From Design to Data: Water Quality Monitoring

Adapted from *Healthy Water, Healthy People Educators Guide* – www.projectwet.org

Students create a study design, then analyze the data to simulate the process of water quality monitoring.

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From Design to Data: Water Quality Monitoring

Summary
Students create a study design, then analyze the data to simulate the process of water quality monitoring.

Vocabulary: indicator, monitoring, parameter

Project WET

Adapted from *Healthy Water, Healthy People Educators Guide*
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Grade Level: 6-8, ages 11-14

Subject Areas: Chemistry, Environmental Science, General Science

Duration:
Preparation: 20 minutes
Activity: Part I: 50 minutes, Part II: 50 minutes

Setting: Classroom

Skills: Gather, Analyze, Interpret, Present

Objectives

Students will:

- investigate the process of water monitoring.
- develop a study design that leads to a monitoring project.
- design an investigation to answer a research question.
- collect and analyze data and develop findings, conclusions, and recommendations from that data.

Materials

- *Copies of **Table Monitoring Worksheet** Student Copy Page*
- *Copy of **Table Monitoring Goals** Teacher Copy Page*
- *Ruler, tape measure and graduated cylinders (optional) to measure changes in objects*
- *Copies of **Kallang River Worksheet** Student Copy Page*
- *Copies of **Kallang River Data Set** Student Copy Page*
- *Copies of **Kallang River Overview** Student Copy Page*
- *Graphing paper (optional)*

Background

Bodies of water are complex systems containing many measurable variables. These variables can serve as indicators of water quality and watershed health. In a perfect world we would monitor *every measurable parameter*, at *all times*, and at *all points* of a watershed. Of course, this is impossible and impractical. Instead, decisions must be made about what parts of a complex system will be measured, when and where measurements will be taken and by whom. Just as a dentist must decide among a myriad of variables when performing a routine checkup, so water quality monitors must choose just how to go about their work. Dentists generally look for indicators of decay, injury, and deterioration of gums and teeth. These check-ups are usually conducted at six-month intervals. In most situations, it would be impractical to check more often. The same is true in water quality monitoring. With so many variables and parameters as well as the complexity of water systems, how can water monitors decide just how, when, where and what to monitor? Who will analyze, interpret and present any data gleaned from such monitoring? The best way to answer these questions and make choices leading to a scientifically credible monitoring program is to develop a study design.

A study design is a document that describes decisions made about a monitoring program. Formulating a study design is also a process that allows people to ask essential questions about water quality monitoring. What can be gained from a monitoring program? What is appropriate data? Where and when will data be collected? Who will interpret the data? How will data be used to make decisions?

There are many reasons to develop a study design. Consider the following scenarios where a study design could meet each individual need.

- A school wants to monitor a stream after a water quality restoration plan has been approved. Teachers and students must determine what sampling protocols would give them appropriately accurate data.
- A Conservation District has diligently implemented new land use management practices designed to improve water quality within a watershed. Now, they want to find out if any of the changes actually improved water quality.
- A River Task Force is funding a monitoring program to assess the cumulative impacts of bank erosion. The Task Force Monitoring Specialist understands the data but will it make sense to the rest of the group?
- A school's water monitoring program is plagued by teacher turnover. The program loses momentum each time a teacher leaves because new teachers must decipher the goals and activities of the program without the aid of a written document.

The study design process mirrors the scientific method in that it strives to answer a research question by designing a method of testing the question, collecting and analyzing data, drawing conclusions and offering recommendations from the analysis. Formulating a study design directly correlates with the investigative process of inquiry described by the National Research Council. "Inquiry is a multi-faceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations" (NRC, 2000).

The steps of a carefully planned study design are:

1. Define the <u>monitoring goal, or purpose</u>

Why are you monitoring? What water quality questions do you want to answer? For example, if the issue is the threat of pollution entering a stream from the mall parking lot, you might ask the question: *Is parking lot runoff adversely affecting aquatic life?* The definition of your monitoring purpose will influence the decisions you make on what, where, when and how to monitor.

