Table of Contents

Tributary 7: Putting It All Together–Research

The Research Project

In Tributary 5 you selected an issue to investigate, conducted background research, and considered stakeholder perspectives. In Tributary 6 you developed a research question. The research question drives the **study design**—the methods you will follow to answer it. In this tributary, you will develop a study design for your question and then, conduct the research.

For some studies, you'll need to select your variables and develop hypotheses to test. You'll need to determine whether or not statistical analyses are warranted and if they are, which analytic tool to use. Some studies may research human opinion or knowledge about an issue. Studies using human participants will need to reviewed through a school review board process to ensure participant wellbeing. Studies using animals should also go through a review process, to ensure no animals are harmed. Other studies may be observational in nature wherein you will accumulate many notes (see sidebar in Streams 101 section), and you will need to determine how to analyze and evaluate the text (coding) to find patterns and insights.

Let's look at this following example to illustrate the need for different methods for collecting data. Here is the research question we will use:

Is it a sound idea to remove the old mill pond dam?

That is a big question with social and ecological implications. It is a huge question, and an awesome one! Some sub questions are:

Does the old mill pond dam affect fish?

Does the old mill pond dam affect chemistry?

Do people think the old mill pond dam should be removed?

Do people value the old mill pond and the dam it creates?

It turns out that there are multiple sub questions to answer before you can determine whether removing the dam is the best of course of action to take. With a class, you can find answers to each question and then, given the findings, decide whether it is feasible or not to remove the old mill pond dam. Divvy up the questions, and invite student groups to each choose and research one. Answering each question will require a different method. This question about fish: “Does the old mill pond dam affect fish?” will need a different method than this question about human values: “Do people value the old mill dam and the pond it creates?” For the study about fish, a comparative study where the researchers survey the fish in the mill pond and compare their findings to another, similar undammed site to see what fish live there is probably the soundest method. A similar method would be used to assess the impacts of the dam on stream chemistry.

To answer the second question about human values, we can’t gather physically observable evidence. We need to collect information from people so as to understand their values. Thus, for this type of question, where we need to ask questions of humans, we would need to develop an opinionaire, a type of questionnaire used to discover beliefs, opinions, values, and attitudes.

If you don’t know what kind of research is needed, you can enter similar questions into scholarly databases to see what methods have been used to answer them. Your library likely has databases you can use, and some schools are linked in with local universities and colleges, and have access to a rich collection of research papers. Google Scholar can be useful as well, and we at NorthBay are always interested and willing to help you find the best method. Just contact us!

Returning to the research question you developed: Next are some questions to guide the development of your **study design.** Later in this chapter you will find the finer details of study design explained. Those who are research experts may decide to skip portions of this chapter and move directly to conducting research.

Questions to Guide Study Design

- What do you think you will find? (Hypothesis)
- What are the independent and dependent variables?
- How will you select your study sample?
- What materials will you need?
- Who are the stakeholders? What are their needs? How might their values influence their support of the study's findings and proposed action?
- Have you acquired necessary permissions and permits?
- Who is available to support you?

Data Collection

- When, where and how will you collect data?

Data Analysis

- How will you sort and display your data?
- What analyses will you use?
- Do you need to conduct statistical analyses? If so, what type? Who can assist you if needed? Please note that you will need to write a null hypothesis if your work will include statistical analyses.

Data/Findings

- How will you use graphs and tables to share your findings?

Conclusion

- How will you summarize the findings and thinking about next steps, while not overstepping the boundaries of what your research results actually show?

Study Design For and With Students

Study design is where your students give legs to their research question. It is essentially the procedures section. The beauty of student-directed learning is that it empowers kids; it brings life and purpose to their learning and makes it all relevant. There is the genuine excitement of discovery. The negative: There is no way to develop a comprehensive methods section in this document as specific study designs will be as diverse as the research questions students develop.

A scientist working for the Department of Natural Resources (DNR) evaluates stream health by following specific protocols and a strict study design. As teachers facilitating student-driven stream based inquiries, our studies will be as scientifically rigorous as possible. At the same time, our outcomes are a bit wider than a DNR biologist's: we want kids to become connected to rivers and streams, and to take ownership of their well being. We want them to learn how to do science and the content necessary to conduct their investigation; we want students to read and write and do math at or above grade level. All this in addition to generating quality data. Our primary outcomes are educational so data quality may suffer a little. The point is, don't get hung up on developing a scientifically watertight study. There is no such thing.

