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Water Sampler Design Project
Student Guide

Introduction

In the course of analyzing and solving problems in the everyday world, it is important to understand that mathematical analysis, scientific inquiry and technological design are often used in combination. In trying to meet certain criteria within constraints, a good problem solver will find they need to call on other sources of knowledge and skill, such as cost, system design, risk, benefit, trade-offs, and aspects of critical thinking and creativity.

As an example, in a water monitoring program, water samples are collected by wading into a stream or with the aid of a boat. While these methods would be applicable to most streams, ponds, and lakes, there are situations where more creative sampling means will be needed. In the scenario described below, the problem solver will need to respond to a specific design problem before they can engage in the rigors of science.

Scenario

A mysterious fish kill has occurred in a 100-ft section of the Arquin Creek that flows through one of the glacial gorges in Hester State Park. You are part of a student research team that has been granted permission by the state to perform a preliminary investigation of the site. Your team has decided to take water samples at various depths so that you can perform chemical tests. Maximum depth of the creek within the gorge has been estimated to be 10 feet. The structure

of the gorge where the fish kill has occurred limits your access to the creek. The stream is 20 feet across and is bounded on both sides by nearly vertical rock ledges that extend from a minimum of 2 feet to a maximum of 15 feet above the water's surface. You decide to build a sampling device that will allow you to retrieve water samples from the creek's edge to midstream from various locations along the rock ledges.

Challenge

Build and test a device for retrieving water samples from the rock ledges along the creek. Samples will be taken at various depths along the creek from the sides to midstream.

Restrictions

- Your sampling device must be operated from the rock ledges.
- Additional people may aid in device operation at an increase in cost to the design.
- You have access to the rock ledges on both sides of the stream.
- The only items that can be added to the design besides those listed in the parts catalog are ones that are not man-made and are accessible to everyone.

Design Criteria

1. **Your water sampler must cost $10.00 or less**
    - Use listed prices for items included in the parts catalog
    - Add $2.00 for each additional person needed to operate the water sampler
2. **Time**
    - building time for the water sampler is not to exceed 30 minutes
    - sampling speed (# of trials) should not exceed 5 minutes between trials
3. **Accuracy of sampling**
    - depth precision
    - no mixing with water from other depth
    - sampling success
    - volume of sample must exceed 100 ml
4. **Your water sampler should be durable.**
    - easy to handle
    - capable of performing several trials without repair

5. **Safety**
    - sampler components pose no hazards to the user
    - obtaining a water sample with the device poses no danger

Protocol #1

Define the Problem

Objective: To redefine the problem so that it includes all the general specifications and restrictions of the scenario.

Background:
It is very difficult to understand all aspects of a problem by just examining the original question. Many times the statement of the problem is biased by the specific wording used or not used, or by the way the question is asked. Good problem-solvers must constantly use all of their skills to search out and identify all the parameters that surround the problem under investigation. They will continue to redefine the problem until they have a complete understanding of what it is they need to solve.

Materials
- laboratory log

Procedure

1. Along with the members of your class team, read the **Introduction**, **Scenario**, and **Challenge** found on pages 1 and 2. This will give you an overview of the problem that your team is going to solve.

2. Read **Student Supplement A** found in the back of the **Student Guide**. This will supply your team with some basic background on water sampling. You may want to consult with your teacher on doing further research on water monitoring and water sampling. Record all appropriate information in your laboratory log.

3. Reread the **Introduction** and **Challenge**. In your laboratory log, write a statement of the problem that you will be attempting to solve.

4. Reread the **Scenario** carefully. In your laboratory log, make a list of the sampling constraints created by the specific structure of the gorge and the stream within it. Once this has been completed, redefine the problem. Your new problem statement should include the general specifications of the specific location to be sampled.

5. Read the **Restrictions** and **Design Criteria**. In your laboratory log, make a list of additional sampling constraints and design specifications and constraints. Based on

these additional parameters, redefine the problem. This new statement should be the problem that your design project is solving.

Analysis

1. Compare the problem statement contained in the original **Challenge** to the problem statement completed in step 5 of the protocol. How has it changed?

2. How did obtaining more background information assist you in redefining the problem?

Protocol #2

Identify Alternative Design Solutions

Objective: To brainstorm possible design solutions.

