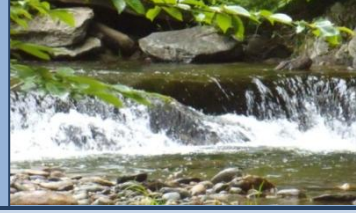
Data Analysis Tutorial



Overview

The following is a series of tutorials that have been created to help Streams Project participants understand and analyze Project data.

Module 1: **What is science?**
Module 2: **Understanding Streams Project Data**
Module 3: **Refining and Retrieving Data**
Module 4: **Data Exploration**
Module 5: **Using Statistical Analysis to Explore Relationships**
Module 6: **Summarizing Results and Drawing Conclusions**

** There are several videos in this tutorial. To watch the videos, download the QuickTime Player, if it's not already on your computer: http://www.apple.com/quicktime/download/

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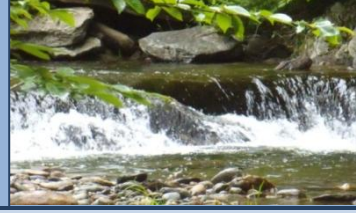
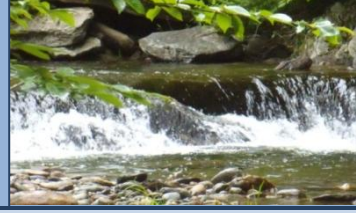


Module 1: What is science?

Module 1



What is science?

"The whole of science is nothing more than a refinement of everyday thinking" – Albert Einstein, Physics and Reality, 1936

This module helps you understand and review:

1) **What science is**
2) **What makes a question scientific**
3) **How the scientific community makes advances**
4) **What type of study is the Streams Project**
5) **How to find your research hypothesis or question**

These topics might seem simple.
Taking a few minutes to contemplate them will help you develop or refine your research.

Module 1

What is science?

Science is…

…both **a body of knowledge** and **an ongoing process of discovery !** The process of discovery doesn't stop: one answer can lead to new and exciting questions. [1]

How can scientists find new topics to research?
Nature is filled with mysteries! Scientists are on an age-old quest to solve them. Scientists have been investigating nature's mysteries for centuries.

Many times scientists follow the same main topic, and chip away at the answer over many years or generations. Check out the example of evolution, where the driving questions is "what is the history of life on Earth?"

What's *natural*? [1]

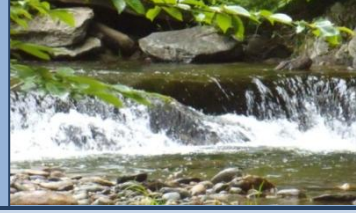
In everyday language, you may use or hear the word *natural* to refer to food, cleansers, remedies, or other products.

In science, *natural* has a much broader meaning. It refers to any element of the physical universe – whether made by humans or not, including matter, the forces that act on matter, energy, the constituents of the biological world, including humans and society.

Science can study things like the human smile, decision-making, and precipitation patterns because they are part of the physical universe, which we also call the *natural world*.

[1] Understanding Science. UCMP.
[2] Ambrose & Ambrose. Pp 7

Module 1



How science advances

"All questions start with an observation." – Ambrose & Ambrose p9

Ideas that scientists have about how to solve the mysteries of nature can be translated to ***expectations***.

Example: If Professor Champlain has an idea that temperature affects the rate of algae growth, the Professor could say "I expect algae to grow faster at higher temperatures."

Scientists make ***observations*** to test their ideas. They use those ***observations*** to determine whether their ***expectations*** and ***ideas*** hold true.

Example: To find out if algae grows faster at higher temperatures, Professor Champlain grows algae in two aquariums, one cool and one warm, and then observes or measures which one has more algae.

While scientists have access to many powerful tools, science and scientist have limits. The checklist helps us understand what kinds of mysteries science can help solve.

What makes a question scientific:

- ☑ Focuses on the natural world
- ☑ Aims to explain the natural world
- ☑ Uses testable ideas
- ☑ Relies on evidence
- ☑ Involves the scientific community
- ☑ Leads to ongoing research
- ☑ Benefits from scientific behavior

Module 1

How science advances:

Hypothesis vs Theory

Scientists use the existing body of knowledge to make hypotheses about observed phenomena.

All science advances by rejection of a hypothesis.[2]

What's the difference between a **theory** and a **hypothesis**?[1]

	In everyday language		In science
Theory	A hunch; intuition	vs	A powerful explanation that applies to a broad range of observations.
vs			
Hypothesis	A guess	vs	A proposed explanation of a fairly narrow set of phenomena. Based on reason and prior information.

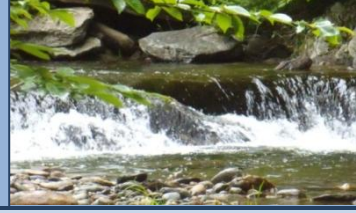
It is essential that a hypothesis is testable!

