshwater organisms?* and the overall results (thermal pollution or no thermal pollution). Check to see if any of the student questions were addressed with this lesson. You may add other ideas to the DQB.

Connect to the driving question, *"How healthy is our stream for freshwater organisms and how do our actions on land potentially impact the stream and the organisms that live in it?"* Ask students if they feel confident to answer the driving question and make overall conclusions about the stream's health for supporting organisms. Relate this back to the basketball analogy. Was seeing that the person was a good free-throw shooter enough evidence to make a claim that she could succeed as a college basketball player?

Remind students that the stream is a complex system. We now have two pieces of water quality data to use as evidence about the stream's overall health. Let students know that tomorrow we will begin to develop models of the stream to help us figure out how healthy the stream is overall, based on what we know so far.

Homework: None

LESSON #5:

Lesson question: How healthy is our stream based on pH and temperature evidence?

Overview: In the previous two lessons, students investigated two water quality measures, pH and temperature (thermal pollution). In this 2-day lesson, student groups develop a model of the stream system based on what they know now to assist them to figure out the overall quality of water for organisms. The lesson begins with a discussion of models - what are scientific models? Why do we want to create models? SageModeler, a modeling tool designed for student use, is introduced as a computer modeling program. A simple, non-science model that connects to students everyday lives is built by the teacher to introduce students to the tool. Student groups are then asked to construct a model of the stream. This is a formative assessment that serves to provide both students and the teacher with information of where students are with their learning right now. This activity should also foster students' continued development of their understanding of the DCI's as well as modeling as an important scientific practice. CCC's of cause and effect, systems, patterns, and change and stability are all integrated in the modeling process. In future lessons, as additional water quality tests are conducted, students will revise their models in order to have a more comprehensive model of the stream as a system.

Learning Performances: LP6: Students develop models to explore patterns of shifts in populations of water organisms that are negatively impacted as the result of human activities that result in disruptions to physical or biological components of an ecosystem.

- Students develop models to explore how pH and temperature changes resulting from human activity affect water quality and the organisms that live in the stream.

Safety Guidelines: None

Preparation: Practice with using SageModeler. Set up various classes on the Learning Portal

Go to the Concord Consortium Website and access the Learning Portal Users Guide for Teachers. This guide will assist you in setting up your various classes as well as how individual students set up accounts. https://learn-resources.concord.org/docs/TeacherUserGuide.pdf

Time: 2-3 days

Materials: A main computer and projection device. Computers for each group. Two students per group is ideal. If you have a computer for each student you may have students working in pairs with each partner on a different computer.

INSTRUCTIONAL SEQUENCE

1. Assessing student prior knowledge. What do they know about models? (~ 5 min)

Purpose: Identify students prior knowledge of scientific models. Discuss purpose of developing models.

Ask students what they think of when they hear the word models. Students often think of miniature representations of very large things (cars, digestive system, solar systems etc.) or large representations of very small things (cells, etc). Stress to students that scientific models are tools that help us explain or predict various phenomena. In order to be a scientific model it has to illustrate relationships between variables. Stress to students that in order for something to be a variable, it has to have quantities that can change.

Background information: Scientific Models are tools that help us explain or predict various phenomena. Models illustrate relationships between variables. Variables have quantities that can change.

2. Developing models of our stream - introduction (~5 min)

Let students know that we can create models of our stream. We can identify variables and set up relationships between the variables to explain the phenomenon of the stream. Our goal is to develop models of the stream system by representing various factors (variables) that influence water quality - we will begin by focusing on the first part of our driving question: How healthy is our stream for freshwater organisms?

Ask students, "What would the variables be in our stream models? What are components of a stream that can change? (pH level, amount thermal pollution, amount of fish/water quality).

Let students know that we're going to use a modeling tool called SageModeler that allows us to plan the model, build the model, use the model by running a simulation, and then revise the model if it doesn't "work" the way we think it should work. Why might this happen? Stress to students that SageModeler doesn't have ANY content! The model builders (the students, in this case) develop the model. They can make a working model that is COMPLETELY wrong! It will still "work" though. WE are responsible to create a model that accurately includes science ideas, that accurately shows the relationships between variables, and that predicts and explains the phenomenon of water quality for organisms. That is why we will critique our own models and revise them as we develop them. We will also share our models to provide each other with feedback so that we can then revise our models. We have to view our model as a "work in progress" where we are open to suggestions to improve the model.

Emphasize that we will build our first version of the model based on what we know right now - our knowledge of pH and thermal pollution and their effects on water quality for fish and other aquatic organisms (in other words, their relationship to water quality which can be expressed as fish populations or the amount of fish). Once we learn about other water quality tests (measures) we will then add them to our current models. So we will expand and revise our models over the next couple of weeks.

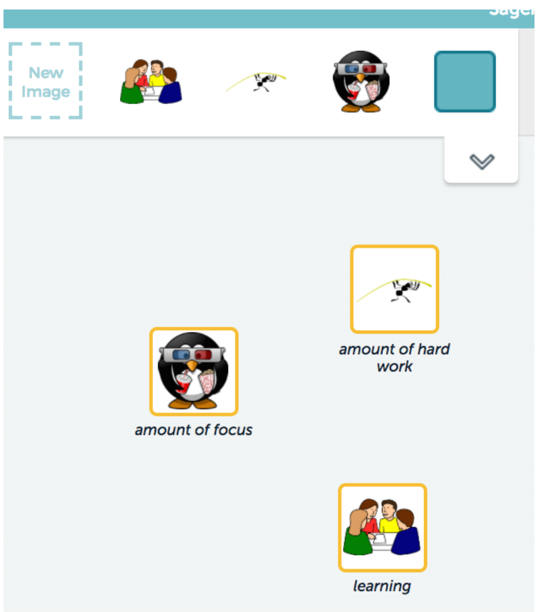
3. Teacher demonstration of SageModerer (~15-20 min)

Purpose: Illustrate to students how to use SageModeler using a non-science example.

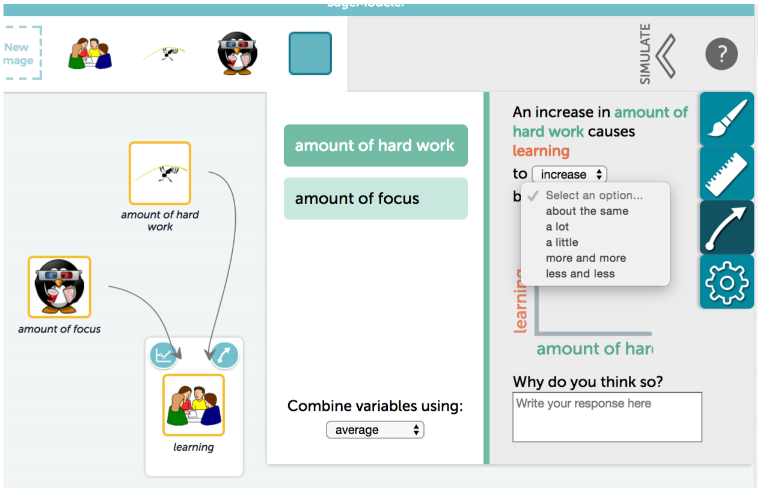
When you open up to build a model, a window called SageModeler Quick Intro can also guide you to learn how to build models. You may also click to close this window so that you have additional space for your model.

Say to students, "Let's create a model to answer the question, "How do people learn?" We need to ask, What does learning depend on - what variables contribute to learning?" Brainstorm with students to probe their ideas. Students may say how hard someone works and if they pay attention in class. Build from student ideas. "One variable is "learning" (the amount of learning) and learning depends on the following two variables: Hard work (the amount of hard work) and in-class engagement (how focused students are). These variables - learning, hard work, and in-class engagement - can change. Some days, for example, you may find that you are very engaged. Sometimes you may not work as hard as other times."

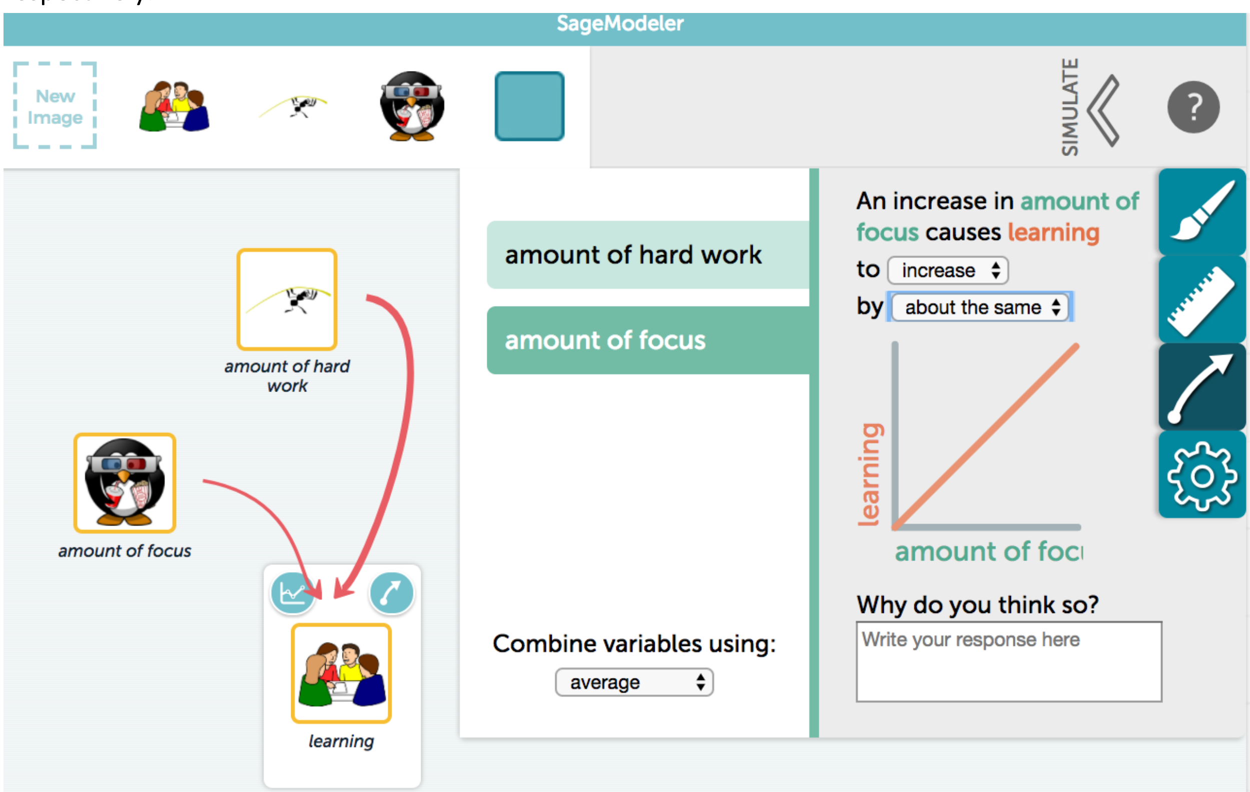
First we need to choose images to represent each of the variables: Learning, hard work, and amount of in-class focus. Remind students again, that in order for something to be a variable, it has to have quantities that can change. Here are possible images that are then labeled:



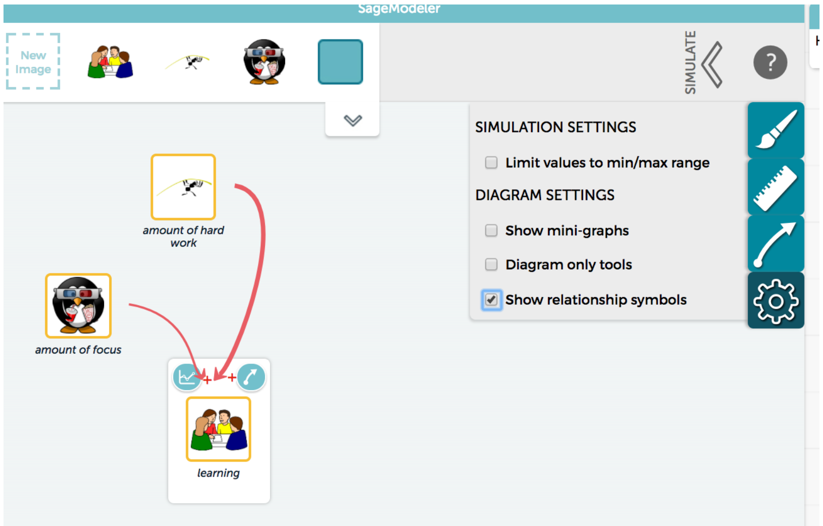
Next, set up the relationships by connecting variables together - hard work is related to learning, and in-class engagement is related to learning. Both variables imply (and you should stress this to students) the amount of work and the amount of focus). Follow this with defining the relationships between them (a little, a lot, more and more).



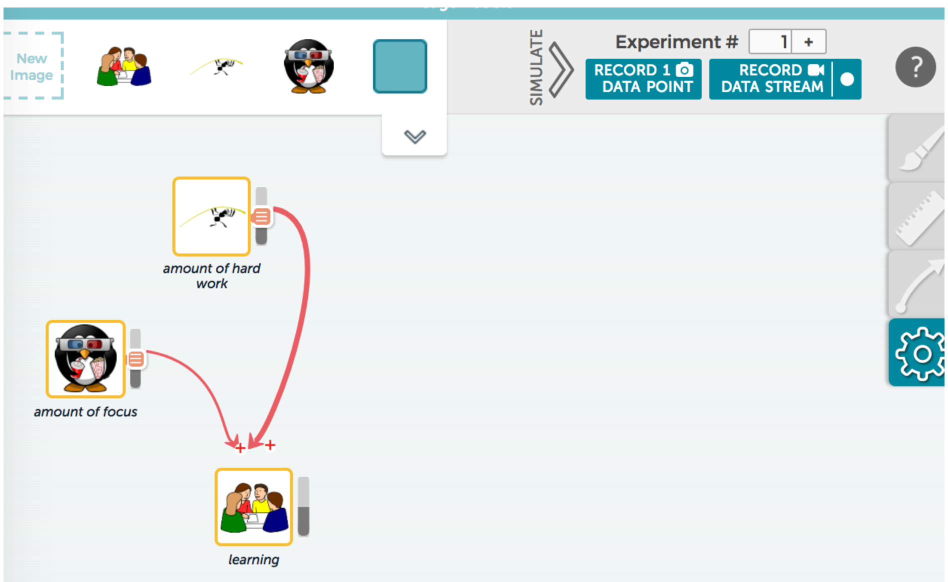
As you set up the relationships you will see red or blue lines that coincide with increase or decrease, respectively.



Go to the vertical toolbar at the far right and select the lowest icon to access the simulations settings. Select the "show relationship" symbols. This will add the "+"or "-" (positive or negative relationship).



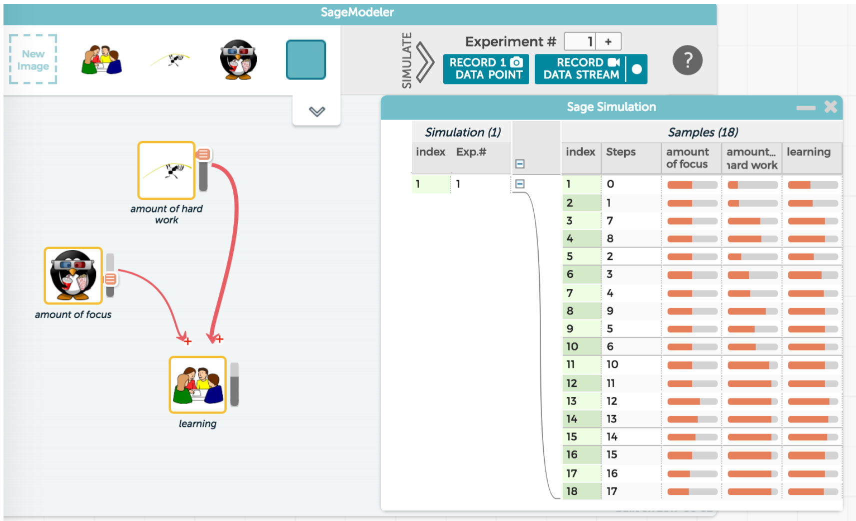
Click off of the simulation settings. Click on the Simulation arrow.



Notice a sliding bar that now appears next to each variable, “focus” and “hard work.” These are independent variables. The bars may be manually slid up and down and will be reflected in the simulation where you can see the effect on learning, which is the dependent variable. The amount of learning depends on the amount of focus and the amount of work (hard work).

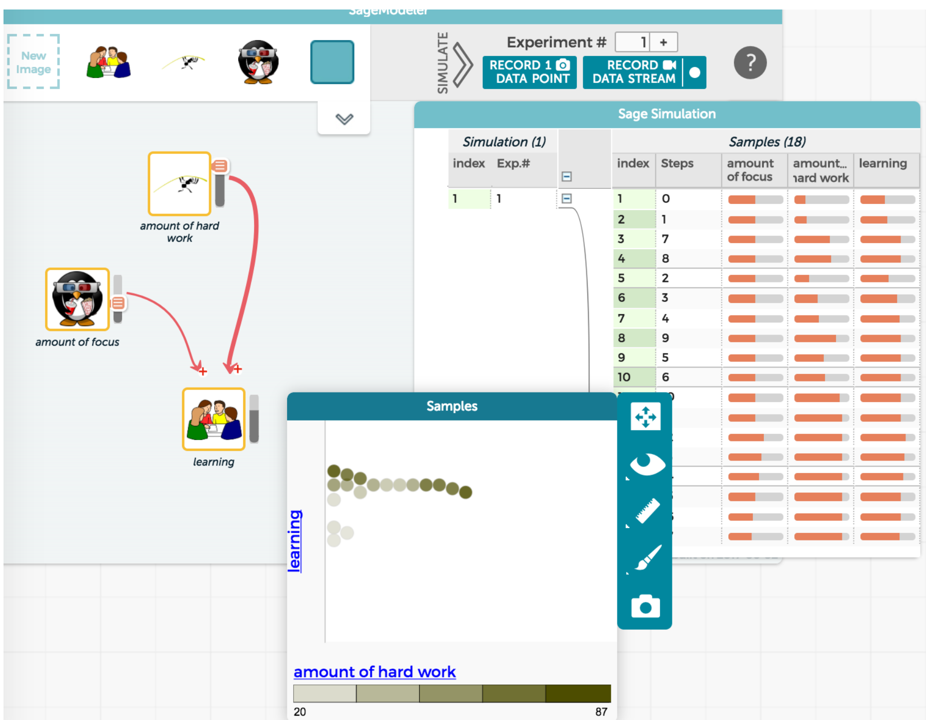
Now look at the top, right and see two boxes: one is called Record Data Point and the other, Record Data Stream. These are under Experiment #1. You have the option of recording one data point at a time or to made a recording of several data points all at once.

Choose Record Data Stream and move the sliding bars for focus and hard work up and down. A data sheet will appear that records the data.



Look at the orange bars to see how changes in focus and hard work affected learning. What patterns to you notice?

Another option is to display the data in a graph. Select the graph option from the top left palette. You can click on the simulation variable and drag it into the graph. For example, drag the word, “learning” into the y-axis (it is the dependent variable) and “hard work” into the x-axis (the independent variable).



Notice that steps 1-2 had low hard work and the graph shows lower learning. The variable hard worked was increased to more hard work in steps 7-8. The screenshot shows that as the amount of hard work increases (the x-axis displays hard work)), the amount of learning increase or decreases (the y-axis graph displays learning) with the change hard work.

Link to Learning Model: https://codap.concord.org/releases/latest/static/dg/en/cert/index.html#shared=22243

4. Student groups develop water quality models (use the remainder of the class to have students start their water quality models). Students will continue to work on the models the following day.

Purpose: Students groups develop models of the stream system to show relationships between the pH and temperature measures of water quality and their impact on the health of the stream for freshwater organisms.

Developing water quality models will assist students to develop understanding of core ideas and crosscutting concepts as they are engaged in the scientific practice of modeling. The models also serve as formative assessment - feedback to both students and the teacher of where students are with their learning now.

This activity is ideal with groups of two students for each computer.

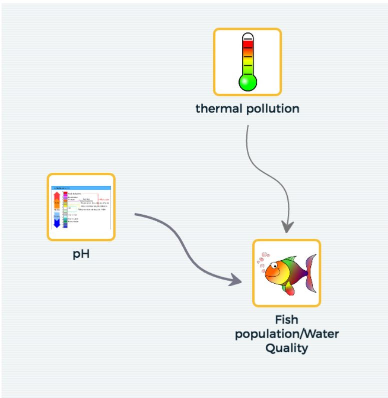
SageModeler Button text: How healthy is our stream based on pH and temperature differences?

Click the button to launch SageModeler to create an initial model of the water quality of the stream based on what we know now using two measures of water quality: pH and temperature differences (thermal pollution).