Equipment

- water sampler parts kit

Materials

- laboratory log
- commercial water sampler designs (**Student Supplement B**)
- design challenge parts list (**Student Supplement C**)
- water sampler parts catalog (**Student Supplement D**)
- cost analysis worksheet (**Student Supplement E**)

Procedure

1. Examine the parts supplied in the water sampler parts kit. The kit includes materials that can be used to build a variety of devices. Brainstorm possible ways of using the materials to construct a vertical water sampling device that meets your specific problem. **Student Supplement B** contains diagrams of commercial water sampler designs. Make a list in your laboratory log of all possibilities developed by members of your team. Include a sketch for each alternative developed. Refer to the **Water Sampler Parts Catalog** (**Student Supplement D**) for diagrams of the specific materials within the parts kit.

2. Calculate the cost of each of your alternative designs by using the **Cost Analysis Worksheet** (**Student Supplement D**). Refer to the **Design Challenge Parts List** (**Student Supplement C**) for costs of specific items that will be used within each design. Record costs for each alternative design in your laboratory log.

3. If necessary, brainstorm ideas for reducing costs of one or more alternatives. Refigure costs and record all changes in your laboratory log.

Protocol #3

Select the Best Alternative

Objective: To create and use a quantitative or qualitative scale to judge all alternative designs and modifications.

Background:
Each member of a problem-solving team will approach a problem using different sets of skills and ideas. As a result, several alternative solutions will be developed. Some similar and others quite different. Good problem-solvers must weigh each alternative and judge its overall worth against a set of conditions. In many cases, tradeoffs will be made in terms of safety, cost, properties, and availability.

Materials
- laboratory log
- design rubric (**Student Supplement F**)

Procedure

1. In order to select your best alternative, your team must determine the advantages and disadvantages of each alternative device. To do this, create a design rubric similar to the example below. List the specifications that you want to use to judge your alternatives and establish a scale to quantify each criteria. The best alternative is selected based on the results of this analysis. Use the blank **Design Rubric** (**Student Supplement F**) or an alternative.

Sample Design Rubric

As an example, students may rank each specification for each alternative on a scale of 1 to 3 as follows:

Numerical scale - Description
1 - poor
2 - acceptable
3 - good

Using the following matrix they can then select the best alternative based on the results of the analysis.

Specifications

Alternatives	cost	vertical	horiz. spec.	time	accuracy	safety	durability	TOTA

		spec.						L
Bill's idea	2	2	2	2	3	3	2	16
Mary's idea	1	2	1	2	2	3	1	12
Ted's idea	3	2	3	2	2	3	3	18
Marsha's idea	2	3	1	1	3	3	1	14

2. Your team may want to make modifications in one or more of the alternatives. For each modification made, repeat the assessment process by completing the design rubric.

3. When your best alternative has been selected, redefine the problem in terms of how your particular design will be used to sample the water and record it in your laboratory log.

Analysis

1. What are some of the tradeoffs that were made to select the best alternative?

2. Describe the reasoning for making modifications in any of the designs?

Exploration

Students could use this design rubric as a tool to make decisions on a variety of problems other than design questions. For instance, in deciding what brand of athletic shoes to buy or what college to apply to, students need to determine general specifications and select alternatives.

Protocol #4

Build and Test the Best Water Sampler Design

Objective: To build a water sampler that meets the specifications contained in the design problem.

Equipment

- water sampler parts kit
- additional items that may be added to the design
- 10 gallon pail or alternative container for water

Materials

- laboratory log

Procedure

1. Construct your water sampler device using the water sampler parts kit and any other acceptable materials that you have included in your design. As you construct your device, you may need to refine, eliminate, or add parts and/or specifications. Record all modifications in your laboratory log.

2. Test your device by sampling water from a 10 gallon pail. Place the pail in an appropriate place in the classroom that best allows you to meet the sampling criteria stated in your problem.

3. Based on the results of your testing, you may need to make modifications in your design. If necessary, make a list of alternatives and repeat **Activity 3** to determine the best alternative.

4. Repeat the testing and modification process until the device is complete. Record all the steps of the process in your laboratory log.

Analysis

1. Describe the modifications, if any, that were made in your design as you built and tested your water sampler device?

2. What additional information about your design did you obtain from the actual testing of the device that was not contained in your problem statement?

Exploration

This design and construction problem could be applied to other problems associated with monitoring water in streams, lakes, and ponds. For example, specific monitoring situations may require the construction of equipment to collect stream bank runoff, measure turbidity, and/or monitor maximum or minimum water levels.