2. Decide what will be monitored
What indicators or parameters will you monitor? How will these parameters attain your monitoring purpose?

3. Identify the data quality objectives (DQOs)
Who will use the data, and for what purpose? What level of precision and accuracy is required? DQOs can help determine specific methods. For instance, if you need to record pH levels to the tenths place, a pH strip won't work. You will need an electronic meter to provide the necessary sensitivity.

4. Choose how to monitor
What are your sampling and analysis procedures? Describe how samples will be collected, analyzed, and reported.

5. Decide where to monitor
Where are your monitoring sites? What are the criteria for choosing these sites? Include site description, latitude/longitude and rationale for choosing each site.

6. Decide when to monitor
What is your sampling frequency (once a year, biannually, monthly)? What time of day will you sample? List the sampling dates, times, and the rationale for choosing them.

7. Document who will do the monitoring
Who will monitor the data and what is their level of expertise? List the name, contact information, and responsibilities of the monitoring personnel.

8. Identify Quality Assurance (QA) measures
How will you document project procedures to ensure that the data collected meets data quality objectives?

9. Manage, analyze and report data
Managing data – How will data be recorded, entered and validated?
Analyzing data – How will data be interpreted?

- assemble information (maps, data sets, other)
- develop observations about the data
- develop conclusions about why the data look the way they do
- recommend action or further study

Reporting data – How will data be presented so different audiences can understand it?

A study design should precede any water quality investigation or field study. Study designs help monitoring groups focus on what they want to monitor, allow students to methodically investigate a question, and model a scientific investigation.

Procedure

Warm Up

1. Place numerous objects on your desk—water bottle, cup of coffee, pencils and pens, chalk, papers, open and closed books, picture frames, etc. There should be at least ten items on the desk, preferably many more. Explain to the students that they will individually monitor and record any changes in the objects on the table. Have them gather around the table and study it for 30 seconds, then return to their seats.

2. Begin a discussion about water monitoring. While you talk, alter the items on the desk (drink the liquids, turn book pages, use chalk and writing implements, etc.). Ask students if they have ever been to a dentist. Have them brainstorm the variables, or parameters, that the dentist is checking or *monitoring* during a dental exam. Examples include teeth hardness, whiteness or color, plaque build-up, cavities, alignment, etc. Ask students why they don't have a dental exam every day. (Don't their teeth change a little bit every day, especially if there is a cavity?) Since it is not practical to have a dental exam every day—the dentist instead monitors teeth at six-month intervals, looking for indicators or problems of declining oral health.

3. Describe how monitoring a stream can be similar to a dental exam. To determine the health of a body of water, monitoring *all parameters* at *all points* at *all times* is important. However, like a daily dental check up, it is impractical, if not impossible to monitor *everything*, *everywhere*, *all the time*. Discuss how choices must be made in order to conduct a scientifically credible monitoring program. Ask students to name other things that undergo periodic monitoring—drinking water, blood pressure, weather-related parameters, economy, etc.

Water Quality Monitoring Parameters

pH - A measure of relative acidity or alkalinity of water. Water with a pH of 7 is neutral; lower pH levels indicate increasing acidity, while pH levels higher than 7 indicate increasingly basic solutions.

Turbidity - The amount of solid particles that are suspended in water and that cause light rays shining through the water to scatter. Thus, turbidity makes the water cloudy or even opaque in extreme cases. Turbidity can be measured in many ways and represented by different units of measure. Formazine Turbidity Unit (FTU) is identical to the Nephelometric Turbidity Unit (NTU). The other two methods used to test for turbidity and their measurement units are the Jackson Turbidity Unit (JTU) and the Silica unit (mg/l SiO_2) U).

Temperature - The degree of hotness or coldness of water; a measure of the average kinetic energy of the particles in water, expressed in terms of units or degrees typically Celsius or Fahrenheit.

Dissolved Oxygen (DO) - Amount of oxygen gas dissolved in a given quantity of water at a given temperature and atmospheric pressure. It is usually expressed as a concentration in parts per million or as a percentage of saturation.