- Find pictures to represent the variables (pH, Temp differences, and health of the stream)
- Draw links between variables you think affect each other.
- Set the relationships between those variables.

Allow students to begin to work on their models. Encourage students to use the data from the two water quality tests. As well, students can refer back to the student readers and/or notes taken during class. Move from group to group. Some groups will need more support than others. Encourage students to help each other. Some groups will work faster than other groups. Once they get their models working in the way in which they think accurately portrays the stream phenomenon, they can expand their models to include the causes of changes in pH and temperature; these are the variables that influence the water quality tests (which in turn affect the water quality of the stream). This connects to the second part of the driving question (how do our actions on land potentially impact the stream and the organisms that live in it?

Here is a possible progression of a basic model that students might develop.

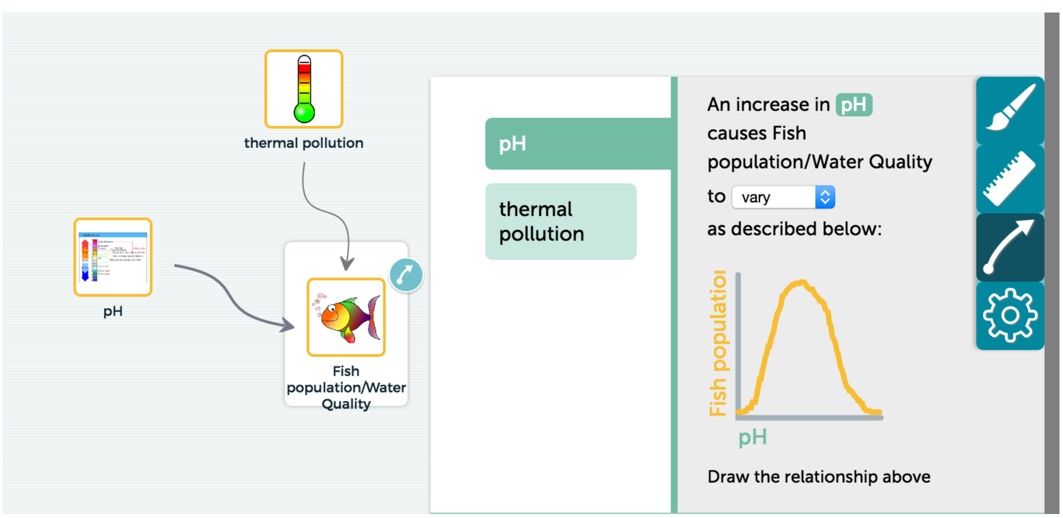


This example is not meant for the teacher to create. Students should spend time in the planning and building phase and then run their models.

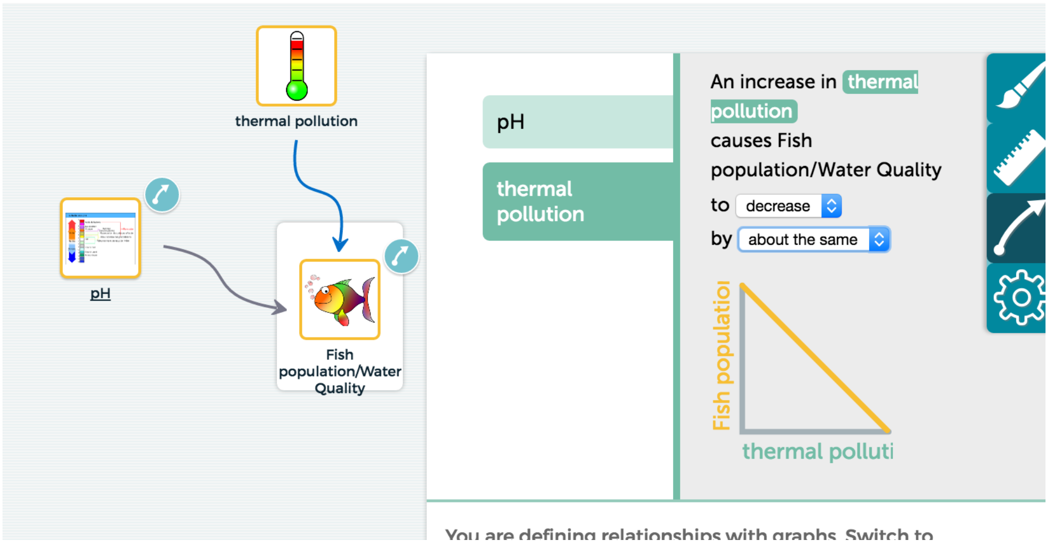
They may choose different icons than the ones here and that is fine:

During the “Plan” stage, students choose variables and identify pictures to represent those variables. Even though it is labelled “thermal pollution” you should stress to students that this means the amount of thermal pollution; the range would be from none to high levels of thermal pollution. This idea of amount applies to all of the variables because there are ranges for each. Remember, variables have quantities that can change, otherwise they are not variables.

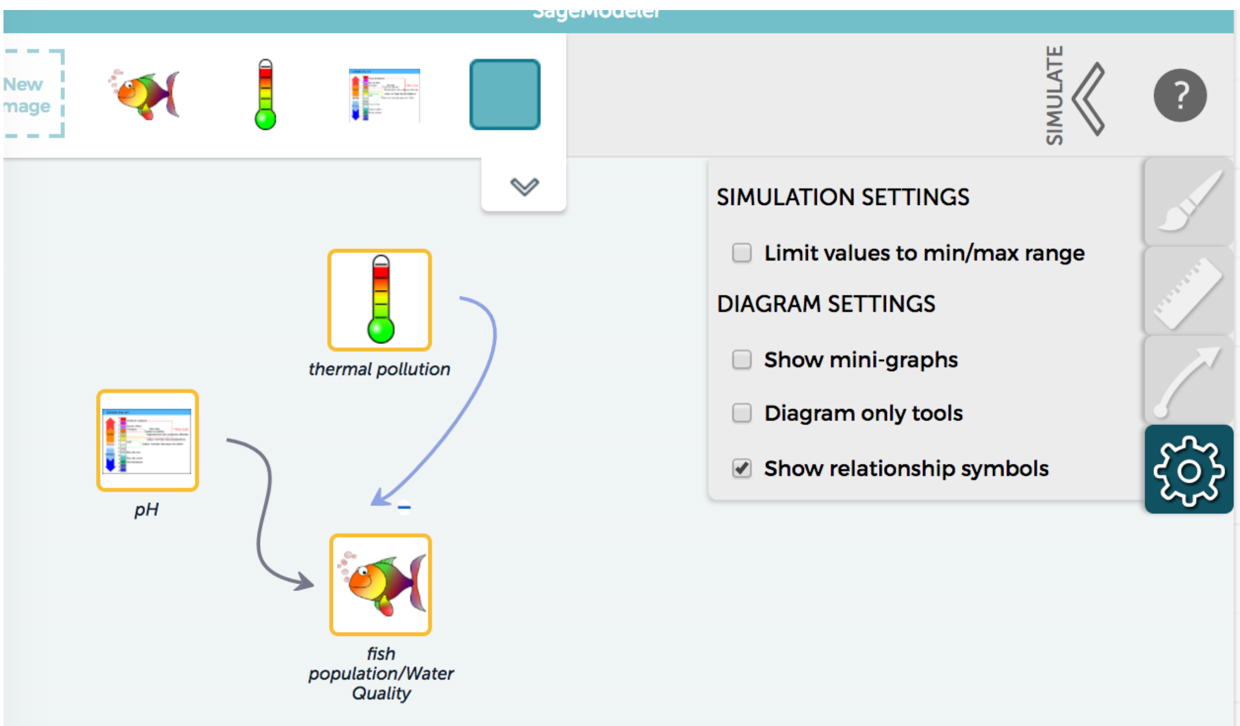
Students then make connections between the variables and define relationships between those relationships during the “building” stage. Below is an example of the pH relationship tool. You can ask students about the relationship between pH and water quality. Students should choose the “vary” relationship and then draw a bell-shaped curve as the best pH would be 7, in the middle, and the water quality decreases as pH becomes acidic or basic.



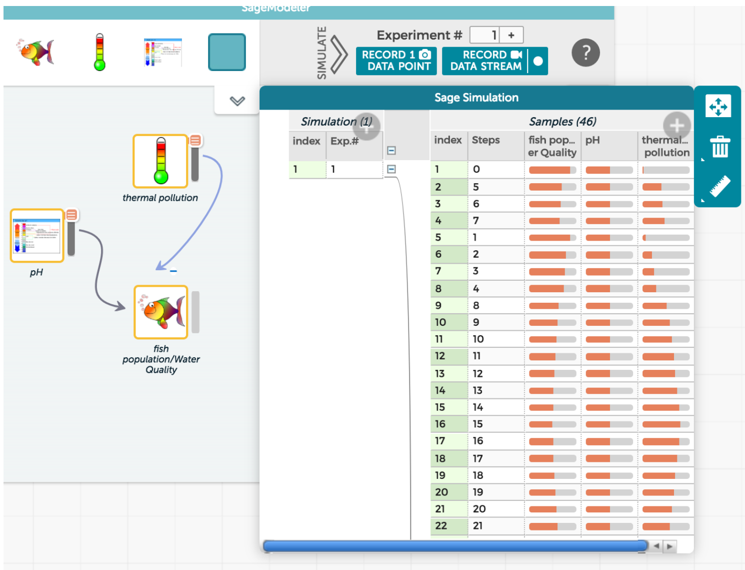
Students next identify the relationship between thermal pollution and fish population/water quality. A text box is available for students to explain why they have created that relationship. Having students use this feature will assist them to think more deeply about the ideas that will foster understanding. As well, it will provide you with more insight into their thinking as you assess their models.



Students can click on the bottom (under the arrow) to check off the "show relationship symbol" (see picture below) to get a visual indication that their relationship is accurate. Notice the blue line between thermal pollution and fish population has a (-) sign indicating that thermal pollution negatively impacts fish.



Students can now "Use" their models to run a simulation. Click the Simulate button. Notice that the independent variables (pH and thermal pollution) now have sliding bars. These may be manually moved up and down. Also notice at the top right, it says "Experiment #" and below are two buttons, Record 1 point, and Record data stream. This pictures shows that a table automatically appears when after pressing Record Data Stream. The sliders will manually moved up and down during the recording then the Record Data Stream button was pushed to stop the simulation. Here is a link to this model: https://codap.concord.org/releases/latest/static/dg/en/cert/index.html#shared=22247



As the sliders are moved, the bars on the simulation also move. HOW they move depends on the relationship that was set up. Students may also choose the "graph" icon near the top left corner. Since water quality (fish population) depends on the other variables it is the dependent variable and is dragged onto the y-axis of the table. One variable (pH or thermal pollution) is dragged on the x-axis as an independent variable. Since the purpose of building the model is to model the combined results of all of the water quality tests, the table option may be more useful at viewing the entire water system.

In the simulation above look at steps 1-4 for the thermal pollution bar on the table. Notice at the beginning the amount of thermal pollution is very low (meaning no thermal pollution) and pH is in the center (meaning neutral pH). The fish population was high. As the amount of thermal pollution increased, you will see that the fish population decreased. These are the types of discussion you can have with your students. They should test their models to see if they "work" the way they think they should work. If not, students then revise their models. They may need to adjust the relationships (more and more, a lot, etc).

Students may also graph their results. Water quality (fish population) would be placed on the y-axis. pH and/or thermal pollution would be placed on the x-axis.

Discussion and Sense-making opportunities:

Purpose: To have students evaluate their models to see if they "work" the way that think they should work.

Remind students that SageModeler has no content and they can develop models that "work" but do not accurately reflect the phenomenon. It is the responsibility of the students to evaluate their models. This process should further foster students learning about important science ideas, crosscutting concepts, and the practice of modeling. Students can use their notes when developing their models. There are several possibilities including the following suggestions:

1. Using their models to predict water quality: Encourage students to use the sliders to put them to the position where the water quality should be the best. Ask them where they should put the sliders? (for pH the slider should be in the middle - 7) and for thermal pollution the slider should be the lowest (the lowest temperature differences are the best). In this way, students are predicting that the water quality will be high. Students can now run their models to see if their predictions match.

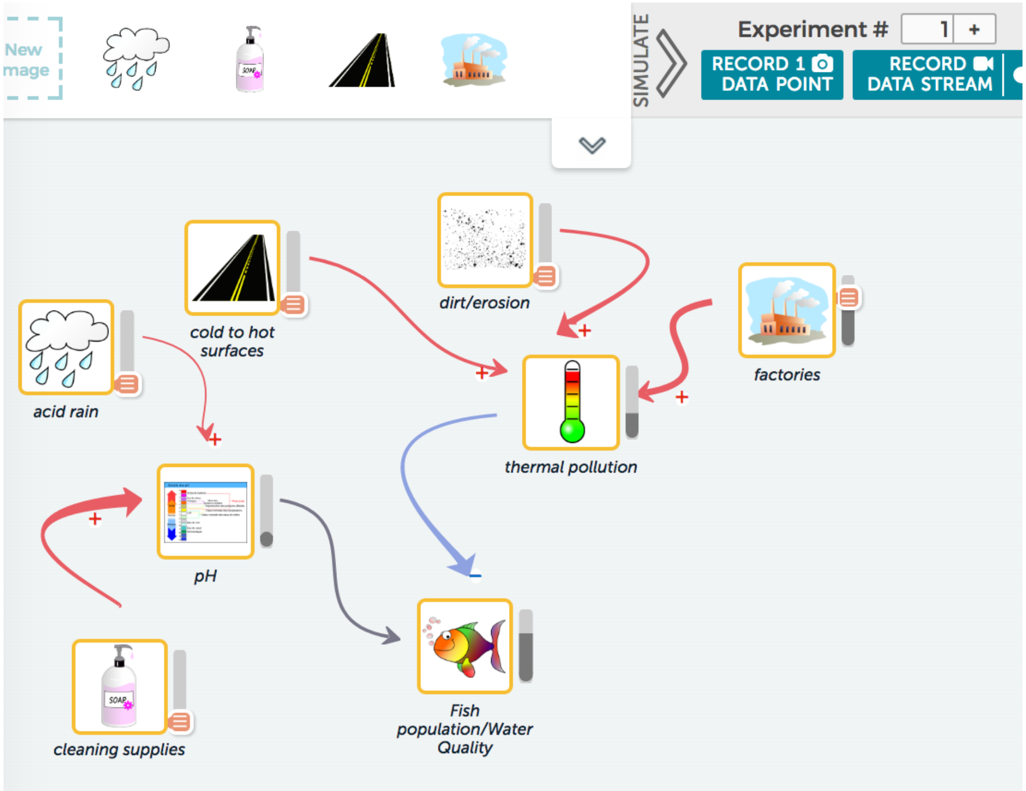
    a. If they match, then students might evaluate that their models work.

    b. If they don't match students should think about why their is a mismatch. Do they need to adjust their models? Do they need to rethink their understanding of the science concepts?
2. Observe what happens as they change one variable to see if it matches their thinking. Does the change in that variable affect the water quality they way that they think it should?
3. Check all parts of the model. Test, evaluate, revise if needed, and retest.

It is often the case that students move at different paces. If a group or two completes their model, including running it and making sure it works the way that they think is accurate, you can have them expand their models to include the various causes for each of the water quality tests. These will be the variables that affect pH, and the variables that affect temperature differences. Encourage students to use the student readers to assist them. Students can choose images and define relationships between these. Here is a screenshot of what an expanded model could look like.

It is not expected that all (or any) students develop models at this level of sophistication. This is enrichment for groups who need it.

Here is an example of a model that includes causes for changes in pH of waterways and the four causes of thermal pollution. The sliders have all been placed at the position for the best water quality except for Factories which represent hot water from factories. This slider is up and the result is that thermal pollution, the dependent variable is also up. Students can move these sliders to test their models. They can also do simulations to obtain a data table as well as graphs.

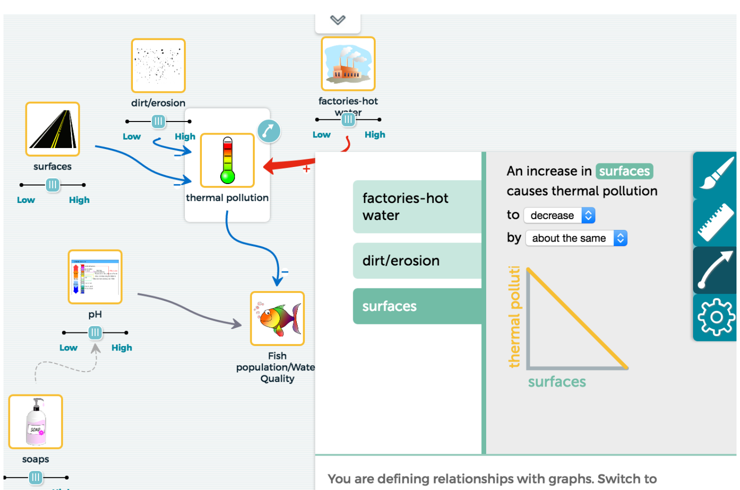


Concluding the lesson (2 min)
This concludes day one of the two-day lesson. Students will continue to work on their models during class tomorrow. Some groups will also share their models.

Homework or reading: None

<u>INSTRUCTIONAL SEQUENCE: Day 2</u>

1. Continue building models (~30 min)



Purpose: Students will use time to work in their groups to complete their water quality models based on pH and thermal pollution.

2. Sharing/Critiquing models (~10-20 min)

Purpose: Sharing and critiquing student models is extremely valuable. It fosters a community of learners and assists students to see connections between ideas. It also allows students to see how different groups have modelled the stream phenomenon.

Option: some groups will complete their models before other groups. Groups can share their models with each other. Ask one group to explain their models to another group. Next, the other group can do the same. They should talk through their models and explain the variables and their relationships to water quality (fish population). They should run their models, using either the graph tool or the simulation tool. They can move the toolbars for the variables to show how the water quality is impacted.

Either request volunteers to share their models with the class or ask a couple of groups. You can display models for everyone to see. Groups should talk through their models and explain the variables and their relationships to water quality (fish population). They should run their models, using either the graph tool or the simulation tool. They can move the toolbars for the variables to show how the water quality is impacted.

As a class, they can discuss if the model "works" and provide any feedback to the group, including any suggestions they might have to improve the model.

Summary: Models are meant to assist us in explaining phenomenon. Ask students what conclusions they would make about the overall health of the stream based on pH and temperature. This can be done first in small groups and then in a class discussion. Ask students to include an overall statement (the stream is very healthy, somewhat healthy, not very healthy, very unhealthy etc), a water quality standard (excellent, good, fair, or poor), and reasons.

Have a discussion to see if the class can come to consensus. This assumes that students' evidence from both water quality tests were similar. If they were not similar, then a discussion to support your statements should follow. Students could illustrate their ideas with their models by placing the the bars at the places where they data falls.

Concluding the lesson (5 min)
This concludes day two of the two-day lesson. A third day may be needed.
Remind students that the stream is a complex system. You may refer back to the analogy of the basketball player and collecting several pieces of evidence to determine her level of play. pH and thermal pollution are two measures of the quality of the water. We will collect more data that can be used as evidence to gain insight into the stream phenomenon.

Introduction to the third water quality measure. Ask students if they are familiar with algal blooms. Show students the following, or a similar video. This video introduces students to algal blooms without divulging any of the science ideas that student will explore in the following lesson.

Toxic Algae Blooms Keep Florida Beachgoers Away Video - ABC News (1:49 minutes)
http://abcnews.go.com/US/video/manatee-emerges-algae-covered-water-40283466

Inform students that algal blooms are related two of the three particular dissolved solids that we will investigate through a third measure of water quality to see its relationship to suitability for freshwater organisms.

Homework: Students will complete the student reader, “How many dissolved solids are in our stream?” The reading follows:

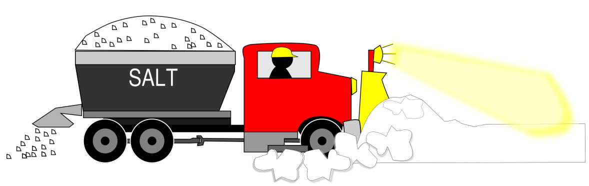
How many dissolved solids are in our stream?
Dissolved Solids as a measure of Water Quality

Why do we measure for dissolved solids of streams? Where do they come from?

People use products outside on land that can get washed into storm drains or simply run downhill during rain or snowmelt and then flow into streams, rivers, and lakes. Some of these products contain substances that dissolve. Three major dissolved solids that impact water quality are road salt, nitrates, and phosphates. High amounts of these can cause problems for organisms in the water.

Road Salt – What is its source and how does it Impact Water Quality?

If you live in a northern climate you probably have experienced snowy winters. In addition to snow covered roads, ice and freezing rain can cause potential safety hazards.