Getting students into the creek and schoolyard serves a number of important purposes. It is a way for students to connect with their local environment and experience their natural world. It is a way to actively and personally engage students as scientists in a research study rather than teaching "about" science. Finally, it is a powerful interactive way to collect real data to inform positive environmental actions. As mentioned earlier in this work, and worth mentioning again, students in Maryland have had the opportunity to submit their stream data and present their findings to state legislators, thereby having a voice in policy.

In the following sections you are going to read about sampling techniques, a brief bit about statistical analysis, and be linked to accepted, standardized scientific protocols for freshwater ecology studies. Don't lose track of the big picture in the nitty gritty details. Getting kids outside and in the creek is a good thing and the most important thing.

What Does a Good Study Accomplish?

When designing a study with your students there are many outcomes to keep in mind and balance with your reality as a busy teacher. Personally, I design my study with these three priorities:

The quality of student learning experience
The quality of scientific skill modeling
The quality of data

My bias as a teacher is that the student learning experience is more valuable than the accuracy and precision of the collected data. However, teaching students to think critically and design a study to answer a question is a very powerful process. The art of this process is engaging students in the design experience to craft a study that is compelling and produces valid results.

In the long term I am looking to facilitate:

Positive change in students
Positive change in the environment

The studies we do at NorthBay appear simple and require minimal tools. Considerable effort has gone into the development of them, however, and a couple of them have informed the larger scientific community. The effort invested has yielded invaluable rewards. Each week we see students inspired to ask tough questions, figure out how to answer them, then take meaningful action. Studies designed to lead to action empower students, showing them they can change not only the world around them, but also the world inside them — I. Palkovitz

Study Design Fundamentals

Variables

An independent variable is a condition or factor that is modified by the researcher. One way to present the independent variable to students is to say, the independent variable is what "I vary." This is also referred to as the manipulated variable since varying this variable may result in a change or effect. What is changed is known as the dependent variable. The dependent variable, also known as the response variable, changes in response to an independent variable. Here are some examples:

Independent Variable (Manipulated variable) = amount of light
Dependent Variable (Response variable) = plant growth

Independent Variable (Manipulated variable) = water temperature
Dependent Variable (Response variable) = species of stream organisms found

Independent Variable (Manipulated variable) = soil pH
Dependent Variable (Response variable) = types of plants that can grow

In social science research there are variables for knowledge, behavior, attitude, and physical characteristics (Hungerford. Litherland, Volk, Ramsey, & Peyton, 2003, p. 63). These variables can function as independent or dependent variables, depending upon the study setup. Here are some examples:

Independent Variable = mini class on stream macroinvertebrate identification
Dependent Variable = increased knowledge of macroinvertebrates. (Knowledge)

Independent Variable = demonstrating to kids that praying mantids do not bite
Dependent Variable = kids become more willing to approach a mantid (Behavior and possibly an attitude shift)

A Note About Controlling Variables & Causality

Let's say we are investigating the effects of temperature on the diversity of aquatic life. We sample a stream along a temperature gradient. We find there are no Brook Trout in the lower reaches of the stream where the water happens to be 3 degrees warmer than the upper reaches, where Brook Trout are abundant. What can we say about this? Nothing more than there were more brook trout in the upper reaches than the lower reaches and the temperature was warmer in the lower reaches. We can't say that warmer temperatures is the reason for the lack of trout. There are too many other variables that could account for this finding such as other water chemistry parameters like dissolved oxygen and pH, or maybe the habitat is different. Maybe there is a predator or competitor present in the lower reaches, not present in the upper. The point is, a constant struggle in field ecology is to control as many variables as possible, and to note each of the variables, and which ones we are not able to control. Let’s say we repeated the same study and controlled all those other variables by eliminating predators from both reaches, adding oxygen and lime to the water to make sure the dissolved oxygen and pH were the same, and modified the habitat to ensure there were no differences between the two reaches. We still can’t say there is causality between temperature and trout. We might be able to say there appears to be a relationship, but causality is very difficult to prove in the field.

Sample Size

Population: A population is the group of organisms you wish to study. It is not possible, however, to include all the members of the population in the study. Thus, a subset of the population, a representative sample, is needed. There are various ways to obtain a representative sample. Two questions emerge: How large of a sample do I need? What method should I use to collect the sample?