4. Commonly, water quality monitoring involves repeatedly testing water for specific water quality variables (pH, dissolved oxygen, turbidity, etc.). Ask students what variables or parameters of a river might change, and which are indicators of a water body's health. Examples include temperature, pH, dissolved oxygen, turbidity, aquatic insects, alkalinity, heavy metals, etc. Write these parameters on the board. Ask students why each of these need monitoring.

5. After the discussion, have students look at the objects on the desk again and record which objects changed and how. Was each student able to record ALL of the changes? Why not? (There were so many variables to monitor that they couldn't keep track of them all.) Explain that in the next part of this activity, they will use a study design to choose specific parameters to monitor.

The Activity

Part I

1. Divide students into groups and distribute the *Table Monitoring Worksheet* to each group. Their task is to "monitor" items on your desk or table at 5-minute intervals for ten minutes. Place numerous items on your desk; include some that change and some that don't (as in the ***Warm Up***). Add more objects to increase variety. Review the ***Table Monitoring Goals*** to ensure the objects on the table meet these goals.

2. Before monitoring, explain that all monitoring projects must start with a target or purpose. Copy the ***Table Monitoring Goals*** and distribute one card to each group. Have students focus on items specific to their assigned monitoring goal. Have them write their goal in the space provided on the ***Table Monitoring Worksheet.***

3. Groups must decide which parameters or objects they will monitor in order to meet their goal. Have them list their parameters in the space provided on the ***Table Monitoring Worksheet.***

4. Instruct groups to record baseline data on their parameters. Baseline data is an initial data set that will be compared to subsequent data so changes can be noted. To establish a baseline, students should record how their chosen parameters look at the start. They must also decide how they plan to record their data (e.g., draw a picture of the object or write a narrative description). Give them ample time to gather this baseline data. When all groups have recorded their baseline data, explain that they will monitor this same desk in five minutes and again in ten minutes, and record any changes they observe in their chosen parameters on their ***Table Monitoring Worksheets.***

5. Start timing. While students share their monitoring goals and parameters with the class, casually alter the items on the desk (e.g., drink the coffee, turn pages in a book, use chalk to write on the board, etc.). Another option is to have the table in a separate room where an assistant makes the changes to the objects. The students then revisit the table as if they were visiting a stream.

6. After five minutes, have groups observe the items and record their observations (data) as before. Allow the groups an appropriate amount of time to collect their data.

7. Ask groups to share what they observed after the first monitoring session (while again changing items on the table). After five more minutes, have the students record their observations again.

8. Instruct the groups to analyze their data and record any changes that they observed in their parameters. Lead a discussion by asking the following questions:

- What changes did you observe?
- What trends did you observe in your data? (e.g., there was less coffee in the mug each time; the clock continued to move in the same direction at a steady rate.)
- What parameters stayed the same?

Part II

1. Review the steps conducted in *Part I:*

a. Establish a monitoring goal
b. Choose parameters to meet your monitoring goal
c. Collect and record meaningful data
d. Analyze the data by:
   1. gathering all needed information.
   2. listing results or findings of the data.

The next two steps in the process are: (not used in *Part I*)

   3. develop conclusions based on findings.
   4. present findings in an organized way.

2. Explain to students that they will now expand this study design to analyze and interpret actual water quality data from a river.

3. Divide students into groups and distribute copies of the *Kallang River Worksheet*, *Kallang River Overview*, and the *Kallang River Data Set* to each group.

4. Have groups write a paragraph describing the land uses occurring in the Kallang River watershed and the possible water quality impacts from them. (Students may conduct further research on the Kallang River and land uses at this time or select a watershed closer to their region of the world.)

5. Have students refer to the *Kallang River Overview* to answer the questions on their *Kallang River Worksheet.*

6. Assign one parameter to each group. Groups should examine the data for all dates to look for trends and anomalies (data that is out of line with the expected trends). Graphing data effectively illustrates trends and anomalies in water quality data.