	URL: https://openclipart.org/detail/15567/open-road Credit: IncessantBlabber License: Public Domain

Road salt is put on surfaces - roads, sidewalks, and parking lots - to help avoid accidents and keep people safe. Organisms in lakes, rivers, and stream are freshwater organisms, not saltwater organisms. Although adding salts to slippery roads is important for safety reasons, too much salt can be a problem for freshwater organisms.

Nitrates and Phosphates – What are they and where do they come from?

Compounds that contain nitrates and phosphates can dissolve. For instance, sodium nitrate can dissolve in water. But what are they? Nitrogen and Phosphorus are both elements. In nature, nitrogen and phosphorous can be found in various compounds like like sodium nitrate and potassium phosphates. Nitrates and phosphates are essential nutrients; all organisms have to have them for growth and repair. However, they are only needed in very small amounts. So where are nitrates and phosphates found? Well, if all living organisms need them, then all living organisms have nitrates and phosphates. But so do products that come from them, like animal waste. All dead organisms, then, have nitrates and phosphates. Another name for dead organisms is organic waste. This includes dead animals and plants. If you live in a climate where leaves change colors and fall off trees every year you are very familiar with dead leaves!

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Dirt can hold nitrates and phosphates. So far, all of these sources are from nature.

Nitrates and phosphates are essential components of the life cycle. When there is organic waste (dead plants and animals), decomposers such as bacteria break down the dead matter. During this process, nitrates and phosphates are released. On land, the nutrients go into the soil and are then used by plants for growth. In the water, water plants use nitrates and phosphates that are released from decomposition. Whether on land or in the water, animals eat plants and other animals. That’s how they get nitrates and phosphates. Both the plants and animals eventually die and become organic waste and the cycle starts all over again. This cycle is important. Without it, new plants and animals would not be able to grow!

Too many nitrates and phosphates in water, however, can cause significant problems for aquatic environments. A major source of excess nutrients (nitrates and phosphates) in waterways is fertilizer. Think about it – farmers use fertilizer to help their crops grow. People use fertilizer to have nice lawns and gardens.

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When it rains, runoff from agriculture, lawns, and home gardens that includes fertilizer can flow downhill and into various waterways, contributing excess nutrients. Dairy farms have cows that produce waste. Cow manure and manure from other animal farms can also runoff into waterways. In addition, nutrients can come from leaking septic tanks and from wastewater treatment plants. Finally, some cleaners contain phosphates. These sources – fertilizer, human waste, animal waste from farms, and cleaners – come from people and result in excess nitrates and phosphates.

What is the effect (consequence) of excess nitrates and phosphates in waterways?

When there are too many nitrates and phosphates it can lead to a disruption of the life cycle that can eventually result in a **dead zone**. Dead zones are areas in water that cannot support life. A chain-reaction cycle occurs. First, excess nitrates and phosphates in water, often from fertilizer runoff, can result in excess algae growth causing algal blooms (remember that both nitrates and phosphates are nutrients for growth). Algae have a short life span. When all the excess algae die, there is an excess amount of organic waste. Do you remember what happens to organic waste? It is decomposed, broken down, by bacteria and other decomposers. If there is an excess amount of organic waste, there is an excess food source for bacteria. The bacteria population dramatically rises. Bacteria need oxygen. These excess bacteria use up all of the oxygen. Fish and other aquatic organisms need oxygen. Without it, they die. This results in more organic waste and the cycle starts again. Eventually, the oxygen is depleted (this cycle is also known as the oxygen depletion cycle) and the area becomes a dead zone.

How do we measure dissolved solids?

There are different ways to measure the amount of dissolved solids in water. One method is to use a conductivity probe. Dissolved solids can conduct electricity. For example, when put in water, sodium chloride (salt) breaks apart into sodium and chloride and can conduct electricity. Sodium nitrate breaks down in water to sodium and nitrate and potassium phosphate breaks down in water to potassium and phosphate and can conduct electricity. Though a conductivity probe can measure the amount of dissolved solids in a lake, river, or stream, it will not identify which solids are dissolved. Qualitative observations are used to help determine which solids might be dissolved in the water. What would you look for **in** the water that might indicate the possibility of nitrates and phosphates? (Students need a box to put their response – dead, decaying leaves, water plants or other plants in the water could indicate nitrates and phosphates. Algal blooms could indicate excess nitrates and phosphates. Soap bubbles could indicate phosphates).

What **area** observations might indicate that people are using products on land that might contain phosphates and nitrates that could have entered water through run-off?
(Students need a box to put their response – nice lawns and/or gardens could indicate fertilizer. Windows, cars, etc. could indicate cleaners. Farms or golf courses in the area could indicate fertilizer use.).

If you live in a northern climate, winter weather could result in snow. High readings from a conductivity probe could be the result of road salt that has entered a waterway through run-off. Road salt, Calcium chloride, can bread down and conduct electricity.

In addition to conductivity probes, nitrate and phosphate kits are sometimes used.

Here are the water quality standards for different ways of measuring the amount of dissolved solids:

Dissolved Solids Water Quality Standards	Conductivity probe mg/L	Total Phosphate mg/L	Nitrates mg/L
Excellent – not too many dissolved solids	0-100 mg/L	0-1	0-1
Good - not too many dissolved solids	100-250 mg/L	1.1-4	1.1-3

Fair - too many dissolved solids	250-400 mg/L	4.1-9.9	3.1-5
Poor - too many dissolved solids	> 400 mg/L	> 10	> 5

Whether due to road salt, nitrates, or phosphates, too many dissolved solids are not healthy for streams and organisms that live in streams. People's actions on the land can significantly impact the amount of these dissolved solids. Are there some action steps that you can think of that people can take to minimize the amount of dissolved solids that may enter waterways? (Students need a box to put their response – use less fertilizer and road salt. Don't use fertilizer at all. Instead, cut your grass and leave it on the lawn to naturally decompose and put nitrates and phosphates back into the soil. Rake leaves away from storm drains)

LESSON #7

Lesson question: How healthy is our stream based on three pieces of evidence: pH, temperature, and dissolved solids?

Overview: In the previous lesson, students investigated a third water quality measure, the amount of dissolved solids measured as conductivity. In this lesson, students revise their model of the stream system that currently includes pH and thermal pollution variables and add conductivity as a third variable. To be accurate, the models must show the relationships between the variables (the various water quality measures and human activity on land) and the water quality illustrated through impact on population of organisms. Students' models must also show that the set of relationships work together to explain the stream phenomenon.

As with the first version of the model, this is a formative assessment that serves to provide both students and the teacher with information of where students are with their learning. This activity should also foster students' continued development of their understanding of the DCI's as well as modeling as an important scientific practice. Crosscutting concepts of cause and effect, systems, patterns, and change and stability are also integral in explaining the phenomenon of water quality.

In lesson #8, students investigate a fourth water quality measure, amount of dissolved oxygen, followed by a fifth water quality measure in Lesson #9, turbidity, that measures the amount of suspended solids. After these additional water quality tests are conducted, students will again revise their models in order to have the most comprehensive model of the stream as a system, based on all of the evidence they have gathered. This will allow students to fully respond to the driving question, "How healthy is our stream for freshwater organisms and how do our actions on land potentially impact the stream and the organisms that live in it?"

Learning Performances:

LP7: Students develop a model based on human activities in agriculture, industry and everyday life can have major impacts on rivers, to illustrate cause and effect relationships, that small changes in one part of the system (the stream phenomenon under study) might cause large changes in another part of the system, and that stability might be disturbed either by sudden events or gradual changes that accumulate over time.

LP5: Students develop models to explore patterns of shifts in populations of water organisms that are negatively impacted as the result of human activities that result in disruptions to physical or biological components of an ecosystem.

Safety Guidelines: None

Preparation: Students initial models.

Time: 2 days (possibly 1 day)

Materials: A main computer and projection device. Computers for each group.

INSTRUCTIONAL SEQUENCE

1. Revising models (~ 5 min)

Purpose: Review SageModeler with particular focus on variables. Set a context for model revision.

Ask students what types of things are modeled - scientific models are tools that explain various phenomena or are used to make predictions. In order to be a scientific model it has to illustrate relationships between variables and take account of all available evidence.

Depending on your data you may want to have a discussion about the water quality of the stream. Some of your data may indicate positive results for your waterway. Other data may indicate negative results. For example, in northern climates a waterway may have a neutral pH and no thermal pollution. However, because of road salt that may be used in winter, dissolved solids measured with conductivity probes may be extremely high. Other very common sources of dissolved solids in many areas of the country are nitrates and phosphates from fertilizer used on lawns, gardens, and in agriculture. Facilitate a conversation asking students if they need to re-think the overall quality of the water under study based on three pieces of evidence. Make sure to seek the views of all students. One strategy is to have students share their ideas in small groups before sharing as a class. This discussion could be at the beginning of the lesson or after students revise and test their models.

2. Revising models of our stream – adding new evidence (~20 minutes)

Purpose: Students revise their initial water quality models by adding dissolved solids (conductivity) data.

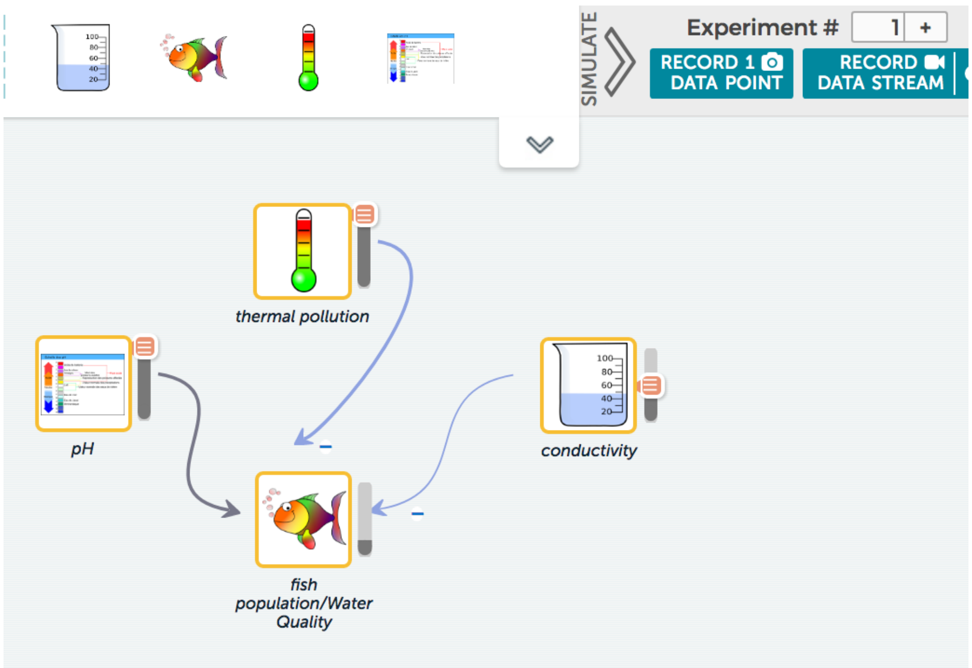
Click the button to launch SageModeler to revise your model of the water quality of the stream based on THREE pieces of evidence: pH, temperature differences (thermal pollution), and conductivity (dissolved solids).

SageModeler Button text: How healthy is our stream based on pH, temperature differences, and conductivity?

- Find pictures to represent the variable of conductivity and label it.
- Draw links between variables you think affect each other.
- Set the relationships between those variables.

Allow students to begin to work to incorporate the variable of conductivity (dissolved solids) into their models. Encourage students to use the data from the water quality test. As well, students can refer back to the student readers and/or notes taken during class. Move from group to group. Some groups will need more support than others. Encourage students to help each other. Some groups will work faster than other groups. Once they get their models working in the way in which they think accurately portrays the phenomenon, they can share their models with other groups that are also finished. Groups should explain their models to each other, request feedback, and revise models, as needed.

Here is a possible basic model that students might develop. They may choose a different icon than the ones here and that is fine. <iframe width="398px" height="313px" frameborder="no" scrolling="no" allowfullscreen="true" webkitallowfullscreen="true" mozallowfullscreen="true" src="https://codap.concord.org/releases/latest/static/dg/en/cert/index.html#shared=22247"></iframe>



Students can now “Use” their models to run a simulation. They can use the table or graphs or a combination of the two to test, evaluate, revise if needed, and re-test their models.

Below are possible questions that students can respond to that may assist them to think more deeply about their models:

1. How did adding conductivity impact how you model worked?
2. What variables did you add to show what causes conductivity?
3. How does your model account for all the evidence you have regarding water quality?

It is often the case that students move at different paces. If a group or two completes their model, including running it and making sure it works the way that they think is accurate, you can have them expand their models to include the various causes for each of the water quality tests. These will be the variables that affect conductivity. Encourage students to use the student readers to assist them. Students can choose images and define relationships between these. It is not expected that all (or any) students develop models at this level of sophistication. This is enrichment for groups who need it.

Students will continue to work on their models during class tomorrow. Some groups will also share their models.

3. Sense-making opportunities: Critiquing models:

Purpose: To have students evaluate their models to see if they "work" the way that think they should work.

Remind students that SageModeler has no content and they can develop models that "work" but do not accurately reflect the phenomenon. It is the responsibility of the students to evaluate their models. This process should further foster students learning about important science ideas, crosscutting concepts, and the practice of modeling. Students should use their notes, their patterns they noticed in their data, and the reading when developing their models. There are several possibilities including the following suggestions:

1. Using their models to predict water quality: Encourage students to use the sliders to put them to the position where the water quality should be the best. Ask them where they should put the sliders? (for pH the slider should be in the middle - 7)l for thermal pollution and conductivity the slider should be the lowest (the lowest temperature differences are the best). In this way, students are predicting that the water quality will be high. Students can now run their models to see if their predictions match.
    a. If they match, then students might conclude that their models work.

    b. If they don't match students should think about why their is a mismatch. Do they need to adjust their models? Do they need to rethink their understanding of the science concepts?
2. Now have them see if they can get the water quality to be poor, and then average.
3. Observe what happens as they change one variable to see if it matches their thinking. Does the change in that variable affect the water quality they way that they think it should?
4. Check all parts of the model. Test, evaluate, revise if needed, and retest.

4. Sharing/Discussion (~10-20 min)

Purpose: Sharing and critiquing student models is extremely valuable. It fosters a community of learners and assists students to see connections between ideas. It also allows students to see how different groups have modelled the stream phenomenon.

Either request volunteers to share their models with the class or ask a couple of groups. You can display models for everyone to see. Groups should talk through their models and explain the variables and their relationships to water quality (fish population). They should run their models, using either the graph tool or the simulation tool. They can move the toolbars for the variables to show how the water quality is impacted.

As a class, they can discuss if the model "works" and provide any feedback to the group, including any suggestions they might have to improve the model. Encourage all students to take part in the discussion.

Summary: Models are meant to explain and predict phenomenon. Ask students what conclusions they would make about the overall health of the stream based on pH, temperature, and conductivity. This can be done first in small groups and then in a class discussion. Ask students to include an overall statement (the stream is very healthy, somewhat healthy, not very healthy, very unhealthy etc), a water quality standard (excellent, good, fair, or poor), and reasons.

Have a discussion to see if the class can come to consensus. This assumes that students' evidence from all three water quality tests were similar. If they were not similar, then a discussion to support your statements should follow. Students could illustrate their ideas with their models by placing the the bars at the places where they data falls.

Concluding the lesson (2 min)
This concludes day two of the two-day lesson. Remind students that the stream is a complex system. You may refer back to the analogy of the basketball player and collecting several pieces of evidence to determine her level of play. pH, thermal pollution, and conductivity are three measures of the quality of the water. We will collect more data that can be used as evidence to gain insight into the stream phenomenon. We will now look at a fourth measure of water quality related to the amount of dissolved oxygen to see its relationship to suitability for freshwater organisms.

Ask students what questions they would need to have answered that would help them know why dissolved oxygen is important to water quality. For each water quality measure students have explored what the test measures and why it is important for water quality, the causes related to each test, and the consequences. Students will do the same for this next test.

Homework: Students will complete the student reader, "Is there enough oxygen to support life in the stream? The reading follows:

Is there enough oxygen for fish and other aquatic animals in the stream?
Dissolved Oxygen as a measure of water quality

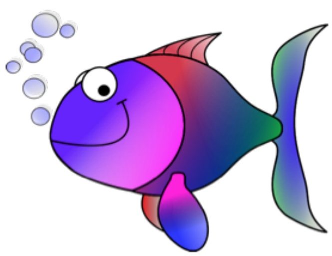
What is dissolved oxygen (D.O.) and why is it important to measure?

Can you imagine what would happen if you didn't have enough air to breathe? Just like people, fish and other aquatic organisms need oxygen to live. Dissolved oxygen is oxygen gas that is in the water. Unlike other water quality measures high amounts of oxygen are positive for organisms in the stream! Fish don't have lungs, like people. Instead, fish have gills that allow them to breathe in the oxygen that is in water. If there isn't enough oxygen in the water, fish and other organisms die. Trout is a type of fish that needs high amounts of oxygen in water to live. That means that trout is an indicator fish. If trout are spotted in a stream, what does it mean?

(students need a box or some sort of space to put their response).

Do you remember other water quality measures and the results that trout need to make the water hospitable?

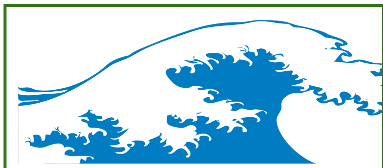
(students need a box or some sort of space to put their response).

	URL: https://openclipart.org/detail/2707/happy-fish Credit: Machovka License: Public Domain

Carp, on the other hand, is a type of fish that can live in high and low oxygen levels.

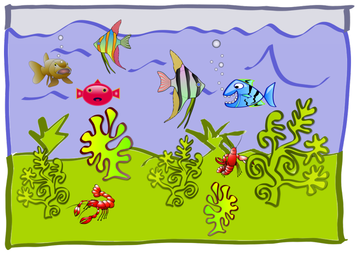
What are the sources of dissolved oxygen – where does it come from?

Have you ever seen water crashing against rocks as it flows downstream? At the bottom of a waterfall, have you observed the water as it hits the water below? The crashing water below a waterfall or against rocks cause turbulence.

	URL: https://openclipart.org/detail/3166/crashing-wave Credit: johnny_automatic License: Public Domain

Turbulent water can capture oxygen from the air. It traps the oxygen and pulls it into the water. The atmosphere, therefore, is one source of oxygen for streams. Any fast moving water that causes turbulence can capture oxygen from the air.

Another source of oxygen in stream comes from water plants. During photosynthesis plants produce

	URL: https://openclipart.org/detail/29473/underwater-world-aquarium Credit: pfluegl License: Public Domain

oxygen. If the plants are on the land, the oxygen goes into the air. If stream, lakes, and rivers have water plants, when these plants produce oxygen, the oxygen goes into the water.

What causes oxygen levels to drop?

The main reason oxygen levels drop is due to excess organic waste. Organic waste is any decomposing waste from an organism. When plants and animals die they become organic waste. Waste from animals and raw sewage are also organic waste. When excess algae (often due to excess nitrogen and phosphorous) dies it becomes organic waste. Bacteria use oxygen as they decompose organic waste.

	URL: https://www.flickr.com/photos/-oiboi/6675894731/in/photolist-baVGVi-bW81yL-8mXPXG-q4rqTM-okR53B-mh6dq-524K9Q-xUAhTc-9WGo3P-aeEYXU-bKMkcg-v3nVr-aj7ocA-9ksVH9-5bePRy-nKqJs9-qu7XG-2j76aA-52NtW3-3Mpx5o-4qAHYh-og7VMz-GcEcD-PmYMf-8EQfkd-9Z9QvD-gyoCY-jBocn7-qK5CNB-2t7Fnc-mcjwFm-6Kx9JN-dVoFmM-CuE4x-76Kxgp-8Dzofi-jBnaGd-86xEQg-aDJ5jX-6o3DvX-acZzua-xLTzY-8d187E-9kmCSa-WYsf3-j16hj-bjMPe1-qr16y5-5YL3dY-ogHn16 Credit: Ana Banderchuk License: Common Domain

Because there is an abundance of organic waste, the bacteria population dramatically increases. Bacteria also use oxygen. If there are excess bacteria they will use up all of the oxygen. Fish and other aquatic organisms die from lack of oxygen. This results in more organic waste. The cycle starts again. The end result may be an oxygen-depleted environment that can lead to a dead zone: a place that lacks the conditions necessary for life.

Another factor that could contribute to lower oxygen levels is thermal pollution. Warm water cannot hold as much oxygen as cold water. So if the water is abnormally hot its oxygen levels may be lower.

Water Quality Standards

Just like other water quality measures there are standards that are used to represent if a fresh water body of water has enough oxygen.