That means that your hypothesis has to be about something that :

- ❑ can be observed and
- ❑ is specific enough to address

[1] Understanding Science. UCMP.
[2] Ambrose & Ambrose. Pp 7

Module 1



How science advances: Surveys vs manipulations

To test their hypotheses, many scientists use:

experimental manipulations

Typically highly- controlled, where one or more factors is regulated by the experimenter

Observation: More algae seems to show up on the lake shores when we have a heat wave.
Hypothesis: Higher temperatures increase algae growth.

Study design: Build experimental chambers where algae can grow, such as aquariums, that are specially designed to regulate temperature. Use the chambers to increase, or manipulate, the temperature of some of the aquariums and observe if algae grew faster in the aquariums with higher temperature.

OR

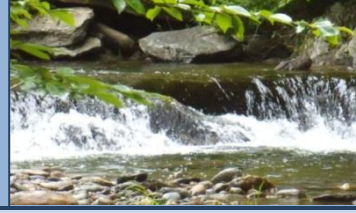
observational studies or surveys

In environmental science, often conducted in an uncontrolled habitat, such as a lake or forest reserve

Observation: Sand shiner minnows are more frequently seen in the shallow waters on sandy beaches of the lake.
Hypothesis: Sand shiners prefer sandy beaches to other habitats, such as those with lots of underwater vegetation or logs.

Study design: Place minnow traps in a range of habitats in the lake: sandy, muddy, vegetated, and in places with or without logs. Deploy the traps for a summer, identify and count the species caught in the traps over regular time intervals throughout the summer. At the end of the summer, when all the data are collected, compare the number of sand shiners caught in each type of habitat.

Module 1



What type of study is the Streams Project?

It's a survey study!

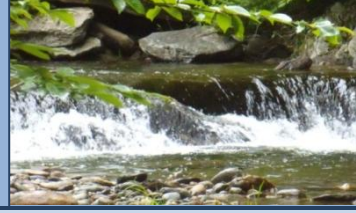
The Streams Project is a survey because throughout the past several months, you and other participants have collected data that tells us about streams. We did not manipulate the streams and they were in uncontrolled habitat.

The types of data that we collect, such as phosphorus and bacteria, were chosen so that you and other scientists could ask insightful questions about relationships among:

- water quality, including macroinvertebrates
- precipitation patterns
- land use

While the Streams Project doesn't manipulate any part of the environment that we monitor, we chose stream sites that are different. For example, one of the sites you monitored was in a watershed that was largely forested and other was probably in a watershed that had more agriculture or urban development.

Module 1



How do you find your question?

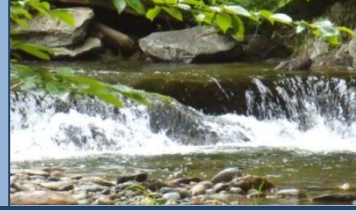
You might be wondering…

"But what kinds of questions can ask when I can't manipulate any of the parameters that I'm interested in (i.e. phosphorus concentration, stream substrate, precipitation)?"

The answer is simple: There are plenty of questions you could ask about streams because the Streams Project database was designed to allow you to research myriad questions.

Take it slow: Start by thinking broadly about the basics: water chemistry, macroinvertebrates, weather, geography, geology….

Module 1



How do you find your question: Brainstorm!

Where do you start?

Remember, science starts with an observation.

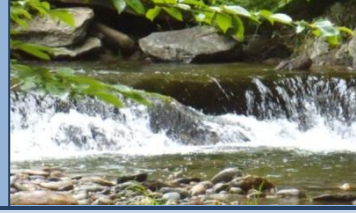
To find your question, you've got a job!

Before moving on to the next slide go through the following steps:

1. Don't worry about what data are available yet. We'll save that for later.
2. Sit down with your team and **recall your visits to your stream sites**, writing down **anything interesting you noticed** in or around the stream site. Do you have any special or strong memories? Even a funny story that you remember might lead to an observation that you can turn into a question. Talk about it with your team!
3. **Go visit your stream sites again and the macroinvertebrate Web pages.** It may jog an old memory or observation. You might notice something you never had before.
4. Write all your thoughts and topics down. Think in terms of **differences and relationships** among the parameters we measure.
5. Draw connections (literally, draw lines!) to show which topics or parameters might be related (e.g. stream discharge and phosphorus concentration).

This is the beginning or your map of ideas!
We'll turn them into scientific and answerable questions.