Protocol #5

Self-assessment of the Constructed Water Sampler

Objective: To self-assess the quality of the constructed water sampler.

Background:

In today's workplace, workers must be able to construct models, arrive at solutions, and evaluate results. The evaluation of results includes worker assessment as well as product assessment. Assessment practices include manager assessment, peer assessment, and self-assessment.

Equipment
- constructed student water sampler

Materials
- laboratory log
- water sampler assessment rubric (**Student Supplement G**) or an alternative.

Procedure

1. Using the Water Sampler Self-assessment Rubric (**Student Supplement G**) to assess your finished water sampler. You will need to obtain the "weighing" importance for each criteria from your teacher.

2. Record the results of your assessment in your laboratory log and submit the rubric to your teacher.

Analysis
1. Why are some areas of the assessment more difficult to complete than others?

2. How does your assessment compare to those of other members of your team?

Protocol #6

Plan a Classroom Presentation

Objective: To develop a classroom presentation of the problem-solving process used to complete and test the student water sampler device.

Background:
A great deal of time and effort has been spent planning, designing, building and testing the finished product. In the workplace or in the world of science, the project or research is not complete until the results have been presented for public scrutiny. In many cases, the

presentation is designed to convince a particular audience about a particular product, method or design.

Equipment
- AV equipment
- presentation tools

Materials
- completed water sampler
- laboratory log
- presentation supplies
- presentation assessment rubric (**Student Supplement H**) or alternative

Procedure

1. In your group, plan a classroom presentation to illustrate how your constructed water sampler meets the specifications outlined in your redefined problem. You will need a presentation assessment rubric to guide your plan. Use the presentation rubric provided (**Student Supplement F**) or an alternative provided by your teacher. Begin preparing for your presentation by jotting down ideas about the advantages of your device. Be specific. The whole class is trying to minimize costs, meet time and sampling specifications, etc., so rather than claim that you have minimized costs, report precisely how much you have spent. Feel free to point out features that you think are good, especially those that are made of replacements for packaged parts. Include a demonstration of the operation of your sampler.

2. Once your group is clear about the important details to be conveyed, determine what presentation aids you will use. You may want to prepare a handout for the class or create transparencies to show on an overhead projector. If time permits, you might include the use of a computer presentation. Consult with your teacher.

3. Before your presentation, decide who in your group will cover each topic. Your presentation time will be limited and your group will need to state its case quickly and clearly.

Protocol #7

Classroom Presentation

Objective: To deliver a quality classroom presentation.

Background:
A great deal of time and effort has been spent planning, designing, building and testing the finished product. In the workplace or in the world of science, the project or research is not complete until the results have been presented for public scrutiny. In many cases, the presentation is designed to convince a particular audience about a particular product, method or design.

Equipment
- AV equipment
- presentation tools

Materials

- presentation supplied
- presentation assessment rubric (**Student Supplement H**) or alternative

Procedure

1. At designated time, give your classroom presentation.

2. When finished, ask your audience for feedback on what they considered the strong and weak points of your presentation.

3. Make an appointment with your teacher to review the results of your peer and teacher assessments of your presentation.

Analysis

1. What parts of your presentation did you feel were very strong?

2. Describe any changes you would make in your presentation if you were to do it again?

Student Supplement A

Water Quality Monitoring**

Designing a water quality monitoring program

The first step in designing a water quality monitoring program is to determine the purpose of the monitoring. This will help you select the variables to monitor. Decisions will be based on factors such as:

- Types of water quality problems and pollution sources that will likely be encountered
- Cost of available monitoring equipment
- Precision and accuracy of available monitoring equipment
- Capabilities of the volunteers

The variables most commonly monitored by volunteers include stream flow, dissolved oxygen and biochemical oxygen demand, temperature, pH, turbidity, phosphorous, nitrates, total solids, conductivity, total alkalinity, and fecal bacteria.

General preparation and sampling considerations

There are two general tasks that are accomplished anytime water samples are taken. They are preparation of the sampling containers and collecting samples.

Plastic or glass bottles along with plastic bags are common sampling containers. Reused sample containers and glassware must be cleaned and rinsed before the first sampling run and after each run. Cleaning usually consists of a washing with a brush and phosphate-free detergent and rinsing with cold tap water and then distilled or deionized water.