Here are the water quality standards for dissolved oxygen:

Dissolved Oxygen Water Quality Standards	Dissolved Oxygen Percents
Excellent – plenty of oxygen	91-110%
Good – enough oxygen	71-91% or over 110%
Fair – not enough oxygen	51-70%
Poor – not enough oxygen	Below 50%

When you test your stream or river for dissolved oxygen, what results are you hoping to get? Can you explain why?
(students need a box or some sort of space to put their response).

LESSON #6

Lesson question: How many dissolved solids are in our stream?

Overview: In previous lessons students explored two water quality measures, pH and temperature, and developed a model of the stream's health based on those two measures. In this lesson, students learn about and obtain a third piece of evidence, the amount of dissolved solids with particular focus on nitrates, phosphates, and road salt. Getting additional insights using a new water quality measure will provide a broader, more comprehensive picture of the stream's health to support freshwater organisms.

In this 3-day lesson, students explore various dissolved substances and their impact on water quality. Through a student reader and class discussion they are introduced to dissolved solids, focusing on road salt, nitrates and phosphates - and the causes and consequences of too many of these dissolved solids. Using the materials tested in the pH lab from Lesson 3, students now test for dissolved solids of various everyday substances that people use on land in large quantities (causes). Students then test the water quality of their stream and have insight into whether or not the stream has too many dissolved solids, what products might be contributing to those levels, and if the stream is healthy for freshwater organisms based on this water quality measure.

In the next lesson, students will expand their models to include their newly obtained evidence.

NGSS Performance Expectation: PE: MS-LS2-4, PE: MS-LS2-1, PE: MS-ESS3-3

Learning Performances:

- Students plan and carry out an investigation to test the level of dissolved solids of everyday substances that people use on land that can get into waterways in large quantities.
- Students collect and analyze data to explore the relationship between the level of dissolved solids of the stream and the quality of the water for various populations of organisms.
- Students construct an argument to infer which specific substances account for the levels of dissolved solids in the water and how human activity impacts those levels.
- Students construct an argument that levels and sources of dissolved solids may or may not lead to a disruption of the life cycle.

Safety Guidelines: Students will be testing everyday substances, but some may be adverse to people if they get into their eyes. They should wear goggles. Students should be careful to avoid falling into the water when testing the conductivity of their waterway.

Preparation: The everyday products that were used for the pH lab (see Lesson #3) will now be utilized in this lesson. Conductivity probes, probes that measure the amount of dissolved solids, are utilized in this lesson.

Time: 3 days

Materials:

For the teacher	groups	individuals
	● One conductivity probe or kits (could use nitrates and phosphate kits) ● Products from Lesson 3 ● Squirt bottles of distilled water for cleaning the probes	● Student reader: Dissolved Solids ● Data table for investigation ● Goggles ● Data table for all water quality tests

INSTRUCTIONAL SEQUENCE: Day 1

Background

Here are elements of the DCI that are introduced in this lesson. Other water quality tests also address some of these DCI's.

- People unknowingly use products outside that can impact the amount of dissolved solids of streams.
- Human activities alter the biosphere and may negatively impact populations of organisms.
- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors

Other background

1. Nitrogen and phosphorus are essential nutrients for growth and repair are often found in compounds as nitrates and phosphates. All organisms need them in small amounts. Plants are able to access nitrates and phosphates from their roots. Animals access nitrates and phosphates through ingestion. Fertilizers contain nitrates and phosphates and are used in agriculture. Individuals put fertilizer on gardens and lawns.
2. Some soaps contain phosphates. Some states have banned the use of phosphates in laundry soap. Other products like dishwashing soap may contain phosphates.
3. Fertilizer and soap can get washed into waterways during rain events. If a waterway has too many nitrates and phosphates it can result in excess algae or algal blooms.
4. Algae have a relatively short lifespan. When this excess algae dies it becomes organic waste. Bacteria decompose organic waste. Because there is an abundance of organic waste, the bacteria population dramatically increases. Bacteria also use oxygen. If there are excess bacteria they will use up all of the oxygen. Fish and other aquatic organisms die from lack of oxygen. This results in more organic waste. The cycle starts again. The result is an oxygen depleted environment that can lead to a dead zone: a place that lacks the conditions necessary for life. Here is a link for more information about dead zones: https://www.scientificamerican.com/article/ocean-dead-zones/
5. Road salt is used in northern climates during the winter in huge quantities. When the snow melts in the spring, the salt is washed into the water. Freshwater organisms are not meant to live in salty water.
6. Low amounts of conductivity are best for waterways.

Optional: You may wish to discuss with students that dissolved solids usually enter water as non-point source pollutants. See the optional box in Lesson 3 for further discussion.

Optional: Students could read labels from cleaning supplies to see if they identify phosphates.

1. After Reading: Probing for understanding (5 min)

Purpose: To briefly probe students understanding by asking students to share what they learned from the reading. For homework, students completed a reading that introduced them to the three main dissolved solids: nitrates, phosphates, and salt and their potential problems for freshwater organisms. Ask students to share what they learned. You may connect back to the introduction video about algal blooms in Florida (Toxic Algae Blooms Keep Florida Beachgoers Away Video - ABC News (1:49 minutes)

http://abcnews.go.com/US/video/manatee-emerges-algae-covered-water-40283466

2. Assist students to develop understanding of Conductivity (45 minutes)

Assist students to begin to describe the relationship between amount of dissolved solids (measured by a conductivity probe) of the stream and the quality of the water for various populations of organisms by discussing the main ideas about conductivity: the causes and consequences of too many dissolved solids, including how people's actions on land can impact waterways.

Include the following:

a. We test conductivity to determine if the water has too many dissolved solids, particularly nitrates phosphates, and road salt.

Optional: You may want to define dissolving, solvent, and solute and that some things do not dissolve. This will add time to the curriculum.

b. Nitrogen and Phosphorus are found in nature and are essential nutrients for growth and repair. They are often found in compounds as nitrates and phosphates. They are essential; ALL organisms need them, BUT in only very small amounts.

c. Nature has a balanced life cycle where plants, both on land and in water, pick up nitrates and phosphates through their roots, in order to grow. When these plants die (whether in the water or on land) they become dead matter, also called organic waste. Bacteria and other organisms decompose the plants. Nitrates and phosphates are released back into soil or water and become available for other plants. This is an "in-balance" cycle referred to as a life cycle.

d. People put nitrate and phosphate compounds in fertilizer to help plants grow. Farmers use it on crops and individuals use it on home gardens or on lawns.

e. Other sources of nitrates and phosphates are any type of organic waste: dog, duck, or geese manure or cow manure from dairy farms.

Teaching extension: This is an opportunity for you to ask students to generate ideas of actions steps that they and others can take to decrease the possibility of unintentionally contributing these pollutants. Ideas include picking up after dogs or avoiding the practice of cutting vegetation near waterways. Vegetation acts as a buffer. Not only does it “catch” pollutants to prevent them from running into a stream, they also inhibit wildlife such as ducks and geese from being on the water’s edge.

f. Phosphates can be found in some cleaners such as laundry and dishwashing soap. Some states have banned phosphorous from laundry soap because of the effects on waterways.

g. When is rains, fertilizer and other products that contain nitrates and phosphates can get picked up and carried downhill to various waterways. Fertilizer can get carried to waterways through storm drains as well. This provides a waterway with excess nitrates and phosphates.

h. Excess nitrates and phosphates can result in an algal bloom – excess algae growth.

i. Algae have a relatively short life span. When all of the algae die they become excess organic waste.

j. Bacteria decompose organic waste. Because there is an abundance of organic waste, the bacteria population dramatically increases. Bacterial also use oxygen. If there are excess bacteria they will use up all of the oxygen.

k. Fish and other aquatic organisms die from lack of oxygen. This results in more organic waste. The cycle starts again. The result is an oxygen depletion cycle that can lead to a dead zone: a freshwater area that lacks the conditions necessary for life – not enough oxygen.

Optional: While dead zones are more common in oceans they can occur in lakes and even rivers.

Search for youtube videos related to algal blooms and fertilizer run-off. In the upper midwest, for example, there are many videos related to algal blooms in Lake Erie. See if you can find an algal bloom issue in a lake in your area. If not, show one from Lake Erie.

l. Road salt is used in northern climates during the winter in huge quantities. When the snow melts in the spring, the salt is washed into the water. Freshwater organisms are not meant to live in salty water.

Next, introduce water quality standards to students:

2. Water Quality Standards: Just as with pH and thermal pollution, water quality experts developed water quality standards for the amount of dissolved solids using the terms excellent, good, fair, and poor to identify if fresh waterways have too much or acceptable levels. Excellent and good indicate that there are not too many dissolved solids in the stream with excellent being better than good. Fair and poor indicate too many dissolved solids*, meaning the results are problematic for streams, with poor being worse than fair.

*It should be noted that when it comes to salt in fresh waterways there is a “tipping point” of 1400-1500 mg/L that will begin to impact freshwater organisms.

Here are the Conductivity Standards as wall as total nitrate and phosphate standards:

Dissolved Solids Water Quality Standards	Conductivity probe mg/L	Total Phosphate mg/L	Nitrates mg/L
Excellent – not too many dissolved solids	0-100 mg/L	0-1	0-1
Good - not too many dissolved solids	100-250 mg/L	1.1-4	1.1-3
Fair - too many dissolved solids	250-400 mg/L	4.1-9.9	3.1-5
Poor - too many dissolved solids	> 400 mg/L	> 10	> 5

Conductivity tools
Scientific probes can be used to ascertain conductivity. Several companies, including Pasco Scientific, https://www.**pasco**.com, and Vernier www.**vernier**.com/ sell a variety of probes, including Probes that are now wireless where data can be sent to cell phones, tablets, or computers. In addition to conductivity probes, nitrate and phosphate kits may be purchased from companies such as HACH.

3. Concluding the lesson (2-3 min)
Ask students whether we are hoping for high, medium, or low conductivity readings (If you are using kits, adjust your questions accordingly). Low reading would be the best for the stream. Let them know that before we measure the conductivity level of the stream we want to conduct an experiment, in class, that will provide us with insight into conductivity.

4. Homework: Ask students to think about how we can investigate conductivity in class. Have them bring their ideas to the next class.

INSTRUCTIONAL SEQUENCE: Day 2

1. Plan in-class investigation (~5 min)

Purpose: Assist students to figure out that they can test the same substances from the pH lab, but now with conductivity probes.

For homework, students were asked to think about how to investigate conductivity in class. Ask students to share their ideas.

Options: You could ask students to share and generate ideas in small groups and then share as a class. You could conduct this as a class discussion only.

Students may say that they want to test lemons and coke, etc. The goal is to steer students to test the products that are already set up from the pH lab (see Lesson 3). These are substances that can get into the stream in large quantities. Many of these substances dissolve in water.

2. Planning an Investigating – What is the conductivity of everyday substances? (~10 min)

If someone has not come up with the idea of testing the products that can get into the stream in large quantities, present the students with the idea and ask them what they think: What do you think about asking the question, "What is the conductivity of everyday products people use on the land?"

Some of the products do not dissolve. No need to let students know this now. Students will later test for turbidity. Turbidity tests for solids that do not dissolve. For now, students can test all of the products.

Options: You could ask students to develop a data table or you could provide students with a data table. If students develop a table they can work with partners to create a "sloppy copy" (rough draft) into notebooks. A few students can put their data table on the board to share. Taking the best from all groups, you can build consensus on the format. Students may then make "nice" tables.

An example of a data table is included below with a link to a conductivity data table here:

Conductivity Data Table: What is the conductivity of everyday products used outside?

Substance	Prediction	Results Trial 1	Results Trial 2	Results Trial 3	Result Ave	Standard
Antifreeze						

3. Investigating the conductivity of everyday substances (~20-30 min)

Pull out the various products that are in tennis cans for testing (see Lesson 3 and the picture below). Discuss the testing procedure with students. Have a list of all of the products on the board.

Be sure to stress to students that they need to rinse the probe between products (not between trials). They should test each three times to ensure the results are consistent. They may record the average or the most consistent number.

Due to the concentration of the mixture (how much of each product per water) conductivity of substances may be exceedingly high. Remind students of how much of each product was added to how much water. Let students know that the results from today's in-class lab should help them with their prediction for the conductivity level of the stream.

4. Engaging in sense-making: sharing and discussing dissolved solids through conductivity results (~10 min*)

It is important to share the data. First, it allows the class to see if the data is consistent. If one group's numbers are continually different from others than you may need to check that probe. Next, it allows students to identify patterns. Make sure that all students have opportunities to discuss their patterns they see. Students may find that fertilizers have very high readings as does road salt. Students may be surprised to see that conductivity reading of dirt is much lower (although nitrates and phosphates can bind with dirt). You can talk with students about the results and discuss concentration of the tested substances compared to concentration of these substances in a waterway.

*Optional. More time may be spent with sense-making if you have time. Encourage students to discuss the various products that they tested. Ask students if there are products that could negatively impact a stream if they were to get into the waterway in large quantities? Are there choices of products that could be used that would not have a negative impact on a stream's conductivity readings? For example, are there alternatives to using fertilizer? If you live in a northern climate are there alternatives to using road salt? What about simply using less?

5. Concluding the lesson: This concludes day two of a three-day lesson. Let students know that they should now be able to first make predictions and then test their stream water and understand what the conductivity numbers that they obtain mean: whether there are too many dissolved solids or not. They can also have some insight into possible products that people use on land that might account for the readings that they obtain. For example, if the waterway that is being tested is near neighborhoods with nice lawns and conductivity readings are high, students may deduce that people could be using fertilizer. Or if testing the spring after road salt has been applied on roads throughout the winter, students might deduce that the high numbers are related to road salt. This will assist students to see the relationship between products people use on land and the impact on a waterway's conductivity levels.

Understanding the idea of causal relationships is key in developing models. Continue to emphasize cause and effect relationships related to the science ideas.

Let students know that tomorrow we will test the conductivity of the stream (or whatever phenomenon you are using). If going outside, remind students to dress appropriately for the weather.

Homework: Students will write a prediction about the conductivity of the stream. (~5 min)

Predictions will include four parts:

- A conductivity number and text about dissolved solids (ie. I predict the stream will have of conductivity of 150mg/L which means not too many dissolved solids).
- The standard for their prediction (Excellent, good, fair, or poor)
- A statement about the consequence (in-balance or could lead to out-of-balance cycle) that matches the standard.
- At least one reason for their prediction (based on science ideas from the Student Reader).

Here's an example:

I predict the stream will have a conductivity reading of 150mg/L. This is good according to water quality standards so there are not too many dissolved solids. I'm predicting this because there are not many lawns near our stream and the homes with lawns don't look very lush; I don't think they use fertilizer.

You will decide if students will write their prediction in a notebook, on paper, or using a computer.

<u>INSTRUCTIONAL SEQUENCE: Day 3</u>

1. Investigating the conductivity of the stream (~30-45 min)

Purpose: Collect the third piece of water quality data: conductivity.

Begin by asking students to share their predictions. Make sure all students are able to share and explain why they made the prediction. Another option is to collect data first and then share predictions. Provide students with instructions for data collection. Below is one possible data table for students to use.

You should follow the same procedure that was done for pH and temperature.

Conductivity of the stream	Observations that could impact the stream's Conductivity
Trial 1 _____ Trial 2 _____ Trial 3 _____ Average ___________ Average divided by 2: _______________mg/L	In the water: Near the water: Recent weather:

2. Engaging in sense-making: Sharing and discussing conductivity results (~5-15 min)

Purpose: Students share data to look for discrepancies and patterns in the data.

You may want student groups to write their results on the board. Results will most likely be similar. There may be plausible factors, however, that influence student results based the location of where they tested in relation to the land, for example, a pipe that is discharging substances into the water. If a plausible factor is not identified, and a group has significantly different results from the other groups, It could be an outlier, in which case the group may want to re-test.

Students may work in groups to focus on these questions:

- According to your results is the stream's conductivity healthy for organisms? Are there too many dissolved solids?
- What water quality standard do your results convey (excellent, good, fair, or poor) for conductivity?
- If there are too many dissolved solids, what do you think could be the cause(s) – where might they be coming from?
- Based on your results what are the possible consequences? Use your science notes to help.

This may be followed up with a class discussion. Major ideas can also be added to the driving question board.

Students should now fill in the comprehensive data table that is provided for them to record data from all of the of the water quality tests that they conduct during the project.

Water Quality Test Results

How Healthy is our stream for freshwater organisms?
How do our actions on land potentially impact the water?

Organize your results from all of the water quality tests into one data table below. Notice the far right column labeled *Observations*. Record any information that you may have observed in or near the water that might help you determine what caused the results you obtained for that test.

Name of Water Quality Test	Results	Water Quality Standard	Observations
pH			
Temperature Difference			
Conductivity			

Concluding the lesson: (2 min) This concludes the three-day lesson on conductivity. Remind students that conductivity is the third water quality measure. Ask if they can feel confident to make an overall conclusion about the stream's health for supporting organisms. Relate this back to the basketball analogy that was introduced in Lesson 2 (Instructional sequence #4). Would seeing that the person was a good free-throw shooter, dribbler, and passer provide enough evidence that she could succeed as a college basketball player? Certainly, having three pieces of evidence is better than having only one piece of evidence; three pieces provide a stronger "picture" of the stream system.

Relate back to the driving question. We are investigating. "How healthy is our stream for freshwater organisms and how do our actions on land potentially impact the stream and the organisms that live in it?" Gathering more evidence from water quality measures will provide an even more comprehensive, evidence-based picture of the stream's overall health for organisms. Make sure all students are able to take part in the discussion.

Homework: None
In the next lesson, students will expand their original models to include their newly obtained evidence.

LESSON #8

Lesson question: Is there enough oxygen to support life in the stream?

Overview: In the previous lesson, students expanded their models to include conductivity. In this lesson, students explore and collect a fourth piece of evidence - dissolved oxygen (DO) to determine if the stream has enough oxygen to support aquatic organisms. Students investigate the sources of DO and consequences for low DO. They also gain insight into what causes DO levels to drop.

In the next lesson, students will collect a final piece of evidence, turbidity, to measure the amount of suspended particles in the water.

NGSS Performance Expectation: PE: MS-LS2-4, PE: MS-LS2-1, PE: MS-ESS3-3

Learning Performances:

LP6: Students collect and analyze data to infer causes and consequences of the result of human activities that result in disruptions to physical or biological components of an ecosystem.

LP8: Students analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

Safety Guidelines: Students will be using chemicals. They should wear goggles. Students should be careful to avoid falling into the water when collecting water samples from their waterway.

Preparation: Dissolved oxygen kits are used in this lesson. Because of the expense, the teacher demonstrates how to conduct the tests in class. Students follow along with the same equipment but do not actually conduct the test. Depending on your resources, however, you may want students to practice using the kits in class. Dissolved oxygen probes may be used instead of the kits.

Scientific probes or dissolved oxygen kits can be used to ascertain dissolved oxygen. Dissolved Oxygen kits may be obtained at HACH (hach.com). Probes Two companies, Pasco Scientific, https://www.**pasco**.com, and Vernier www.**vernier**.com/ sell a variety of probes. Probes are now wireless and data can be sent to cell phones, tablets, or computers.

Time: 3 days

Materials:

For the teacher	**groups**	**individuals**
DO kit or probe for demonstration	• One dissolved oxygen kit or DO probe	• DO student reader • Data table for investigation

DO conversion chart Ruler or straight-edge	● Thermometers or temperature probes ● Directions for use of the DO kit	● Goggles ● Data table for all water quality tests ● DO conversion chart ● Ruler or straight-edge

INSTRUCTIONAL SEQUENCE: Day 1

Background

Here are elements of the DCI that are introduced in this lesson. Other water quality tests also address some of these DCI's.

Resource availability (in this case, oxygen) impacts organisms and populations of organisms in an ecosystem. Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with non-living factors.

- Human activities alter the biosphere and may negatively impact populations of organisms.

Other background

1. Just like humans, aquatic animals, fish and other organisms, need oxygen to survive. Trout, for example, need high amounts of oxygen and are considered an indicator fish; if trout are present, that indicates that there is plenty of oxygen. Carp, on the other hand, can survive in low oxygen levels (although they can certainly survive with lots of oxygenated water). High levels of oxygen are the best for waterways. (Trout also need a very neutral pH – 6.5-7.5 - and cannot live in waters that have thermal pollution)
2. Oxygen gas is dissolved in the water (Optional: you may want to include a discussion of oxygen as the solute and water as the solvent).
3. There are two sources of oxygen in the water:
    a. The atmosphere: fast moving water captures oxygen from the air by trapping it and pulling it into waterways as it falls. Fast moving water can come from waterfalls, water crashing into rocks, rainwater hitting water, etc.
    b. Water plants produce oxygen as a product of photosynthesis.
4. This water quality tests connects to conductivity. Remember: When excess algae (due to excess nitrogen and phosphorous) dies it becomes organic waste. Bacteria decompose organic waste. Because there is an abundance of organic waste, the bacteria population dramatically increases. Bacteria also use oxygen. If there are excess bacteria they will use up all of the oxygen. Fish and other aquatic organisms die from lack of oxygen. This results in more organic waste. The cycle starts again. The result is an oxygen-depleted environment that can lead to a dead zone: a place that lacks the conditions necessary for life.