7. Have groups answer the following questions:
What changes did you notice?
What trends did you observe in your data?
What parameters stayed the same over the monitoring period?

8. Have groups write a paragraph explaining their conclusions, or rationale for their findings. In real-life monitoring, the actual cause of anomalous data is often unclear. Causes may be attributed to testing error (Was it the middle of winter when sampling accuracy is affected by freezing temperatures?) or perhaps a weather event that led to unusually high or low results.

9. Have groups present a summary of their data, findings, and conclusions to the class.

Wrap Up

Have each group compare their parameter data with parameters set by other groups. Identify any relationships between the parameters (e.g., dissolved oxygen goes down as temperature goes up). Have students record their results (e.g., make overheads of their graphs and overlay them with other graphs to analyze relationships between the parameters).

Discuss how difficult it is to draw specific conclusions about the cause of water quality changes in a watershed based on limited data. Explain that this is a common challenge, as the exact cause of a change in water quality is frequently unknown. This uncertainty is the reason that water quality monitoring is critical. What findings and conclusions can be drawn from one sample data set from one date only?

Assessment

Have students:

- investigate the process of water monitoring (***Parts I and II***).
- develop a study design that leads to a monitoring project (***Parts I and II***).
- design an investigation to answer a research question (***Parts I and II***).
- collect and analyze data; develop findings, conclusions, and recommendations from that data (***Part II*** and ***Wrap Up***).

Extensions

Conduct a "town meeting" using the students' findings and conclusions. Have groups of students represent different stakeholders in the meeting—including a monitoring group to share the class findings at the meeting. The other groups could represent local landowners, farmers, businesses, etc. Have each group react to the findings and recommendations of the monitoring group.

Testing Kit Extensions

Develop a study design for a World Water Monitoring Day project on a local stream, river or lake. Use the World Water Monitoring Day Testing Kits to conduct water quality tests to fit chosen parameters.

Have the students submit their data to the World Water Monitoring Day website. Results may be entered anytime prior to December 31 for inclusion in that year's annual World Water Monitoring Day Year in Review report. Reporting data to the program's database allows students to share their experiences with others in the community, as well as around the world.

Resources

Dates, G. 1995. *Study Design Workbook*. Montpelier, VT: River Watch Network.

Edwards, N. 1996. *Singapore - A Guide to Buildings, Streets, Places*. Times Books International.

Mayio, A. 1997. *Volunteer Stream Monitoring: A Methods Manual*. Washington, D.C.: United States Environmental Protection Agency.

National Research Council. 2000. *Inquiry and the National Science Education Standards*. Washington, DC: National Academy Press.

River Network and Pennsylvania Department of Environmental Protection, Bureau of Watershed Conservation, Citizens' Volunteer Monitoring Program. 2000. *Designing Your Monitoring Program: A Technical Handbook for Community-Based Monitoring in Pennsylvania*. Harrisburg, PA: Pennsylvania Department of Environmental Protection.

Table Monitoring Goals

Group 1 Monitoring Goal: Tracking the changes in the amounts of all liquids. **What you will monitor:**	**Group 2** Monitoring Goal: Tracking changes in objects that are taller than 5 cm. **What you will monitor:**
Group 3 Monitoring Goal: Tracking changes in the size and location of writing implements. **What you will monitor:**	**Group 4** Monitoring Goal: Tracking changes in objects that are primarily blue, red, and green. **What you will monitor:**
Group 5 Monitoring Goal: Tracking changes in objects that are primarily white, black, and grey. **What you will monitor:**	**Group 6** Monitoring Goal: Tracking changes in objects that are greater than 50 cm^2 in size. **What you will monitor:**

Table Monitoring Worksheet

1. Monitoring Goal (from monitoring goal card):

2. The parameters you will monitor (from monitoring goal card):

3. Data Collection: Baseline Data–Draw or record the objects you are monitoring as they exist in their original state or position.

After 5 minutes–Draw or record what you observe about the objects you are monitoring.

After 10 minutes–Draw or record what you observe about the objects you are monitoring.