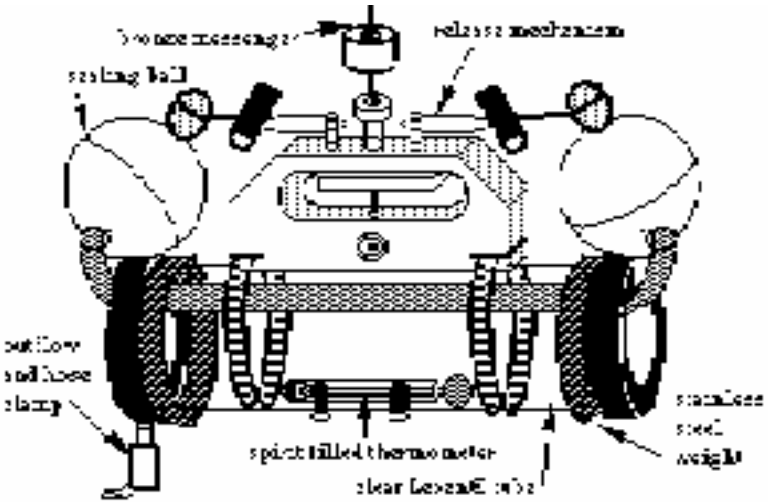
Water samples should be collected away from the streambank in the main current. Never sample stagnant water. The outside curve of the stream is often a good place to sample since the main current tends to hug this bank.. In shallow stretches the volunteer should carefully wade into the center current to collect the sample. A boat will be required for deep sites. An attempt should be made to maneuver the boat into the center of the main current to collect the water sample.

**** Volunteer Stream Monitoring: A methods Manual; EPA**

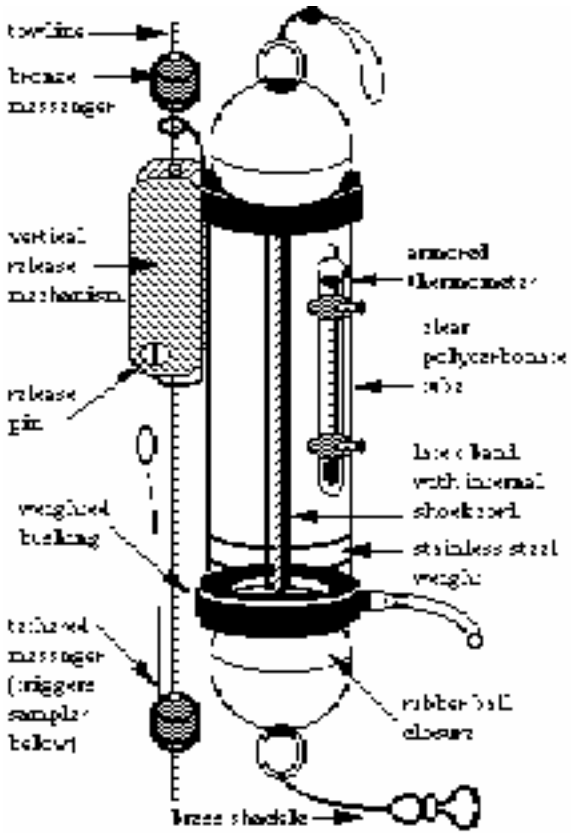
Student Supplement B

Commercial Water Samplers

Horizontal Water Sampler



Vertical Water Sampler



Student Supplement C

Design Challenge Parts List

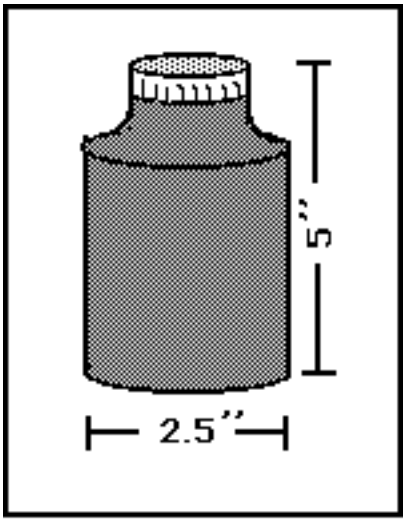
Equipment		Cost per item
8 oz. wide mouth polypropylene bottle with lid	.....	2.00
1/2' PVC pipe	.....	0.16/ft
6" plastic column section (1.5" PVC pipe)	.....	0.75
floats	.....	0.60
nylon string	.....	0.02/ft
duct tape	.....	0.05/ft
stoppers	.....	0.15
straws, paper clip, rubberband	.....	0.03

washers	**.....**	**0.03**
eye screw	**.....**	**0.03**
spring	**.....**	**3.50**
plastic soda bottle	**.....**	**0.05**
coffee can	**.....**	**0.05**
brick	**.....**	**0.50**
glue, rubber cement	**.....**	**free**