1. After Reading: Probing for understanding. **Assisting students to develop understanding of Dissolved Oxygen** (~20-25 minutes)

Assist students to begin to understand the importance of oxygen in waterways and the relationship between amount of oxygen and the quality of the water for various populations of organisms by discussing the main ideas about oxygen: the sources and consequences of too little oxygen, and what causes DO levels to drop. For homework, students completed a reading that introduced them to dissolved oxygen. Ask students to share what they learned.

Because students have completed the reading for dissolved oxygen, you should be able to facilitate an interactive discussion with students, which allows them to generate the main ideas. Guide students using the following questions:

1. Why do we test for dissolved oxygen (DO)? What does it measure and why is it important?
2. What are the sources of DO?
3. What is the consequence of low DO?
4. What causes DO levels to drop?

These ideas include the following:

a. We test dissolved oxygen to determine if the water has enough oxygen to support aquatic animals who need oxygen just like we do. Emphasize to students that oxygen is not a pollutant but rather something that is good for the stream. Students may assume that everything is bad for waterways.

b. There are two sources of oxygen in the stream: the atmosphere and water plants. Discuss each source.

c. Without enough oxygen, fish die. This is the major consequence of too little oxygen.

d. Excess organic waste and thermal pollution cause DO levels to drop. Warm water cannot hold as much oxygen as cold water. Organic waste is decomposed by bacteria. If there is excess organic waste, bacteria and other organisms decompose this waste. Because there is an abundance of organic waste, the bacteria population dramatically increases. Bacterial also use oxygen. If there are excess bacteria they will use up all of the oxygen.

e. Connect oxygen with the conductivity measure. You may to ask students if they can make a connection between the two water quality measures.

Teaching extension: This is an opportunity for you to ask students to generate ideas of action steps that they and others can take to decrease the possibility of unintentionally contributing these pollutants. Ideas include raking dead leaves away from storm drains to prevent them from getting into waterways and providing excess organic waste. Picking up after dogs or avoiding the practice of cutting vegetation near waterways also decreases organic waste.

Next, introduce water quality standards to students:

2. Water Quality Standards: Just as with the other water quality measures, water quality experts developed water quality standards for the amount of oxygen using the terms excellent, good, fair, and poor to identify if fresh waterways have too much or acceptable levels. Excellent and good indicate that there is enough oxygen in the stream with excellent being better than good. Fair and poor indicate too little oxygen meaning the results are problematic for streams, with poor being worse than fair.

Dissolved Oxygen kits provide oxygen reading in mg/L. The standards are in % so a conversion chart is used. Since oxygen levels are impacted by temperature, the temperature of the water also needs to be measured.

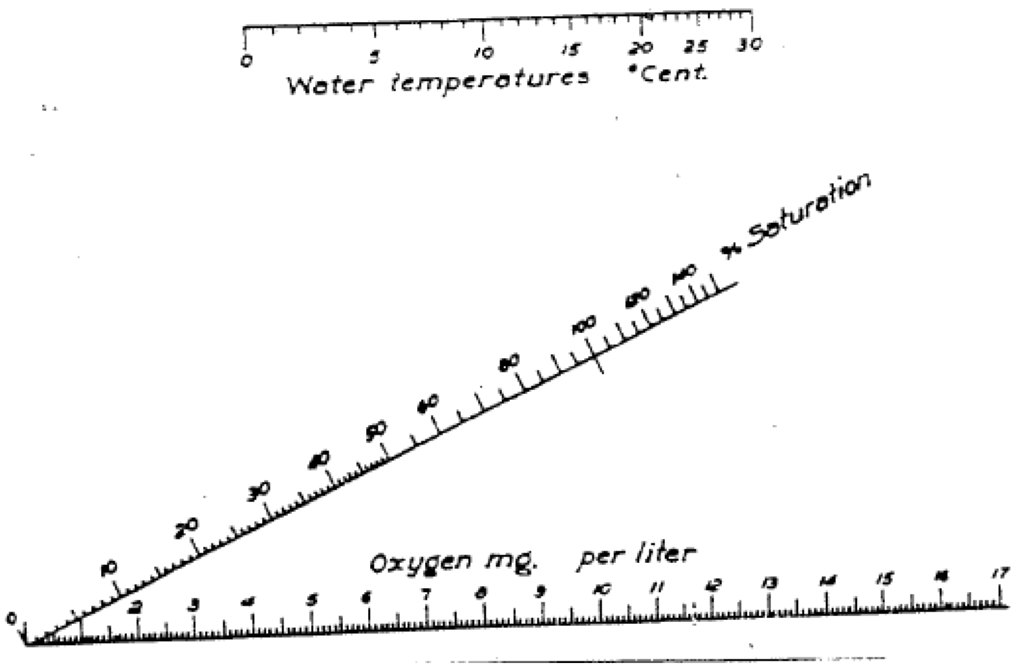
Here are the Dissolved Oxygen Standards:

Dissolved Oxygen Water Quality Standards	Dissolved solids: %
Excellent – plenty of oxygen	91%-110%
Good – enough oxygen	71%-90%
Fair - too little oxygen	51-70%
Poor - too little oxygen	Below 50%

3. Converting Dissolved Oxygen from mg/L to percent.
Students will need directions and practice to convert DO from mg/L to percents. Below is a conversion chart. Notice across the top is a bar for water temperature. Dissolved oxygen is impacted by temperature; warm water can hold less DO so temperature of the water needs to be collected. Across the bottom of the chart is oxygen in mg/L. The DO kit provides this data. To convert to DO % a dot is marked on the temperature line followed by a dot on the oxygen in mg/L line. Next, connect the dots using a ruler. Read the diagonal line which is the % saturation, or DO %.

Practice using the DO conversion chart (link to conversion chart – 3 charts per page)
Provide students with a couple of opportunities to convert their DO readings into DO percents. Here are a couple of possible examples:

1. Your water has a dissolved oxygen reading of 10mg/L and a temperature of 12^0 Celsius. What is the DO percent of your water? What water quality standard (excellent, good, fair, or poor) does this represent? Based on your results is there enough oxygen in the water to support aquatic animals? (DO = 90%, excellent water quality for oxygen which means there is enough oxygen to support aquatic animals).
2. Your water has a dissolved oxygen reading of 6mg/L and a temperature of 10^0 Celsius. What is the DO percent of your water? What water quality standard (excellent, good, fair, or poor) does this represent? Based on your results is there enough oxygen in the water to support aquatic animals? (DO = 55%, fair water quality for oxygen which means there is not enough oxygen to support aquatic animals).



4. Concluding the lesson (2-3 min)
Ask students whether we are hoping for high, medium, or low oxygen readings. High readings would be the best for the stream. If you are using kits, let students know that before we measure the oxygen levels of the stream we need to learn how to use the kits. That leads to tomorrow's lesson.

4. Homework: None

<u>INSTRUCTIONAL SEQUENCE: Day 2</u>

1. Demonstrate and practice using dissolved oxygen kits (~5 min)

Purpose: Demonstrate and carefully read through the directions for conducting the dissolved oxygen test using a DO kit.

Students should wear goggles if using DO kits. The test can be done at the stream or samples of water can be obtained and brought back to the class to conduct the test. If the test is conducted in the classroom students can set up the chemicals and only need to take out the bottle for the water sample. Students need to carefully follow the directions. It is easy for students to mix up packets #1 and #2 so they need to read carefully.

Depending on your science budget you may demonstrate how to use the kits or have students also practice.

Options: You may demonstrate how to use the kit. Student groups would also have kits and follow along but not actually open the packets of chemicals. Another option is for students to test a sample of water with you. Either way, going through together, step-by-step, will help to ensure that students follow the procedure accurately.

It is helpful to have the directions projected on a screen in addition to a hard-copy for students.

Here is one suggestion for demonstrating the procedure for testing the oxygen level in a sample of water:

Slowly and gently fill up a tennis can (or other container) with water from the tap. Fill up a second container, but this time run the water at full force so water quickly pushes into the container. Make sure that the water is at the same temperature (cold water, for example). Ask students which container they predict will contain more oxygen (fast water captures oxygen from the air so the second container will have more oxygen).

Step-by-step conduct the DO test, showing students as you read through the directions.

Following the DO test you will have results in mg/L. You will use measure the temperature of the water and then use the DO conversion chart to obtain a percent. Discuss the results with students.

2. Concluding the lesson: This concludes day two of a three-day lesson. Let students know that they should now be able to first make predictions and then test their stream water and understand what the dissolved oxygen numbers that they obtain mean: whether there is enough or too little oxygen to support aquatic animals. When making predictions encourage students to think about how fast their water flows and if there has been recent heavy rain etc. These are things that can contribute to DO. They can also think about various aspects related to temperature

Let students know that tomorrow we will test the oxygen levels of the stream (or whatever phenomenon you are using). If going outside, remind students to dress appropriately for the weather.

Homework: Students will write a prediction about the dissolved oxygen of the stream. (~5 min)

Predictions will include four parts:

- A dissolved oxygen percent
- The standard for their prediction (Excellent, good, fair, or poor)
- A statement about the consequence (enough or not enough oxygen to support life) that matches the standard.
- At least one reason for their prediction (based on science ideas from the Student Reader).

Here is an example:

I predict the stream will have 95% oxygen. This is excellent according to water quality standards so there will be enough oxygen for fish. I'm predicting this because there is very fast water that hits large rocks and captures oxygen from the air.

You will decide if students will write their prediction in a notebook, on paper, or using a computer.

INSTRUCTIONAL SEQUENCE: Day 3

1. Investigating the oxygen of the stream (~30-45 min)

Purpose: Collect the fourth piece of water quality data: dissolved oxygen.

Begin by asking students to share their predictions. Another option is to collect data first and then share predictions. Provide students with instructions for data collection. Below is one possible data table for students to use. Students will also need the DO conversion chart (link D.O. chart)

Because the Dissolved Oxygen test is labor intensive and costly (if kits are used) students will not do three trials and average.

Dissolved Oxygen

D.O. mg/l	Temperature 0 Celsius	D.O. %	Standard	Observations that could impact the stream's DO
				In the water: Near the water: Recent weather:

2. Engaging in sense-making: Sharing and discussing oxygen results (~5-15 min)

Purpose: Students share data to look for discrepancies and patterns in the data.

You may want student groups to write their results on the board. Since oxygen level are influenced by rapids, waterfalls, etc. they may be different. However, if there is an outlier, this group may want to re-test. Students may work in groups to focus on these questions:

- According to your results is the stream's oxygen level healthy for organisms? Is there enough oxygen? Too little?
- What water quality standard do your results convey (excellent, good, fair, or poor) for the amount of oxygen?
- If there is not enough oxygen, what do you think could be the causes (have students look at what causes DO levels to drop)
- Based on your results what are the possible consequences? Use your science notes to help.

This may be followed up with a class discussion. Looking for causes and consequences and patterns are important crosscutting concepts that will also assist students in learning important science ideas as they analyze their data. Stability and change is another important crosscutting concept, particularly related to excess organic waste that was the result of human activity of using fertilizer in agriculture and home gardening and lawns.

Students should now fill in the comprehensive data table that is provided for them to record data from all of the of the water quality tests that they conduct during the project.

Water Quality Test Results
How Healthy is our stream for freshwater organisms?
How do our actions on land potentially impact the water?

Organize your results from all of the water quality tests into one data table below. Notice the far right column labeled *Observations*. Record any information that you may have observed in or near the water that might help you determine what caused the results you obtained for that test.

Name of Water Quality Test	Results	Water Quality Standard	Observations
pH			
Temperature Difference			
Conductivity			
Dissolved Oxygen			

Concluding the lesson: (2 min) This concludes the three-day lesson on dissolved oxygen. Remind students that oxygen is the fourth water quality measure. Ask if they can feel confident to make an overall conclusion about the stream's health for supporting organisms. You may relate this back to the basketball analogy that was introduced in Lesson 2 (Instructional sequence #4). Would seeing that the person was a good free-throw shooter, dribbler, passer, and defender enough evidence that she could succeed as a college basketball player? Certainly, having four pieces of evidence provides a stronger "picture" of the stream system. Relate back to the driving question. We're investigating "Is our stream healthy for freshwater organisms and how do our actions on land potentially impact the stream? Gathering more evidence from water quality measures will provide an even more comprehensive, evidence-based picture of the streams overall health for organisms. Let students know that we will collect and analyze one more piece of evidence, called turbidity, then evaluate all of the evidence to answer our driving question. We will expand our models to assist us in the process.

Homework: Student Reader: Turbidity. The reading follows:

Are there too many floating particles in the stream?

Turbidity as a measure of Water Quality

What is turbidity and why is it important?

Did you ever see water that was so dirty that you couldn't see through it? Turbidity measures the amount of floating particles in water that cause the water to look murky. Floating particles, whether on top of the water, throughout the water, or sitting on the waterbed, do not dissolve. Water that is not turbid is clear. High turbidity in freshwater lakes, rivers, and streams means poor water quality.

What causes high turbidity?

There are many different types of particles that float in water. Dirt is a very common cause of high turbidity. Dirt in the water can be the result of two different activities that people do on land. One, when people build houses, apartments, or other buildings, part of the building process often includes digging a hole for a basement or for underground parking. Mounds of dirt can sit at a construction site.

	URL: https://openclipart.org/detail/210414/misc-proto-dirt-pile Credit: Glitch License: Public Domain

When it rains, the rainwater can pick up the dirt and carry it downhill into streams, rivers, or lakes, or it can first go to storm drains that have pipes that are connected to these waterways. Preventing stormwater pollution is a component of the Clean Water Act (http://www.epa.gov/region5/water/cwa.htm) passed in the United States in 1972. Do you have any ideas of how this dirt run-off might be prevented?

(Students need a box to put their response)

Did you ever see two-foot fences around a construction site? These silt fences are one solution that the construction industry came up with to help ensure that dirt would not run-off from construction areas. The solid mini fences capture dirt by acting as a barrier. They work to prevent dirt run-off.

A second source of dirt is from erosion. Plants have roots that hold the soil in place. If people cut down trees or other plants the result can be loose soil. Just like from construction sites, loose dirt anywhere be picked up by rain and be carried into waterways. Have you ever seen how rivers turn brown after a heavy rain? One solution to erosion is to make sure to plant grass or other plants that will hold soil in place.

There are many other particles that float in the water besides dirt. Organic waste – dead leaves, plants, etc., animal waste and algae or other tiny plants are examples. Human waste, either from leaking septic tanks or from discharge from wastewater treatment plants can contribute to turbidity. Floating particles also come from urban run-off including car oil, litter, etc., and from industrial waste.

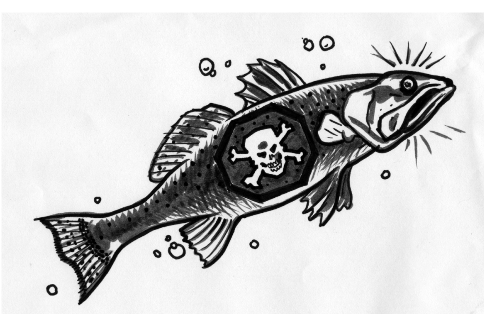
Look back through the causes of turbidity and identify which ones are the result of people and which ones are from nature?

(Students' need a box to put their response)

What are the consequences of high turbidity?

Why is high turbidity a problem? There are four consequences to the water quality of a stream if it has high turbidity.

First, floating particles in the water absorb heat. This can lead to thermal pollution. Remember learning about thermal pollution in Lesson 4? Thermal pollution can kill fish.

	URL:https://www.flickr.com/photos/apeshot/9019017468/in/photolist-eJYPFb-79gJse-aVyxQn-6FChTi-5gUXSk-89G1qK-786A7r-idfDxA-duTeka-djVJWa-dLco5X-eVE6TL-cSHspN-p7NhiT-jUVget-orK2ad-4hTJau-owdbiX-ovgPia-a484nX-7EeeEQ-owXki6-z32oUp-7qknZ3-2VuU7z-otkGM9-owhuMq-ocadJf-9i2xth-ow4HHZ-oeUoWb-4pny3Q-tf1NWw-83FdwQ-8fiA77-4hTKdE-9AFQ1k-ba75qK-93bkEi-a3m5Gj-daNBR9-GUMJHC-afbq3p-ry5k5p-9DNCxB-nVazPY-hyRZat-dvgtDC-oy6Gjn-re3kVo

	Credit: scottapeshot License: Common Domain

It can also promote algal blooms. And remember, warm water cannot hold as much oxygen as cold water. Floating particles also block sunlight. Plants need the sun to photosynthesize. That means that water plants cannot undergo photosynthesis so plant growth can then be limited. This is a second consequence of high turbidity. A third consequence of high turbidity is that floating particles can clog fish gills. Can you imagine trying to breathe when the air is full of particles? Perhaps you have been some place where there is lots of smog and it was hard to breathe. Fish don't breathe with lungs; they use gills. The final consequence of high turbidity is that particles can sink and kill fish and insect eggs that are on the bottom.

Water quality standards

There are several different ways to measure turbidity. Depending on the method your class decides to use, there are also different units. Can you identify the method that you will use? Put an "X" over the column to identify the method and units.

Turbidity Standards:

Turbidity Water Quality Standards	Turbidity probes NTU's:	Secchi disk or Turbidity Tube	Engineered filtration system
Excellent – no (or very little) turbidity, not too many floating particles	0-10	➢ 3 feet ➢ 91.5 cm	1 = none or very little turbidity
Good – low turbidity	10.1-40	1 foot to 3 feet 30.5 cm to 91.5 cm	2 = low turbidity
Fair – Medium turbidity, too many floating particles	40.1-150	2 in to 1 foot 5 cm to 30.5 cm	3 = medium turbidity
Poor – high turbidity, too many floating particles	> 150	< 2 in < 5 cm	4 = high turbidity

LESSON #9

Lesson question: How many floating particles are in the stream? Is this a problem for freshwater organisms?

Overview: Turbidity, the final water quality measure, rounds out the evidence-based exploration of how healthy a waterway is for freshwater organisms and peoples impact on water quality. This measure connects to other water quality measures: thermal pollution and dissolved oxygen. While conductivity measures the amount of dissolved solids, turbidity measures the amount of suspended solids. Knowing the turbidity of the water, along with the other water quality measures, will allow students to make claims about the overall health of the water supported with a wide range of evidence, and use the modeling tool to model the entire water system. A final model will be developed in the concluding lesson of the unit, Lesson 10.

There are several different ways to collect turbidity data including an optional design opportunity.

In the previous lesson, students explored and collected a fourth piece of evidence - dissolved oxygen (DO) to determine if the stream (or other waterway) has enough oxygen to support aquatic organisms. In this lesson, students will collect a final piece of evidence, turbidity, to measure the amount of suspended particles in the water.

Prior to data collection, students learn what turbidity measures and they investigate the sources of turbidity and consequences for high turbidity.

This lesson leads to the final lesson of the unit where students add dissolved oxygen and turbidity to their existing models. They use their final models to respond to the driving question for the unit, "Is our stream healthy for freshwater organisms and how do our actions on land potentially impact the stream?"

NGSS Performance Expectation: PE: MS-LS2-4, PE: MS-LS2-1, PE: MS-ESS3-3, MS-ETS1-1*

Learning Performances:

LP6: Students collect and analyze data to infer causes and consequences of the result of human activities that result in disruptions to physical or biological components of an ecosystem.

LP8: Students analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

LP9*: Students design and build a device to capture pollutants that allow them to collect, analyze and interpret data to infer causes and consequences of the result of human activities that result in disruptions to physical or biological components of an ecosystem.
*A design opportunity is an optional activity

Safety Guidelines: No matter which method is used to test turbidity, students should wear goggles. Students should be careful to avoid falling into the water when collecting water samples from their waterway.

Preparation: There are several options for turbidity data collection.

1. A Secchi disc is a round disc that is lowered into the water. The depth at which the markings are no longer visible is a measurement of the clarity of the water. This method is not feasible if measuring in shallow water.
2. Turbidity sensors may be obtained from Pasco Scientific https://www.**pasco**.com, and Vernier www.**vernier**.com/
3. Turbidity Tube: This long tube has a mini-secchi disc at the bottom. Students completely fill the tube with a sample of water and look through the top of the tube. Water is siphoned from the bottom of the tube. When the secchi disc is clear the water flow is stopped and a reading is taken to see the depth at which the markings are clearly visible. Turbidity tubes may be purchased at scientific companies.
4. Students can design and build their own system for measuring turbidity (discussed in the lesson).