Sample size is determined by the variability in the population to be studied. For example, if you are studying fish length, and it is assumed that fish lengths are really similar in the population, (variability is low) it will take few samples to characterize the population, compared to if the lengths of the fish were highly variable. The kicker is how do you know what the variability is?

Most statistics programs have the capability of determining IDEAL sample size to characterize the population based on a reported or assumed variability. You can estimate that variability a few ways. First you can conduct some pilot sampling just to see how much variability exists in the population. Simply go out and take some samples, and measure the variable you want to measure. You can look at past studies that evaluated the same variable to see how much variability was in that population and make the assumption that your population has the same degree of variability. Or you can just make an educated guess about the variability you expect to see. The important point is to make sure you record your assumptions, and know why you made them.

You can collaborate with a math or statistics teacher in your school or district (or better yet, engage the statistics class in the study by handling the statistical aspects of the research) to help determine the appropriate size. What is perhaps most important is that you explain how the samples were collected and why particular methods of study were chosen. It is the quality and type of thinking that is most important, especially when teaching others how to conduct research.

That is how you determine the IDEAL sample size. Ideal will be modified with real time conditions. For example, if your analysis indicates you need to sample 100 Darters (really cool bottom-dwelling fish) but there aren't even 100 darters in the stream, you might just select a sample size of as many darters as you can catch, noting that in the ideal world, statistically, “I should have captured 100 fish.” Biology doesn't always listen to statistics. Or maybe stats says you need to capture 50 crayfish, but the DNR will only permit you to capture 10. It is what it is. Make note, collect the data you can. This is real science, and reality happens all the time.

Now that you have sample size, it’s time to determine collection approach. There are hundreds of sampling schemes. We have compressed those into three main categories: Random, systematic, and convenience.

Data Collection

Random Sampling

In a true random sample, each individual of a population has an equal chance of being selected. It is important to note here that haphazard sampling, such as throwing a hoop one direction, and then another, and then another to sample for a plant study, is not the same as random sampling. It is haphazard sampling. This is not right or wrong, but call it what it is.

In true random sampling an x y grid is laid out on the stream. It is usually easiest to place a stake in the bank near the water's edge. Run a line upstream marked in some increment that makes sense for the study (i.e. cm or M) This is the y axis. Run a second line equally marked at 90 degrees to the first string, across the stream. This is the x axis.

Use a random numbers table, or random number generator (www.random.org) to determine your first x coordinate. Make that number equal to the number of cm or meters from the stake on the x axis. Find that coordinate. Choose a second random number from the table or random number generator. Follow that distance on the y axis. These two coordinates will establish sample point 1. Continue the process until you have identified the random points from which to collect the number of samples needed for your research. Your samples may be invertebrates, aquatic plants, fish, substrate, etc.

If you want to randomly sample a human population about their opinions or knowledge of an issue, use a random numbers generator or table to randomly select phone numbers from a database of phone numbers. Set up rules ahead of time. For example, the first random number may be the page number in the database, and the second number may be the number of names down from the top of the page.

Systematic Sampling

Random sampling ensures that every member of the population has an equal chance of being sampled as any other member of the population. Random sampling does not guarantee that the study area will be equally sampled. There are times when you may want to ensure that the entire study area will be sampled. In these cases, systematic sampling is the preferred method. For example, you are trying to determine if freshwater mussels are equally distributed in the stream. Therefore, you sample for mussels at each node on the x y grid. That way you cover the entire stream to determine their spacing.

Systematic sampling of human subjects may involve selecting a particular subset of the population, a particular group within the community, and sampling to get opinions from across that population. You might go to a PTA meeting and administer the opinionaire to every third person who comes into the meeting.

Sample of Convenience

A sample of convenience is exactly what it says: samples selected based on their convenience. For example, the study may call for a systematic sampling of the stream reach, but half of the reach is ten feet deep which makes sampling here impractical, so you modify the sampling plan to only sample accessible areas. This is a sample of convenience. Using crayfish traps or other traps also would be considered samples of convenience.

If you stand in front of a grocery store to administer a questionnaire or opinionaire to people coming and going from the store, this is a sample of convenience.