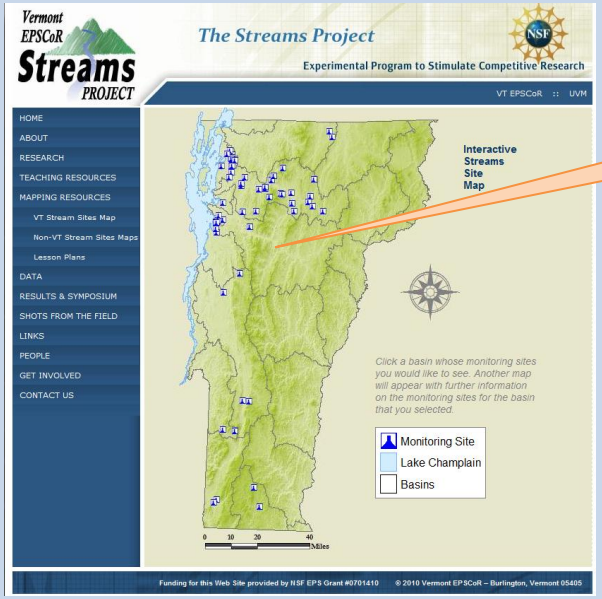
Module 1



How do you find your question: Think geographically!

Now that you've thought about how several parameters are related, let's make sure we **explore the geographic component** of the Streams Project.
Keep in mind that you can incorporate data from other group's stream sites into your own research.

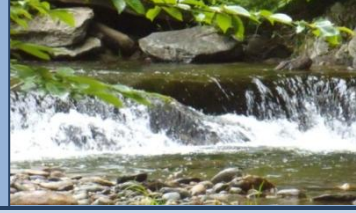
1. Visit the Streams Project mapping Web page: http://www.uvm.edu/~streams/?Content=pages/map_watersheds.inc
2. Explore the geographic range of the sites that other Streams Project participants monitor



Click on watersheds to view more detailed information about stream sites. In this example, we chose to look at the Winooski Watershed.

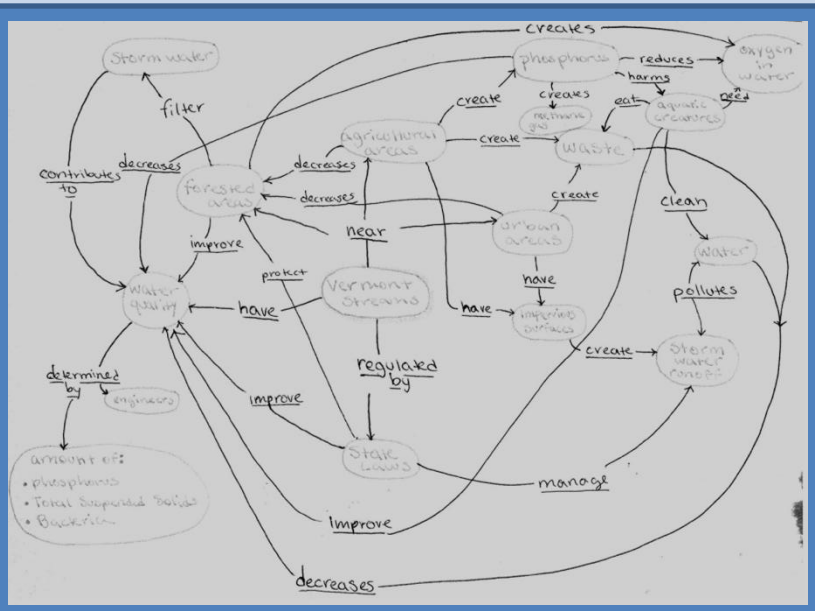
3. As a Vermonter you have some knowledge about water bodies, like streams, throughout the state. Have you ever heard a news article about water quality or water use? Use that local knowledge and experience to your advantage as you brainstorm about water quality issues throughout the state.
4. Add topics and thoughts that address geography, geology and water quality to the concept map or web that you made in the previous exercise.

Module 1



How do you find your question: Refine your observations.

Review your concept map or web with your team:



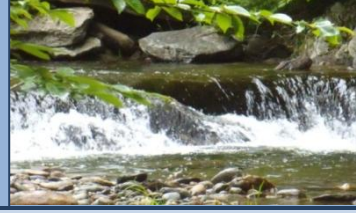
Example of a concept map or web of ideas[3]

Draw (literally!) stronger, bolder connections between parameters that you think might have interesting differences or relationships.

Talk about what kind of differences or relationships you might expect to see among the parameters. Why might you expect to see those relationships?

[3]This concept map originated from a freshman engineering course at UVM in Fall 2009 taught by Dr. Nancy Hayden. The students who created it are: Liana Schneidman, Sebastian Downs, Will Chandler, Tom Brayden.

Module 1



Refining and Retrieving Data

SUMMARY

- Science is a body of knowledge and ongoing process.
- Science tests ideas and expectations about observable phenomena.
- “Hypothesis” and “theory” have a specific meaning in science that may differ from how we use those words in everyday language.
- Science advances by rejecting hypotheses.
- Scientists can test hypotheses through experimental manipulations or observational studies (a.k.a. surveys).
- The Streams Project is a survey study.
- You should have a well-developed concept map or web of ideas about differences and relationships about water quality, land use, geography, and/or macroinvertebrates.