Time: 2 days (3 days if students engage in the optional design challenge)

Materials:

For the teacher	groups	individuals
	● Data collection device: One of the four options described in the preparation section ● Materials to design and build a turbidity collection device	● Turbidity student reader ● Data table for investigation ● Goggles ● Data table for all water quality tests

INSTRUCTIONAL SEQUENCE: Day 1

Background

Here are elements of the DCI that are introduced in this lesson. Other water quality tests also address some of these DCI's.

- Human activities alter the biosphere and may negatively impact populations of organisms.

Other background

1. Turbidity is the murkiness of water caused by suspended (floating) solid particles that can enter the water through run-off. High turbidity means poor water quality.

2. There are several causes of floating particles in water that include dirt, organic waste, human and animal waste, algae or other floating tiny plants, and urban and industrial waste. These are discussed in the Student Reader for Turbidity.
3. Some floating particles occur in nature. The focus of this lesson, just as with the earlier lessons, will be human activities that occur on land that can contribute to the number of floating particles.
4. One consequence of high turbidity is that particles in the water absorb heat which can result in thermal pollution and therefore, turbidity is related to thermal pollution. As well, warm water cannot hold as much oxygen. Therefore, turbidity is also related to DO. Help students to make these connections.
5. There are other consequences of high turbidity, which are discussed in the student reader.

1. After Reading: Probing for understanding. **Assisting students to develop understanding of Turbidity** (~25-30 minutes)

Assist students to begin to understand the importance of having low turbidity in waterways and the relationship between amount of turbidity and the quality of the water for various populations of organisms by discussing the main ideas about turbidity: what is measures, and the sources and consequences of too many floating particles. For homework, students completed a reading that introduced them to turbidity. Ask students to share what they learned.

Because students have completed the reading for turbidity, you should be able to facilitate an interactive discussion with students, which allows them to generate the main ideas. Guide students using the following questions:

1. Why do we test for turbidity? What does turbidity measure and why is it important?
2. What are sources of turbidity?
3. What are consequences of high turbidity?

These ideas include the following:

a. We test turbidity to measure the amount of suspended/floating particles in water. These particles cause the water to be murky so turbidity provides information of how clear or the clarity of the water. Low turbidity is best for waterways.

b. There are many causes of turbidity. Any particles that do not dissolve contribute to turbidity. Nature provides some suspended particles. However, some particles enter water because of human activity on the land.

    a. Dirt, that runs off from construction sites or from erosion caused when people cut down trees etc. is a major cause of turbidity. The water looks dark.

    b. Organic waste: dead leaves, plants etc. floating in the water

c. Human waste from leaking septic tanks and animal waste from not picking up after your dog or from ducks/geese that congregate near water because people feed them.

d. Algae/other tiny plants in water (if fertilizer runs into water causing an algal bloom). The water looks a pea-green color.

e. Urban waste from cities: litter, car oil, etc. Anything that does not dissolve.

f. Industrial waste: waste from factories that do not dissolve.

Teaching extension: What are microbeads and why are they illegal? Microbeads are tiny plastic particles that have been put in various products such as facial scrubs and toothpaste. Environmental groups worked to ban them. Visit this Popular Science site to learn more: https://www.popsci.com/what-are-microbeads-and-why-are-they-illegal

c. There are several consequences of turbidity:

   a. Floating particles in the water absorb heat and can result in thermal pollution:

      i. Connect thermal pollution with the turbidity measure. You may want to ask students if they can make a connection between the two water quality measures.

      ii. Connect dissolved oxygen with turbidity and thermal pollution. Again, ask students if they can make connections between the water quality measures. Warm water can hold less oxygen.

   b. Floating particles block sunlight. Water plants cannot photosynthesize without the sun. This also impact dissolved oxygen level.

   c. Floating particles can sink and smother fish and insect eggs.

   Note: Floating particles are not only on top of the water. Turbidity pertains to all particles that do not dissolve. Therefore, these particles could float on top of the water, be suspended in the water, or sink to the bottom of the water.

   d. Floating particles can clog fish gills. Fish use their gills to obtain oxygen from water and to allow carbon-dioxide to pass out.

   e. Turbidity is indirectly related to conductivity. When dead matter is in the water (dead leaves, animal waste, etc.) it initially is solid and is not dissolved. Through decomposition the dead matter breaks down and nitrogen and phosphorous are released. These nutrients dissolve.

Teaching extension: This is an opportunity for you to ask students to generate ideas of action steps that they and others can take to decrease the possibility of unintentionally contributing these pollutants. Ideas include putting up retention fences around constructions site so that when it rains, loose dirt is trapped. Raking dead leaves away from storm drains to prevent them from getting into waterways and providing floating particles. Picking up after dogs or avoiding the practice of cutting vegetation near waterways also decreases organic waste.

Next, introduce water quality standards to students:

2. Water Quality Standards: Just as with the other water quality measures, water quality experts developed water quality standards for turbidity using the terms excellent, good, fair, and poor to identify if fresh waterways have too much or acceptable levels. Excellent and good indicate that there are low levels of turbidity in the stream with excellent being better than good. Fair and poor indicate too many suspended particles meaning the results are problematic for streams, with poor being worse than fair.

Since there are several different ways to measure turbidity there are also different units. Use the table below to identify the units and standards based on the way you measure turbidity.

Turbidity Standards:

Turbidity Water Quality Standards	Turbidity probes NTU's:	Secchi disk or Turbidity Tube	Engineered filtration system
Excellent – no (or very little) turbidity, not too many floating particles	0-10	➢ 3 feet ➢ 91.5 cm	1 = none or very little turbidity
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2. Data collection procedure for turbidity probes, turbidity tubes, or Secchi Disk (if you are going to design your own data collection equipment skip to #3). (~10 min)
Purpose: Demonstrate how to use the various instruments to collect turbidity data.

Show students, step-by-step the procedure that they will use to collect turbidity data. Next, match up your collect data with the correct units from the turbidity standards. Skip to Number 4.

3. Design Challenge: How can we collect turbidity data? (This optional activity may add one additional day to the curriculum)

Purpose: Students design and build a device to capture floating pollutants that allow them to collect, analyze and interpret turbidity data.

Stress to students that all of the water quality equipment and procedures were invented by someone at some point in time; that's what scientists do! What that means is that we can also invent a design and build our own turbidity measuring device.

You may have students work with a partner or small group to brainstorm ideas of how to capture pollutants. This could include having students draw and label a picture as well as writing a procedure. You may want to provide students with some constraints prior to their discussion. These include having students think about 1. How to obtain water samples, 2. What procedures they will follow to ensure that they control variables (do everything the same), 3. What materials they will need. 4. Students need to generate ideas that are safe and feasible. Great ideas that are impractical or unsafe are not useful. 5. Another consideration is to determine if all groups should follow the same procedure.

Once student groups generate ideas, guide a class discussion where groups share their ideas. Ask students to look for common ideas across the groups. Build on students' ideas. Help students to think about possible advantages and disadvantages or possible challenges in the designs.

One possible design: Students could use coffee filters and place them into tennis cans to create a well. Wrap the edges of the coffee filter around the outside of the tennis can and secure with a rubber band. Students could obtain a sample of water from their water source and pour the water through the coffee filter. All students should get the same amount of water (perhaps a cup filled ¾ full) that they scoop from the stream. Students should avoid scooping the bottom of the stream. Once the water has completely filtered through the coffee filter students remove the coffee filter to observe the amount of floating particles. They decide if there are none/very few (excellent), low (good), medium (fair), or high (poor) number of particles. They can compare their results. This design/procedure is a little subjective, but it is a measure of turbidity.

You and your students may come up with additional designs.

4. Concluding the lesson (2-3 min)
Ask students whether we are hoping for high, medium, or low turbidity readings. Low readings would be the best for the stream.

Let students know that tomorrow we will test the turbidity levels of the stream (or whatever phenomenon you are using). If going outside, remind students to dress appropriately for the weather.

Homework: Students will write a turbidity prediction. (~5 min)

Predictions will include four parts:

- A turbidity amount (high, medium, low, none or a number) based on how the test is conducted
- The standard for their prediction (Excellent, good, fair, or poor)
- A statement about the consequence (not too many or too many floating particles) that matches the standard.
- At least one reason for their prediction (based on science ideas from the Student Reader).

Here is an example:

I predict the stream will have high turbidity. This is poor according to water quality standards so there will be too many floating particles. I'm predicting this because there is lots of erosion near the stream so loose dirt will be floating in the water.

You will decide if students will write their prediction in a notebook, on paper, or using a computer.

<u>INSTRUCTIONAL SEQUENCE: Day 2</u>

1. Investigating the turbidity of the stream (~30-45 min)

Purpose: Collect the fifth piece of water quality data: turbidity.

Begin by asking students to share their predictions. Another option is to collect data first and then share predictions. Review instructions for data collection (These will depend on which type of instrumentation you will use). If students designed filtration devices they will need to prepare them. Below is one possible data table for students to use. The first column will depend on which data collection device students use. Units may need to be added.

You can decide if students will do three trials and get an average or if they will complete one.

Turbidity

Amount of turbidity	Standard	Observations that could impact the stream's turbidity
		<u>In the water</u>: <u>Near the water</u>: <u>Recent weather:</u>

2. Engaging in sense-making: Sharing and discussing turbidity results (~5-15 min)

Purpose: Students share data to look for discrepancies and patterns in the data.

You may want student groups to write their results on the board. Students may work in groups to focus on these questions:

- According to your results is the stream's turbidity level healthy for organisms? Are there too many floating particles?
- What water quality standard do your results convey (excellent, good, fair, or poor) for turbidity?
- If there are too many floating particles, what do you think could be the causes (have students look at what causes turbidity)
- Based on your results what are the possible consequences? Use your science notes to help.

This may be followed up with a class discussion. Looking for causes and consequences and patterns are important crosscutting concepts that will also assist students in learning important science ideas as they analyze their data. Stability and change is another important crosscutting concept, particularly related to excess organic waste that was the result of human activity of using fertilizer in agriculture and home gardening and lawns.

Students should now fill in the comprehensive data table that is provided for them to record data from all of the of the water quality tests that they conduct during the project.

Water Quality Test Results
How Healthy is our stream for freshwater organisms?
How do our actions on land potentially impact the water?

Organize your results from all of the water quality tests into one data table below. Notice the far right column labeled *Observations*. Record any information that you may have observed in or near the water that might help you determine what caused the results you obtained for that test.

Name of Water Quality Test	Results	Water Quality Standard	Observations
pH			
Temperature Difference			
Conductivity			
Dissolved Oxygen			
Turbidity			

Concluding the lesson: (2 min) This concludes the two-day lesson on turbidity. Remind students that turbidity is the fifth water quality measure they will be investigating. Ask if they can feel confident to make an overall conclusion about the stream's health for supporting organisms. You may again relate this back to the basketball analogy that was introduced in Lesson 2 (Instructional sequence #4). Would seeing that the person was a good free-throw shooter, dribbler, passer, defender and if she's a team player, be enough evidence that she could succeed as a college basketball player? Certainly, having five pieces of evidence provides a strong "picture" of the stream system. Relate back to the driving question. We're investigating "Is our stream healthy for freshwater organisms and how do our actions on land potentially impact the stream? We now have a variety of evidence from water quality measures that provide us with a picture of the streams overall health for organisms. Let students know that we will now evaluate all of the evidence to answer our driving question. We will expand our models to assist us in the process.

Homework: None

LESSON
#10

Lesson question: Is our stream healthy for freshwater organisms and how do our actions on land potentially impact the stream?

Overview: This lesson is the concluding lesson of the unit where students add dissolved oxygen and turbidity to their existing models. They use their final models to respond to the driving question for the unit, "Is our stream healthy for freshwater organisms and how do our actions on land potentially impact the stream?"

The model should illustrate relationships between all of the water quality measures and water quality for organisms. Some of the water quality measures are related to other water quality measures. This final model will now portray pH, temperature differences, conductivity, Dissolved oxygen, and turbidity as five variables that impact water quality.

Students are now answering the driving question - Students are figuring out that all 5 variables, the various water quality measures, impact the stream water quality and that these will impact organisms.

Additionally, they should see that temperature, DO, turbidity and conductivity have some relationships.

NGSS Performance Expectation: PE: MS-LS2-4, PE: MS-LS2-1, PE: MS-ESS3-3

Learning Performances:

LP7: Students develop a model based on human activities in agriculture, industry and everyday life can have major impacts on rivers, to illustrate cause and effect relationships, that small changes in one part of the system (the stream phenomenon under study) might cause large changes in another part of the system, and that stability might be disturbed either by sudden events or gradual changes that accumulate over time.

Safety Guidelines: None

Preparation: Students models need to accessed.

Time: 2 days (possibly 1 day)

Materials: A main computer and projection device. Computers for each group.

INSTRUCTIONAL SEQUENCE

1. Revising models of our stream – adding new evidence (~20 minutes)

Purpose: Students will revise their initial water quality models by adding dissolved oxygen and turbidity.

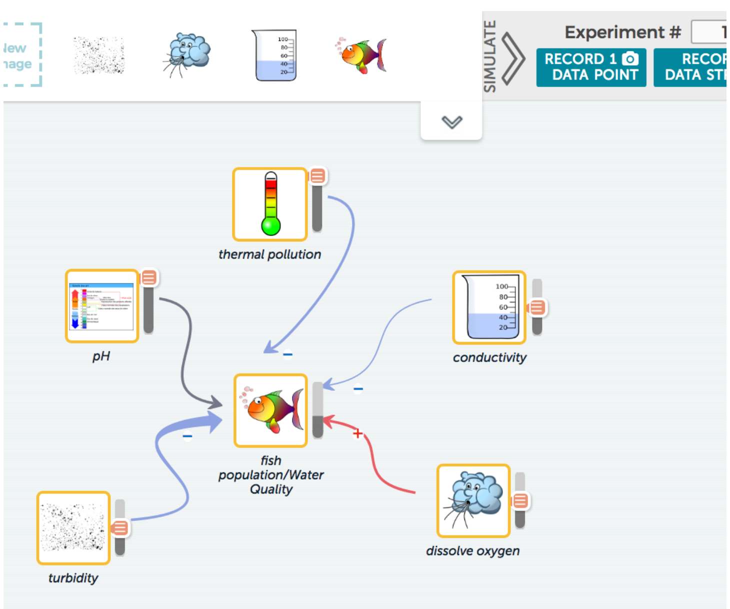
Click the button to launch SageModeler to revise your model of the water quality of the stream based on FIVE pieces of evidence: pH, temperature differences (thermal pollution), conductivity (dissolved solids), dissolved oxygen, and turbidity.

SageModeler Button text: How healthy is our stream based on five pieces of evidence: pH, temperature differences, conductivity, dissolved oxygen, and turbidity?

- Find pictures to represent the variable of conductivity and label it.
- Draw links between variables you think affect each other.
- Set the relationships between those variables.

Allow students to begin to work to incorporate dissolved oxygen and turbidity into their models. Encourage students to use the data from the water quality test. As well, students can refer back to the student readers and/or notes taken during class. Move from group to group. Some groups will need more support than others. Encourage students to help each other. Some groups will work faster than other groups. Once they get their models working in the way in which they think accurately portrays the phenomenon, they can expand their models to include the causes for change in oxygen and turbidity levels; these are the variables that influence the water quality test (which in turn affect the water quality of the stream).

Here is a possible final basic model that students might develop. They may choose a different icon than the ones here and that is fine



<iframe width="398px" height="313px" frameborder="no" scrolling="no" allowfullscreen="true" webkitallowfullscreen="true" mozallowfullscreen="true" src="https://codap.concord.org/releases/latest/static/dg/en/cert/index.html#shared=22247"></iframe>

Students can now “Use” their models by running a simulation. They can use the table or graphs or a combination of the two to test, evaluate, revise if needed, and re-test their models.

Below are possible questions that students can respond to that may assist them to think more deeply about their models:

1. What did you change in your most recent model?

2. What were your reasons for making these changes?

3. Do the changes you made in your model help respond to the driving question better? Why / why not?

4. What are you still uncertain about in your model?

Students will continue to work on their models during class tomorrow. Some groups will also share their models.

3. Sense-making opportunities: Critiquing models:

Purpose: To have students evaluate their models to see if they “work” the way that think they should work.

Remind students that SageModeler has no content and they can develop models that “work” but do not accurately reflect the phenomenon. It is the responsibility of the students to evaluate their models. This process should further foster students learning about important science ideas, crosscutting concepts, and the practice of modeling. Students can use their notes when developing their models. There are several possibilities including the following suggestions:

1. Using their models to predict water quality: Encourage students to use the sliders to put them to the position where the water quality should be the best. Ask them where they should put the sliders? (for pH the slider should be in the middle - 7)l for thermal pollution and conductivity the slider should be the lowest (the lowest temperature differences are the best). In this way, students are predicting that the water quality will be high. Students can now run their models to see if their predictions match.

    a. If they match, then students might evaluate that their models work.

    b. If they don’t match students should think about why their is a mismatch. Do they need to adjust their models? Do they need to rethink their understanding of the science concepts?
2. Observe what happens as they change one variable to see if it matches their thinking. Does the change in that variable effect the water quality they way that they think it should?

3. Check all parts of the model. Test, evaluate, revise if needed, and retest.

Just as in the prior modeling classes, If a group or two completes their model, including running it and making sure it works the way that they think is accurate, you can have them expand their models to include the various causes for each of the water quality tests. These will be the variables that affect conductivity. Encourage students to use the student readers to assist them. Students can choose images and define relationships between these. It is not expected that all (or any) students develop models at this level of sophistication. This is enrichment for groups who need it.

4. Sharing/Discussion (~10-20 min)

Purpose: Sharing and critiquing student models is extremely valuable. It fosters a community of learners and assists students to see connections between ideas. It also allows students to see how different groups have modelled the stream phenomenon.

Either request volunteers to share their models with the class or ask a couple of groups. You can display models for everyone to see. Groups should talk through their models and explain the variables and their relationships to water quality (fish population). They should run their models, using either the graph tool or the simulation tool. They can move the toolbars for the variables to show how the water quality is impacted.

As a class, they can discuss if the model "works" and provide any feedback to the group, including any suggestions they might have to improve the model.

Summary: Models are meant to assist us in explaining phenomenon. Ask students what conclusions they would make about the overall health of the stream based on all of the evidence. Again, this can be done first in small groups and then in a class discussion. Ask students to include an overall statement (the stream is very healthy, somewhat healthy, not very healthy, very unhealthy etc), a water quality standard (excellent, good, fair, or poor), and reasons.

Have a discussion to see if the class can come to consensus. This assumes that students' evidence from all three water quality tests were similar. If they were not similar, then a discussion to support your statements should follow. Students could illustrate their ideas with their models by placing the the bars at the places where they data falls.

Concluding the lesson (2 min)
This concludes day two of the two-day lesson as well as the entire unit. Remind students that the stream is a complex system. You may refer back to the analogy of the basketball player and collecting several pieces of evidence to make a more confident determination of her level of play.

Probe student understanding, not only of the science ideas and their answer to the driving question, but also of the nature of science. These ideas include that scientists work to explain phenomena in the natural world and how they go about explaining phenomena is to begin by gathering evidence. Any explanation of phenomena and conclusions made about phenomena should be based on evidence. Developing models is one way to systematically analyze these data, to look for cause and effect relationships and patterns to explain phenomena, in this case a complex system - the quality of a stream (or whatever waterway you investigated) for supporting life.

<u>Overview of Water Quality Unit</u>

The driving question for this middle school unit is, "How healthy is our stream for freshwater organisms and how do our actions on land potentially impact the stream and the organisms that live in it?" This project-based science unit utilizes three-dimensional learning envisioned by the Framework for K-12 Science Education (2012) and further articulated through the Next Generation Science Standards (NGSS Lead States, 2013). It builds towards several performance expectations, integrates DCI's from life and earth science, several crosscutting concepts, and many scientific practices, including the use of modeling. Students actively engage in investigation to figure out the health of a stream or other freshwater body of water as they develop deep understanding of the phenomenon. Throughout the unit, students are engaged in practices such as asking questions, designing and carrying out investigations, analyzing and interpreting data, and developing models. A major focus is supporting students in understanding several crosscutting concepts -- cause and effect relationships, stability and change, and systems -- that are integrated throughout the unit. A summary of the unit's 3-Dimensional Learning Ideas from the Framework/NGSS as well as the performance expectations that the unit builds towards are below in Table 1 and Table 2.

In this unit students collect pH, temperature, dissolved solids (conductivity), dissolved oxygen, and turbidity data at a local creek, stream, river or pond. In this authentic context, students use this real-time data as evidence to create a model that they revise, over time, as more data is collected. Model building assists students to systematically analyze these data, to look for cause and effect relationships and patterns to determine the quality of the stream for supporting life. Modeling complex phenomena, like the water quality of streams, can support students in developing integrated understanding of content as well as in building understanding of the practice (Mayer & Krajcik, 2015). There are many causal relationships, so it is an ideal phenomenon for students to model. Students can also use their models to predict water quality if changes happen within the system.