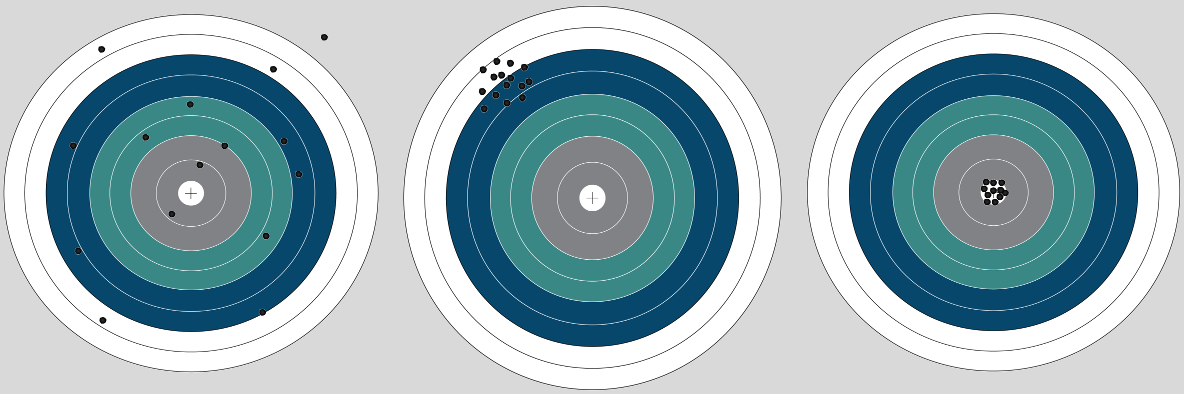
Data Evaluation

Having determined the number of samples needed, visited the study site and gathered the data, it is time for the next step, data analysis, to understand what your data reveals. If you are carrying out statistical analyses of your data, Excel has the basic statistical functions you might need. If your data is text or interviews, you need to identify how you will code it and then, complete the coding.

After your numbers are statistically analyzed, and texts or verbal conversations have been analyzed using qualitative methods, you need to thoughtfully consider what it all means. While being in the stream collecting data is fun, this is when the work becomes really exciting as you stand at the frontier of new knowledge.

Data Reporting

Here is a fundamental idea about data: When reporting results, it is important to be accurate and precise. These two words are often used interchangeably. When carrying out and teaching science, they need to be used appropriately. The sport of archery can assist us here. Picture an archer's target.



In the first picture on the left, the archer is neither precise, or accurate. There are arrow holes scattered around the entire target. In the second picture, in the middle, the archer is precise, but not accurate. The arrow holes are concentrated in an upper area of the target, not in the center. In the third picture, on the right, the archer is accurate and precise. The arrow holes are *all* in the bull's eye. All of them.

Some examples follow to show how this translates into stream assessment data. *Accurate* data means that the macroinvertebrates identified at a stream are correctly identified. It may also mean that measurements taken of any plant or animal are representative of the individual's true length or width or mass. *Precision* represents a different quality. Multiple measurements of the same phenomena should be similar, or better yet, the same. The closeness of these measurements is precision. Here is an example: If different students measure the oxygen concentrations in a river at the same time using the same techniques, their results should be similar.

Conclusion

The conclusion is the place to declare findings. The very act of declaring findings can be exciting, momentous, even thrilling! It is important, however, when working with students, to remind them to explain their findings with caution, so as to not suggest linkages or causes that do not exist. Remind students to choose words carefully, using phrases such as “our research suggests” to acknowledge uncertainty, and to stay within the bounds of what the data collected might actually mean. It is particularly important to be mindful of attributing cause, meaning or suggesting a single event or variable caused a change to happen. This is especially true in a field situation, where the variables are complex and interacting. The same precautions apply when inferring from the results. Students are often quick to assume causality, or to equate an inference with a truth. A teacher may find her/himself in a balancing act between supporting students' enthusiasm for their results while recognizing the limits of what the findings mean. Keep in mind your overall learning goals as you navigate these situations.

How to Manage Student-Directed Projects

Managing multiple student-directed projects can be a daunting task. However, the engagement benefits of student-directed learning make it worth it. There are a few ways to make it easier than keeping track of 25 different projects. A few suggestions to make this a bit more manageable:

1. You aren't the expert and don't have to be. Go on this learning adventure with your students. Rely on community experts to provide technical guidance. Process is as important as content.
2. Give students parameters they need to operate within. For example, they can choose an issue that interests them related to invasive species, dams or sedimentation. Each student still does their own investigation, but the field is narrower.