4. Data Analysis and Findings:
   - What changes did you observe?
   - What trends did you record in your data? (e.g., was there less coffee in the mug each time?)
   - What parameters stayed the same over the monitoring period?

Kallang River Worksheet

Refer to the ***Kallang River Overview*** and ***Kallang River Data Set*** to complete the following study design:

1. Monitoring Purpose:
2. Parameters to be monitored (see ***Kallang River Data Set***):
3. Data Quality Objectives:
4. How monitoring will be conducted:
5. Where monitoring will be conducted:
6. When monitoring will be conducted:
7. Who will conduct monitoring:
8. Quality Assurance Measures:
9. Data Analysis: Develop Findings about the Data:
    a. Graph the data for your parameter.

    b. Develop conclusions based on your findings about the data?

    c. Develop recommendations (e.g., no action, ways to reduce pollution, further monitoring, etc.):

Kallang River Data Set

Date	Turbidity (JTU)	Water Temp (°C)	DO (mg/L)	pH	Air Temp (°C)
29-Mar-09	1.7	27	6	8.4	28
19-Apr-09	0	28	5.2	8.5	28
7-Jun-09	0	29	5.8	7	29
21-Jun-09	0	29	3.1	6.9	31
5-Jul-09	0	29	6	8.1	30
12-Jul-09	0	30	6.2	7.7	29
19-Jul-09	0	30	5.2	7.1	30
25-Jul-09	7.2	30	5.3	7.2	30
26-Jul-09	4.3	29	6.7	7.2	30
2-Aug-09	0	30	7.3	7.8	31
18-Aug-09	0	30	4.4	6.9	31
23-Aug-09	46.4	30	5.8	7	30
29-Aug-09	0	30	7.6	8.3	30
6-Sep-09	20.5	29	6.7	6.8	29
13-Sep-09	2.6	30	8.6	8.7	30
27-Sep-09	5.1	32	9	9	29

Kallang River Overview

The Kallang River in Singapore flows from Pierce Reservoir to Merdeka Bridge (approximately 10km) making it the longest river in Singapore. In pre-colonial times, the original inhabitants of Singapore, the aboriginal biduanda orang kallang, lived in the swamps at the mouth of the Kallang River. They fished by boat and rarely traveled into the open sea. Sir Stamford Raffles landed in Singapore in 1819 to find half the population of 1,000 were orang kallang. Thus, the river was named the Kallang after its original inhabitatnts.

The Kallang River was once the victim of pollution from industrial and farming activities. However, in April 2006, the Singapore government announced plans to give a 200-meter stretch of the Kallang River at Kolam Ayer a US$2.5 million facelift. The "demonstration project" is part of the Active, Beautiful and Clean Waters Program to transform rivers and reservoirs into vibrant community hubs, and to get Singaporeans to cherish and take care of their waterways. Some of the world's best rivers such as the Charles River in the United States and the Cheonggye Stream in Seoul were used as examples when determing the best practices for this project.

By August 2007, the Kolam Ayer stretch of the river was transformed to include more greenery, floating decks, pathways and boardwalks for recreational activities. A water wheel was constructed as the centrepiece of the project. The water level in this section will be maintained at a contatnt 3 meters deep to allow for activities such as kayaking and dragon boating.

The river is now a popular spot for water sports. The Kallang Watersports Center provides facilities for water skiing, canoeing and dragon boating. There are beautiful sandy beaches at the Kallang Riverside Park which make a perfect location for picnicing and sunbathing. The park even has palm trees and gazebos to provide shade on hot days.

In 2009, the Environmental Engineering Society of Singapore conducted water quality testing at the location of the Merdeka Bridge on the Kallang River. The bridge and testing spot is located at a latitute of 1.3048 and longitude of 103.8684. World Water Monitoring Day Testing Kits were used and all testing was conducted at 13:00 on clear days with no preciptiation. The area surrounding the Merdeka Bridge is mainly commercial. All data collected was submitted on the World Water Monitoring Day website so that people from around the world could access the data.