Adapting and personalizing your water unit

This curriculum is flexible! You have options to adapt this curriculum in three areas: personalizing the curriculum to your local community and your access to a body of freshwater, access to technology tools and/or water quality test equipment, and the amount of time you have available to enact the unit.

First, you should personalize and situate the unit to your community. Students are always more motivated to learn when the curriculum is made meaningful and important to them. Set a context with a waterway and water issues in your community. There may be water issues right in your local community, a nearby community, or in your state. You may live in a water-rich area or a water-scarce area. You may have a stream or a pond within walking distance of your school. Your stream or river (any freshwater body) may be a bus ride away. You may not have ready access to a freshwater body and may need to bring in containers of water from your local water source that you investigate inside your classroom.

The second area of adaptation is related to technology. This curriculum engages students in using five water quality measures to investigate a freshwater stream. You may have scientific probes. You may have water quality kits. You may only have thermometers and pH paper. You may have these tools for all of your students or a limited amount. This unit can be adapted and provides suggestions for classrooms with varying data collection tools.

The third area of flexibility is time. In this unit, students collect five pieces of evidence, over time, in order to figure out the water quality of the stream. The stream is a complex system with many components. Students use evidence from the various water quality measures, over time, to build and revise a model of the water system. If you have time constraints or equipment constraints you can do three or four of the water quality measures. You may also expand this unit to include additional water quality measures that are not in this unit.

Regardless of your situation you can utilize this unit, adjust it to fit your needs, and engage your students in investigating and explaining freshwater phenomenon using 3-dimensional teaching and learning.

Table 1: Performance Expectations Water Curriculum builds towards (Framework/NGSS)

MS-LS2: Ecosystems: Interactions, Energy, and Dynamics	MS-ESS3: Earth and Human Activity	MS-ETS1: Engineering Design*
Students who demonstrate understanding can:	Students who demonstrate understanding can:	Students who demonstrate understanding can:
· MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. · MS-LS1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.	MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	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 nature environment that may limit possible solutions.

*A design opportunity is an optional activity in Lesson 9

Table 2: Water Unit's 3-Dimensional Learning Ideas from the Framework/NGSS

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Practice 1: Asking Questions and Defining Problems. Practice 2: Developing and using models Practice 3: Planning and carrying out investigations Practice 4: Analyzing and interpreting data Practice 5: Using Mathematics and Computational Thinking Practice 6: Designing Solutions Practice 7: Engaging in argument from evidence Practice 8: Obtaining, evaluating, and communicating information	MS-LS2 Ecosystems: Interactions, Energy, and Dynamics LS2.A: Interdependent Relationships in Ecosystems · Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with non-living factors (MS-LS2-1) · Growth of organisms and population increases are limited by access to resources. (MS-LS2-1) LS2.C: Ecosystem Dynamics, Functioning, and Resilience · Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4) · Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. (MS-LS2-5)	1. Patterns. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them. 2. Cause and Effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multi-faceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Connections to Nature of Science: Scientific Knowledge is open to Revision in Light of New Evidence	MS-ESS3 Earth and Human Activity ESS3.A: Natural Resources · Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geological processes. (MS-ESS3-1) 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. (MS-ESS3-3) · Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3), (MS-ESS3-4)	4. Systems and system models: Defining the system under study- specifying its boundaries and making explicit a model of that system- provide tools for understanding and testing ideas that are applicable throughout science and engineering. 7. Stability and change. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.
	MS-ETS1: Engineering Design* ETS1.A: Defining and Delimiting Engineering Problems The more precisely a design tasks' criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes considerations of scientific principles and other relevant	

	knowledge likely to limit possible solutions. (MS-ETS-1)		

Name:________________________________

pH Lab set-up and experimental procedure

A famous science book publisher has hired you to design and write a lab set-up and procedure for conducting a lab that investigates the pH of various substances that can get into streams. In addition, she also wants you to create a data table where students will record their data.

What are the directions you will write to teachers to set up the lab? What procedure will students follow, step by step, during the lab? Write the lab set-up and lab procedure below.

<u>Lab set-up</u>:
(Directions to teachers)

<u>Lab procedure</u>
(How to conduct the lab)

A. Initial ideas

B. Lab Set-up

(OVER)

What will your data table look like? Draw a "sloppy copy" empty data table below.

Name:________________________________

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B. Lab Set-up

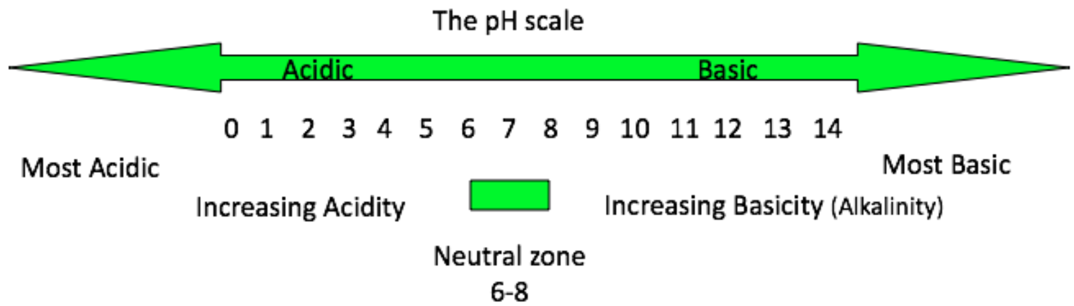
Lab procedure
(How to conduct the lab)

(OVER)

What will your data table look like? Draw a “sloppy copy” empty data table below.

Are everyday products people use outside acidic, basic, or neutral?

We know that products we use on land can run downhill into storm drains or down a hill and end up in streams. If we test the pH of everyday products it can help us to understand why we might get the pH results when we go out to the stream to test for pH. Fill in each box. Use the pH scale provided to help you with your predictions and results. An example is provided.



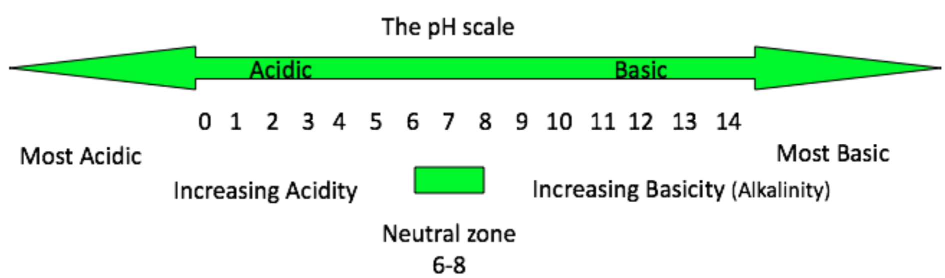
pH Data

Substance	Prediction pH# and acid, base, neutral	Results Trial 1	Results Trial 2	Results Trial 3	Result Ave	Result: Acid, base, neutral
Antifreeze	4 weakly acidic	8.9	9.1	9.1	9.0	Weakly basic

Is the stream acidic, basic, or neutral? pH as a measure of Water Quality

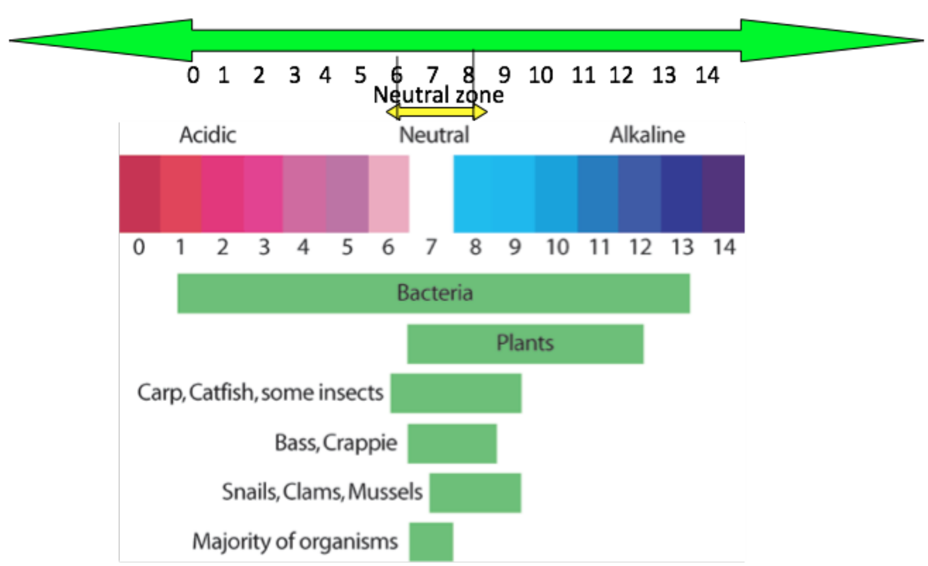
What does pH measure?

pH is a water quality measure that determines if a stream, river, or any body of water is acidic, basic, or neutral. Look at the pH scale below and you'll see that it runs from a value of zero, which is very acidic, to 14, which is very basic. Right in the middle is 7, which is neutral.

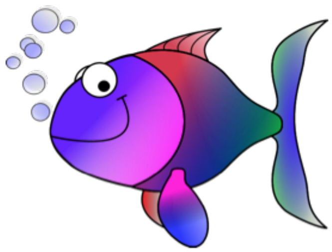


Credit: Ann M. Novak

What is the pH range that is the best for freshwater organisms - the pH range that is the best for the majority of organisms? To find out, look at the chart below. Read the types of organisms and line them up with the pH scale. (students need a small box to put their response).



Do you see that the majority of freshwater organisms need a pH between 6.5 and 7.5? This is the best pH range for freshwater organisms and would be considered <u>excellent</u> water quality for pH. Examples of organisms that need this pH range in order to live include trout, mayfly nymphs, stonefly nymphs, and caddishfly larvae.

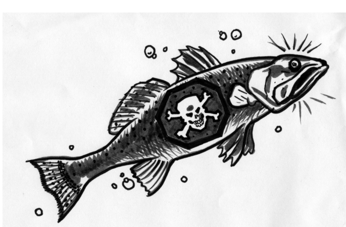
	URL: https://openclipart.org/detail/2707/happy-fish Credit: Machovka License: Public Domain

Many other organisms can live in a pH range that falls between 6–8 on the pH scale. This is called the *neutral zone* for freshwater organisms. It's a pretty healthy pH for water and would be considered *good* water quality, even though 6.5-7.5 is the best. Look back at the pH scale. Do you see that 6-8 is labeled as the neutral zone? When we test the water quality of a river or stream (or any freshwater body) we hope that the pH is either excellent (pH between 6.5-7.5) or good (pH between 6.0-6.5 or 7.6-8).

What happens when the water's pH becomes more acidic or basic? Write down your guess.

(small box for student response here)

If something causes a stream to become either too acidic or too basic, the organisms that need a more neutral pH will die. The water is no longer healthy for them. For example, trout, mayfly nymphs and stonefly nymphs need a pH range between 6.5-7.5. Bass and Crappie would also die; they need a pH between 6-8.5. Remember, most organisms need neutral pH.

	URL:https://www.flickr.com/photos/apeshot/9019017468/in/photolist-eJYPFb-79gJse-aVyxQn-6FChTi-5gUXSk-89G1qK-786A7r-idfDxA-duTeka-djVJWa-dLco5X-eVE6TL-cSHspN-p7NhiT-jUVget-orK2ad-4hTJau-owdbiX-ovgPia-a484nX-7EeeEQ-owXki6-z32oUp-7qknZ3-2VuU7z-otkGM9-owhuMq-ocadJf-9i2xth-ow4HHZ-oeUoWb-4pny3Q-tf1NWw-83FdwQ-8fiA77-4hTKdE-9AFQ1k-ba75qK-93bkEi-a3m5Gj-daNBR9-GUMJHC-afbq3p-ry5k5p-9DNCxB-nVazPY-hyRZat-dvgtDC-oy6Gjn-re3kVo Credit: scottapeshot License: Common Domain

Look back at the pH chart. What organism can live in the largest range of pH? What is the pH range? What other types of organisms also have a large pH range? What is the range? (students need a box to put their response).

Reading the chart, you should see that bacteria can survive in a pH range from 1-13. This is a huge range - bacteria are very hearty organisms! Plants can live in a pH range between about 6-12 or 13.

What *causes* pH to become acidic or basic?

People use products on land and do various activities outside that can end up causing a stream to change its pH. How can this happen? If someone puts fertilizer on their lawn, when it rains, the fertilizer can get picked up with the rain and then be carried by the rain downhill into the nearest water. If someone has a car wash, the car wash soap

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will run downhill and into a storm drain. Did you know that storm drains are connected underground to pipes that flow directly into streams, rivers and lakes? LOTS of people use fertilizer and wash their cars.

	*Credit*: Ann M. Novak

People use lots of other of products outside: soaps, windshield wiper fluid, antifreeze. We wash our driveways with a garden hose using tap water or we water our lawns with a sprinkler system. Tap water is water that is treated with chemicals to make it safe for people to drink. Those chemicals in tap water, along with products people use outside on the land can have an acidic or basic pH.

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If they run-off the land, either through storm drains or downhill on land, they can enter various waterways and change the pH. This can happen even if we live far away from a body of water. Many farmers also use fertilizer and pesticides that can run off into water. So do many people who take care of golf courses. Acid rain can also change the pH of water. Pollution from automobiles and coal-burning power plants can enter the air and interact with moisture and oxygen to form acid rain. The acid rain can enter the streams and lake and change the pH to be more acidic. All of these, use of fertilizer, car washes, and acid rain, and lot of other activities people do outside can cause the pH of freshwater to become either acidic or basic.

Water Quality Standards

Remember earlier that we said 6.5-7.5 pH range is excellent and that just below or just above these numbers in the neutral zone are good? A group of scientists got together and developed National Water Quality Standards for freshwater lakes, rivers, and streams (Stapp, & Mitchell, 1995). They used four categories for all water quality test results. They are *excellent*, *good*, fair, *or* poor. If a water quality test falls into the *excellent* or *good* range for water quality standards, the stream is considered healthy for freshwater organisms with *excellent* being better than *good*. If, on the other hand, the test results match up with *fair* or *poor* water quality, the stream has problems related to supporting freshwater organisms with *poor* being the most problematic.

Here are the pH water quality standards:

pH Water Quality Standards	pH Range
Excellent - neutral	6.5-7.5
Good - neutral zone	6.0-6.4 or 7.6-8.6
Fair - too acidic/basic	5.5-5.9 or 8.1-8.0
Poor - too acidic/basic	Below 5.5 or Above 8.5

When you test your stream or river for pH, what results are you hoping to get? Can you explain why? Can you include some examples of organisms and pH ranges they need in your response? (students need a box to put their response).

Water Quality Test Results
How Healthy is our stream for freshwater organisms?
How do our actions on land potentially impact the water?

Organize your results from all of the water quality tests into one data table below. Notice the far right column labeled *Observations*. Record any information that you may have observed in or near the water that might help you determine what caused the results you obtained for that test.

Name of Water Quality Test	Results	Water Quality Standard	Observations

How healthy is our stream for freshwater organisms and how do our actions on land potentially impact the stream and the organisms that live in it?

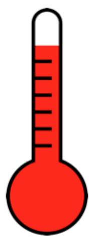
Table of Contents

"Is the stream too warm for freshwater organisms?

Temperature as a measure of Water Quality

Why do we measure temperature of streams?

We are all familiar with temperature. Temperature tells us how hot or cold something is. The temperature of a stream or river can change. If you live in a northern climate, the water's temperature will be different in the summer than it will be in the winter - that's normal. At the same time of year, the temperature of rivers and streams in the south, like in Florida or Texas, will be different than temperatures in rivers and streams in the north, like in Michigan or Alaska - that's normal too. Climate and the seasons naturally affect the temperature of the water.

	URL: https://openclipart.org/detail/218124/thermometer Credit: Bartovan License: Public Domain

When we measure for temperature we are trying to determine if the temperature is **abnormally warm** - we're looking for an abnormal temperature increase. For example, we would expect the temperature of waters in Canada to be cool in the winter. If we measure temperature of a river and find it to be hot we would be surprised. We might think, "something isn't right here" and need to investigate further.

An abnormal temperature increase is called **thermal pollution**. It is a very different type of pollution than what we usually think of, because a change in temperature isn't "stuff" that got into the water causing it to be polluted.

How do we measure for thermal pollution?

When experts test for thermal pollution, they take a temperature reading at two different locations that are a mile apart. They then subtract to obtain a temperature difference. They look to the water quality standards for temperature differences to see if there is thermal pollution.

Here are the water quality standards for temperature differences, or thermal pollution:

Thermal pollution Water Quality Standards	Temperature differences degrees Celsius
Excellent - no thermal pollution	0-2^0 Celsius change

Good - no thermal pollution	2.1-5^0 Celsius change
Fair - thermal pollution	5.1-10^0 Celsius change
Poor - thermal pollution	above 10^0 Celsius change

What are the causes of Thermal Pollution?

Think about this:

> It's a hot summer day and you want to go swimming. You throw on your suit, grab a towel, and jump into your car and an adult takes you to the pool. You were in such a hurry that you didn't put anything on your feet. Now, you get to the pool and pull into the parking lot and park. You leap from the car and, "Ouch! Ouch! Ouch!" Your feet are burning up because the parking lot is SO hot! You rush to the grass and "whew! - that feels so much better!" - the grass feels cool.

There are four causes of thermal pollution. One cause of thermal pollution is **hot surfaces**. Human-made parking lots, roads, even rooftops heat up when it's hot outside. If it rains, the rainwater hits these hot surfaces. The rainwater now also becomes hot. Do you remember where rainwater goes? It goes downhill to the nearest storm drain. Do you also remember where the water in storm drains go? It flows into nearby creeks, streams, rivers and lakes. This now **hot** rainwater then flows into the water and heats it up, causing thermal pollution, an abnormal temperature increase.

	URL: https://openclipart.org/detail/15567/open-road Credit: IncessantBlabber License: Public Domain

A second cause of thermal pollution is from factories that produce products we use everyday, other industries, and power plants. They pull in water from a river or lake and use it to cool their machinery. The water warms up as it cools the hot machines. If this hot water is then discharged back into the river or lake then it warms up, causing thermal pollution.

	URL: https://openclipart.org/detail/23962/factory Credit: Anonymous License: Public Domain

A third cause of thermal pollution is soil erosion or other macro particles that are in the stream. Erosion can be caused when people cut down trees because the roots hold soil in place and without the roots allowing for this stability, erosion can occur. It can be caused during construction

	URL: https://openclipart.org/detail/210414/misc-proto-dirt-pile Credit: Glitch License: Public Domain

when people dig holes in the ground and loose dirt is put in piles. Poor farming practices can result in loose dirt; all of this loose dirt can be carried into rivers and streams when it rains. Whether from cutting down trees, construction, or from farming, soil that runs into water causes the water to become muddy (turbid). Dark water captures more heat from the sun and the water heats up. This can be a huge problem in the summer when the sun feel so hot. These dark particles absorb the energy from the sun.

A fourth cause of thermal pollution occurs when people cut down trees along a riverbank or pond. Trees help to shade the river from the sun. Without the trees to provide shade the sun shines directly on the water and it warms up.

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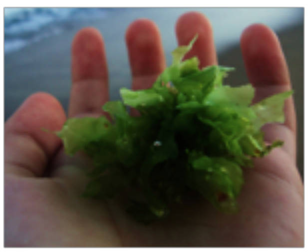
What are the effects (consequences) of Thermal Pollution?

Water temperature is very important for the health of a stream or river. There is a negative relationship between thermal pollution and water quality for freshwater organisms. Fish and other aquatic organisms live in certain temperature ranges. If water is too warm they die. For example, trout and stonefly nymphs need cool temperatures. Organisms' dying is one of four consequences of thermal pollution.