3. Form investigation teams, and have each team select their investigation so that you have four or five projects to manage rather than 25.

Student Research Report Guidelines

While working through the inquiry using the templates provided the students will have identified and described a problem, stakeholders, their research question, and methods. This provides context for the research question they have developed. At some point, additional background research will need to be conducted to find out what is known about the issue, and what has already been done to address or resolve the issue. Students can conduct this research using online databases from their libraries. A summary of these literature findings should be included in the final report.

Teachers may ask students to create their reports using electronic media, such as video, or request more formal written reports. All formats should include the following elements, adjusted for students' developmental levels. A final thought: If your learning outcomes will allow, please include a place in the research project for students to showcase their creativity. Creativity and science are often interdependent.

TITLE-AUTHOR-DATE

ISSUE - What is the watershed problem being addressed? Include the reasons that explain why this one was chosen.

STAKEHOLDERS - Who are they? What are their perspectives and positions? How might they be impacted by the proposed solution?

RESEARCH QUESTION - What is the question to be investigated?

LITERATURE REVIEW - Additional background research that explains what is known about the issue, and what has already been done to address or resolve the issue.

METHODS - The steps used to conduct the research. Also known as the study design.

VARIABLES - If appropriate

DATA COLLECTION

When and where and how did you collect data?

What is your data?

DATA ANALYSIS

Data/Findings

What did you find? Please use graphs, tables and text to share findings.

CONCLUSION

What might the data mean? What are potential next steps?

ACTION PLAN - What will you do now that you have gained this knowledge?

As students move through grade levels, their inquiries should become increasingly sophisticated and detailed to reflect their growing knowledge and skills.

Assignment 7a. Conduct Inquiry

Use the study design questions to guide your research study. Record responses, data, analysis and conclusions in your journal. *Please* keep the research project simple and doable in a few hours. This, like everything else in the course, is practice to support your work with students.

Summary Thoughts About The Research Process

Research is a process developed and refined over time for acquiring new knowledge and deepening understanding. It provides ways to know and understand more fully and thoroughly our local waterways, their stories, their significance in our lives, and our impacts on their healthy functioning. We are all contributors in watersheds. We hope you and your students will develop creative experiments that result in significant findings. Findings that inspire you and your students to act in ways that make communities of all life even stronger and healthier. Here is one more story to inspire you.

A local 7th grade math class wanted to get Eastern Elliptio mussels to reproduce in captivity. The class intended to grow juvenile *Elliptio complanata* for a year to release them into streams where the species had been extirpated due to historic poor water quality. The students used water temperature data to predict when mussels would release their glochidia, a larval life stage that is dependent upon water temperature. The larvae are dependent upon migrating eels to transfer them to upriver tributaries. Eastern Elliptio mussels were collected from the river when temperatures were predicted to come close to glochidia release temperatures and brought into the classroom. Eels were introduced into the tanks with the mussels. The mussels successfully released glochidia and the eels were infested with them. The students were unable to get the animals successfully to the next developmental stage, however, where metamorphosed mussels drop from the eels into the streams. Since students were unable to get metamorphosed mussels to drop from eels, the experiment in terms of conservation was unsuccessful. The story doesn't end there, though. The Maryland Department of Natural Resources (MDNR) realized that if they released glochidia infested eels into streams, they were likely to repopulate those streams with mussels. The experiment conducted by 7th graders informed Maryland DNR restoration efforts!

Most likely, you will be surprised by something that happens during the research process or in what you discover. Perhaps, however, your experiments will fail. If they do, carry on. There is always something to be learned. Whatever the outcomes, we look forward to celebrating with you your greater understanding of our magical, ever changing, life-nurturing waterways. Let us know how it is going, and how we can support you at any step in the process. Good luck & Thank you!

Interlude 7

Delicate, slender, powerful fish—

your nest of small rocks

is built in a tiny tributary, next to an oft-used path

in a degraded forest

where dogs and their humans

Roam.

Shy, elusive species—

how many people have walked past,

while their dogs churned up and trampled your habitat

unaware of your fragile nest and young?

– K. Chambliss
Photo Credit: Freshwater Journeys