	URL: https://openclipart.org/detail/173960/fish Credit: acvarium. License: Public Domain

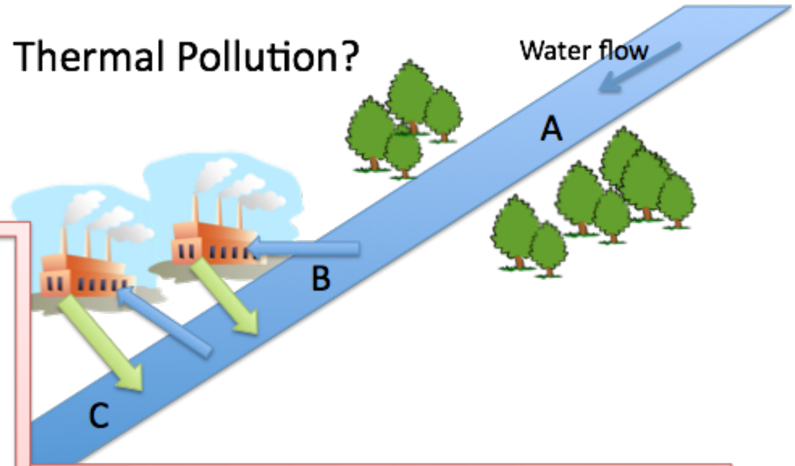
A second consequence of thermal pollution is that warm water can promote an algal bloom. Warm water increases the rate of plant growth and plants, like algae, can thrive. When these plants die they

	URL: https://www.flickr.com/photos/-oiboi/6675894731/in/photolist-baVGVi-bW81yL-8mXPXG-q4rqTM-okR53B-mh6dq-524K9Q-xUAhTc-9WGo3P-aeEYXU-bKMkcg-v3nVr-aj7ocA-9ksVH9-5bePRy-nKqJs9-qu7XG-2j76aA-52NtW3-3Mpx5o-4qAHYh-og7VMz-GcEcD-PmYMf-8EQfkd-9Z9QvD-gyoCY-jBocn7-qK5CNB-2t7Fnc-mcjwFm-6Kx9JN-dVoFmM-CuE4x-76Kxgp-8Dzofi-jBnaGd-86xEQg-aDJ5jX-6o3DvX-acZzua-xLTzY-8d187E-9kmCSa-WYsf3-j16hj-bjMPe1-qr16y5-5YL3dY-ogHn16 Credit: Ana Banderchuk License: Common Domain

are decomposed by bacterium. The bacteria use up the oxygen. Third, warm water cannot hold as much oxygen as cold water so a third consequence of thermal pollution is the potential for less oxygen. Finally, thermal pollution can weaken fish and insects and make them more vulnerable to disease and toxic waste.

Use the picture, the thermal pollution standards, and causes of thermal pollution to help you answer the following questions.

Thermal Pollution?



At Point A of a stream the temperature reading is 11.8 degrees Celsius. At Point B, father down the stream, the temperature reading is 12.8 degrees Celsius. What can you say about the water quality at Point B based on the temperature test? How do you know? What might be the reason for these results? Show all of your work.

At Point B of a stream the temperature reading is 12.8 degrees Celsius. At Point C, farther down the stream the temperature reading is 20.2 degrees Celsius. What can you say about the water quality at Point C based on the temperature test? How do you know? What might be the reason for these results? Show all of your work.

Are there too many floating particles in the stream?
Turbidity as a measure of Water Quality

What is turbidity and why is it important?

Did you ever see water that was so dirty that you couldn't see through it? Turbidity measures the amount of floating particles in water that cause the water to look murky. Floating particles, whether on top of the water, throughout the water, or sitting on the waterbed, do not dissolve. Water that is not turbid is clear. High turbidity in freshwater lakes, rivers, and streams means poor water quality.

What causes high turbidity?

There are many different types of particles that float in water. Dirt is a very common cause of high turbidity. Dirt in the water can be the result of two different activities that people do on land. One, when people build houses, apartments, or other buildings, part of the building process often includes digging a hole for a basement or for underground parking. Mounds of dirt can sit at a construction site.

	URL: https://openclipart.org/detail/210414/misc-proto-dirt-pile Credit: Glitch License: Public Domain

When it rains, the rainwater can pick up the dirt and carry it downhill into streams, rivers, or lakes, or it can first go to storm drains that have pipes that are connected to these waterways. Preventing stormwater pollution is a component of the Clean Water Act (http://www.epa.gov/region5/water/cwa.htm) passed in the United States in 1972. Do you have any ideas of how this dirt run-off might be prevented?

(Students need a box to put their response)

Did you ever see two-foot fences around a construction site? These silt fences are one solution that the construction industry came up with to help ensure that dirt would not run-off from construction areas. The solid mini fences capture dirt by acting as a barrier. They work to prevent dirt run-off.

A second source of dirt is from erosion. Plants have roots that hold the soil in place. If people cut down trees or other plants the result can be loose soil. Just like from construction sites, loose dirt anywhere be picked up by rain and be carried into waterways. Have you ever seen how rivers turn brown after a heavy rain? One solution to erosion is to make sure to plant grass or other plants that will hold soil in place.

There are many other particles that float in the water besides dirt. Organic waste – dead leaves, plants, etc., animal waste and algae or other tiny plants are examples. Human waste, either from leaking septic tanks or from discharge from wastewater treatment plants can contribute to turbidity. Floating particles also come from urban run-off including car oil, litter, etc., and from industrial waste.

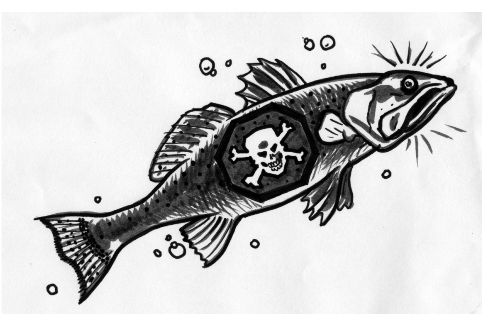
Look back through the causes of turbidity and identify which ones are the result of people and which ones are from nature?

(Students' need a box to put their response)

What are the consequences of high turbidity?

Why is high turbidity a problem? There are four consequences to the water quality of a stream if it has high turbidity.

First, floating particles in the water absorb heat. This can lead to thermal pollution. Remember learning about thermal pollution in Lesson 4? Thermal pollution can kill fish.

	URL:https://www.flickr.com/photos/apeshot/9019017468/in/photolist-eJYPFb-79gJse-aVyxQn-6FChTi-5gUXSk-89G1qK-786A7r-idfDxA-duTeka-djVJWa-dLco5X-eVE6TL-cSHspN-p7NhiT-jUVget-orK2ad-4hTJau-owdbiX-ovgPia-a484nX-7EeeEQ-owXki6-z32oUp-7qknZ3-2VuU7z-otkGM9-owhuMq-ocadJf-9i2xth-ow4HHZ-oeUoWb-4pny3Q-tf1NWw-83FdwQ-8fiA77-4hTKdE-9AFQ1k-ba75qK-93bkEi-a3m5Gj-daNBR9-GUMJHC-afbq3p-ry5k5p-9DNCxB-nVazPY-hyRZat-dvgtDC-oy6Gjn-re3kVo Credit: scottapeshot License: Common Domain

It can also promote algal blooms. And remember, warm water cannot hold as much oxygen as cold water. Floating particles also block sunlight. Plants need the sun to photosynthesize. That means that water plants cannot undergo photosynthesis so plant growth can then be limited. This is a second consequence of high turbidity. A third consequence of high turbidity is that floating particles can clog fish gills. Can you imagine trying to breathe when the air is full of particles? Perhaps you have been some place where there is lots of smog and it was hard to breathe. Fish don't breathe with lungs; they use gills. The final consequence of high turbidity is that particles can sink and kill fish and insect eggs that are on the bottom.

Water quality standards

There are several different ways to measure turbidity. Depending on the method your class decides to use, there are also different units. Can you identify the method that you will use? Put an "X" over the column to identify the method and units.

Turbidity Standards:

Turbidity Water Quality Standards	Turbidity probes NTU's:	Secchi disk or Turbidity Tube	Engineered filtration system
Excellent – no (or very little) turbidity, not too many floating particles	0-10	➢ 3 feet ➢ 91.5 cm	1 = none or very little turbidity
Good – low turbidity	10.1-40	1 foot to 3 feet 30.5 cm to 91.5 cm	2 = low turbidity
Fair – Medium turbidity, too many floating particles	40.1-150	2 in to 1 foot 5 cm to 30.5 cm	3 = medium turbidity
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Are there too many floating particles in the stream?
Turbidity as a measure of Water Quality

What is turbidity and why is it important?

Did you ever see water that was so dirty that you couldn't see through it? Turbidity measures the amount of floating particles in water that cause the water to look murky. Floating particles, whether on top of the water, throughout the water, or sitting on the waterbed, do not dissolve. Water that is not turbid is clear. High turbidity in freshwater lakes, rivers, and streams means poor water quality.

What causes high turbidity?

There are many different types of particles that float in water. Dirt is a very common cause of high turbidity. Dirt in the water can be the result of two different activities that people do on land. One, when people build houses, apartments, or other buildings, part of the building process often includes digging a hole for a basement or for underground parking. Mounds of dirt can sit at a construction site.

	URL: https://openclipart.org/detail/210414/misc-proto-dirt-pile Credit: Glitch License: Public Domain

When it rains, the rainwater can pick up the dirt and carry it downhill into streams, rivers, or lakes, or it can first go to storm drains that have pipes that are connected to these waterways. Preventing storm water pollution is a component of the Clean Water Act (http://www.epa.gov/region5/water/cwa.htm) passed in the United States in 1972. Do you have any ideas of how this dirt run-off might be prevented?

(Students need a box to put their response)

Did you ever see two-foot fences around a construction site? These silt fences are one solution that the construction industry came up with to help ensure that dirt would not run-off from construction areas. The solid mini fences capture dirt by acting as a barrier. They work to prevent dirt run-off.

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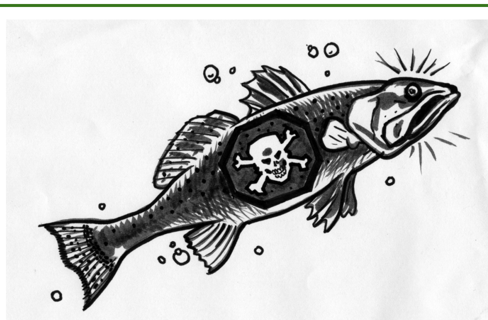	URL:https://www.flickr.com/photos/apeshot/9019017468/in/photolist-eJYPFb-79gJse-aVyxQn-6FChTi-5gUXSk-89G1qK-786A7r-idfDxA-duTeka-djVJWa-dLco5X-eVE6TL-cSHspN-p7NhiT-jUVget-orK2ad-4hTJau-owdbiX-ovgPia-a484nX-7EeeEQ-owXki6-z32oUp-7qknZ3-2VuU7z-otkGM9-owhuMq-ocadJf-9i2xth-ow4HHZ-oeUoWb-4pny3Q-tf1NWw-83FdwQ-8fiA77-4hTKdE-9AFQ1k-ba75qK-93bkEi-a3m5Gj-daNBR9-GUMJHC-afbq3p-ry5k5p-9DNCxB-nVazPY-hyRZat-dvgtDC-oy6Gjn-re3kVo Credit: scottapeshot License: Common Domain

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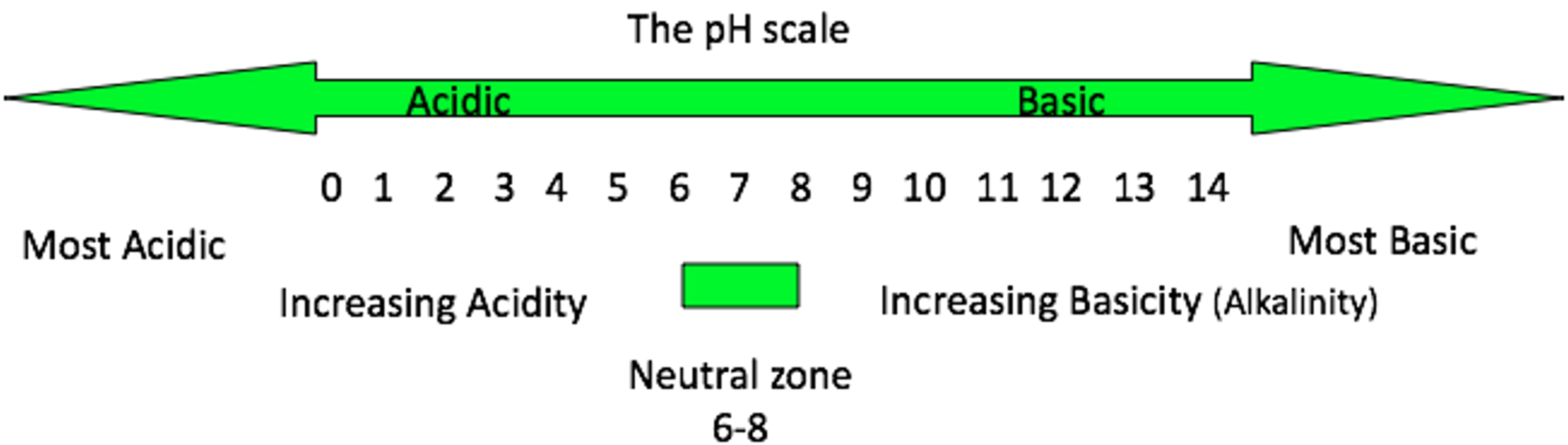
pH: A water quality measure to see if a waterway is acidic, basic, or neutral

- People use products on land and do various activities outside
  - Fertilize lawns
  - Wash cars
  - Use soaps for cleaning windows/garbage cans,
  - Windshield wiper fluid, antifreeze

- When it rains or during snowmelt, these products get washed downhill
- Products get carried with water to storm drains
- Storm drains flow into creeks, stream, rivers – untreated!

- Rainwater that hits the earth, our lawns, gardens, and natural areas can either soak into the land or flows downhill and eventually gets into waterway.
- Acid rain can be produced from factory and car emissions
- If large quantities of pollutants enter a waterway the pH can change.

pH - Is the pH of the water acid, base or neutral?

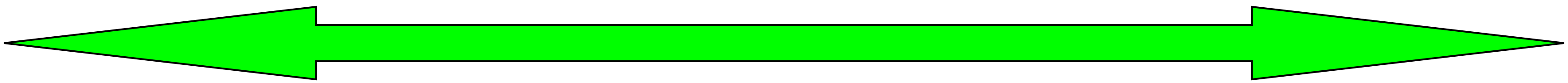


The <u>largest variety</u> of aquatic animals need a neutral pH range between <u>6.5 to 7.5</u> to live. Many organisms can live in a pH range between 6-8.

As the water becomes more acidic or basic more and more organisms die off.

The pH scale is logarithmic

The pH scale



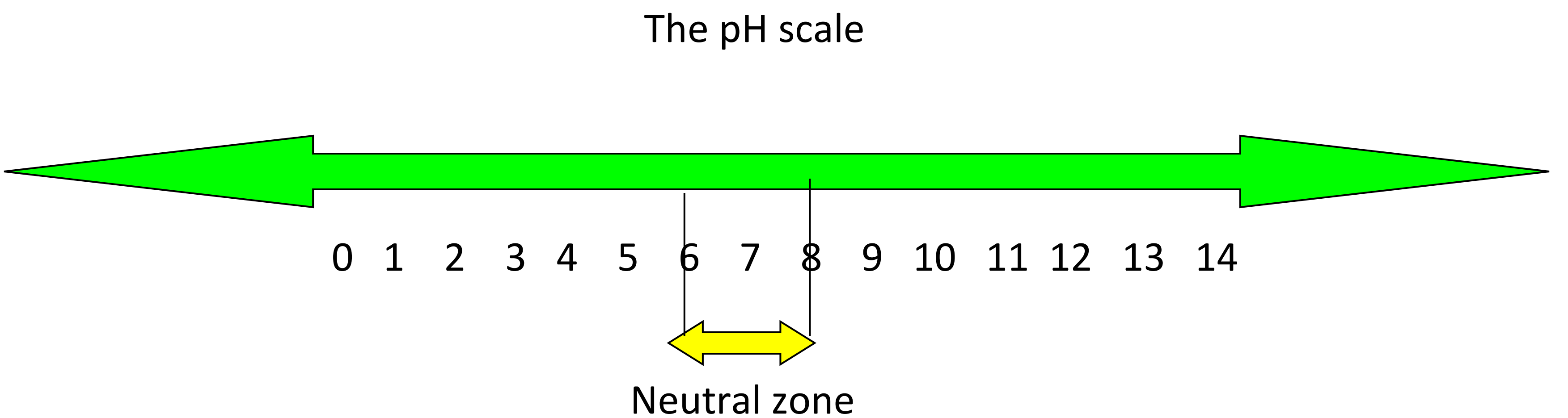
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

When the pH of a substance changes by one number on the scale, the level of acidity changes by a factor of ten.

A substance with a pH of 5 is 10 times more acidic than a substance with a pH of 6.

- A substance with a pH of 3 is 100 times more acidic than a substance with a pH of 5.

pH and water quality

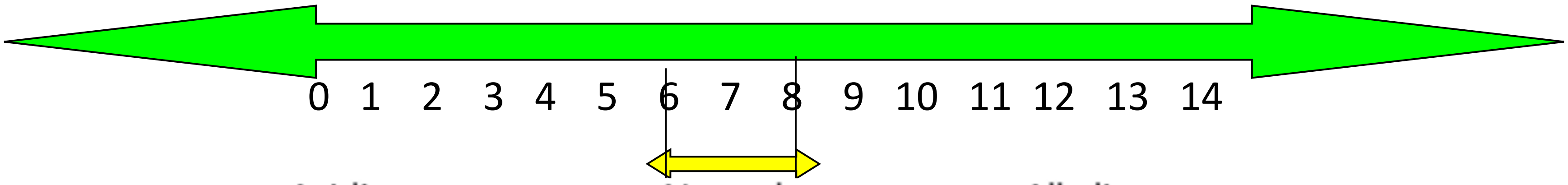


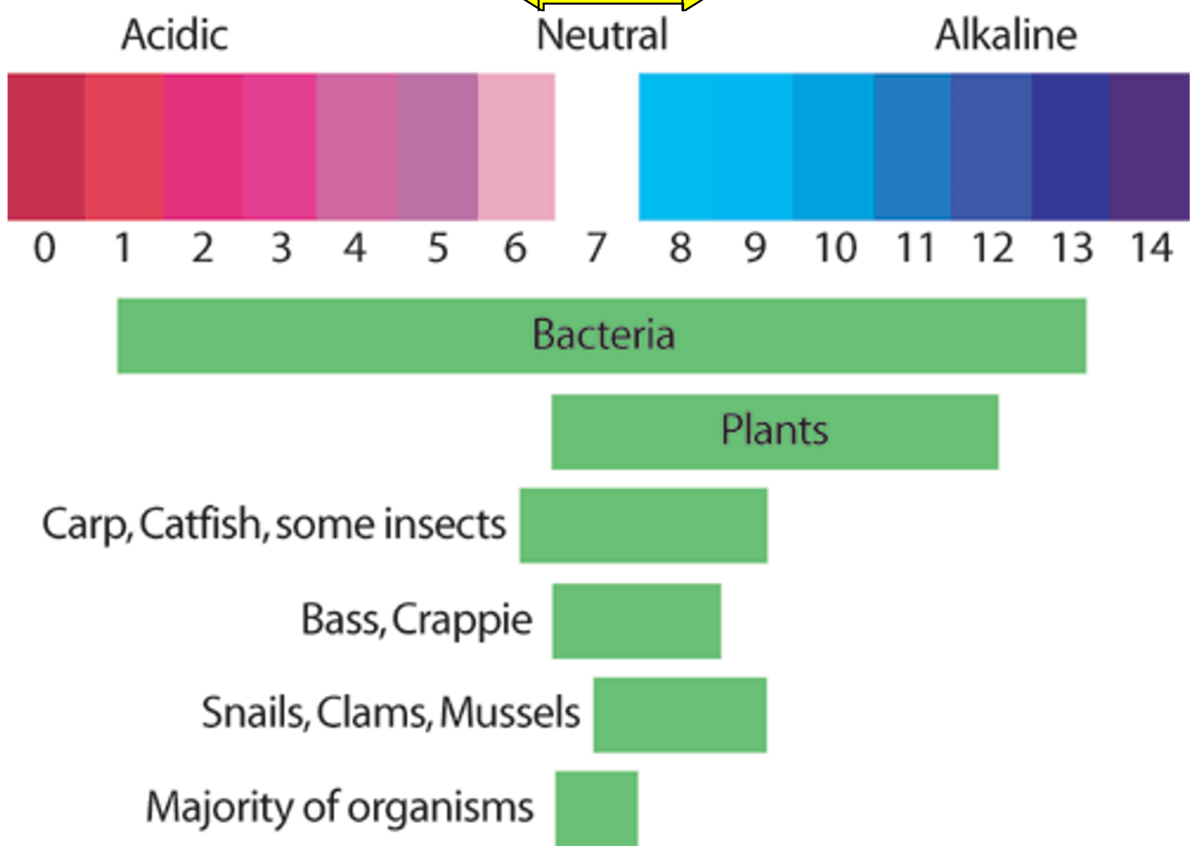
pH: 7 = excellent water quality
pH: 6 or 8 = good water quality

pH less than 6 or greater than 9 = fair/poor water quality

Range of pH that different organisms can tolerate

The pH scale





pH water quality standard	**pH range**
excellent	6.5-7.5
good	6.0-6.4 7.6-8.0
fair	5.5-5.9 8.1-8.5
poor	Below 5.5 Above 8.6