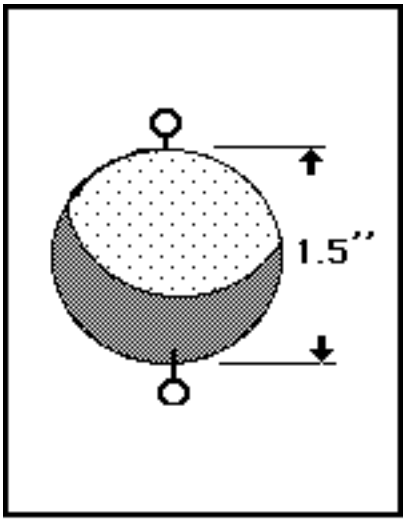
(see Design Parts Catalog for diagrams of specific parts)

Student Supplement D

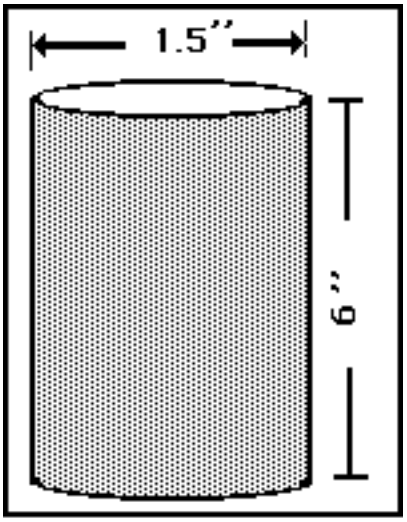
Water Sampler Parts Catalog



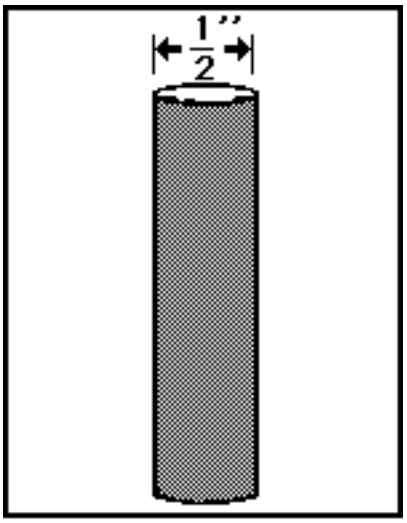
Item: 8 oz. bottle
Cost: $2.00



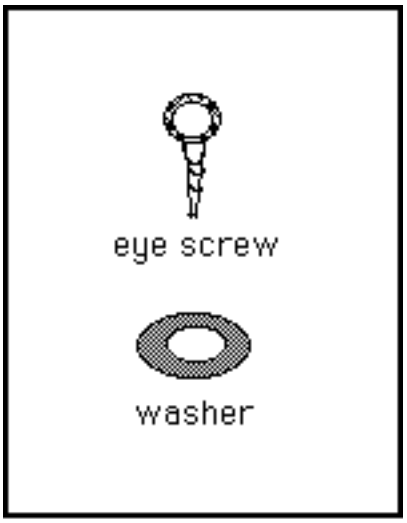
Item: float
Cost: $0.60



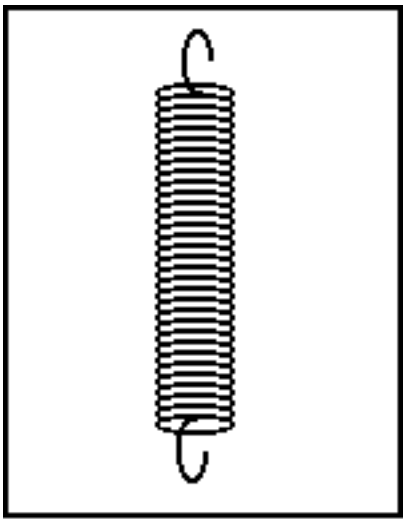
Item: plastic tube
Cost: $0.75



Item: 1/2" PVC pipe
Cost: $0.16/ft



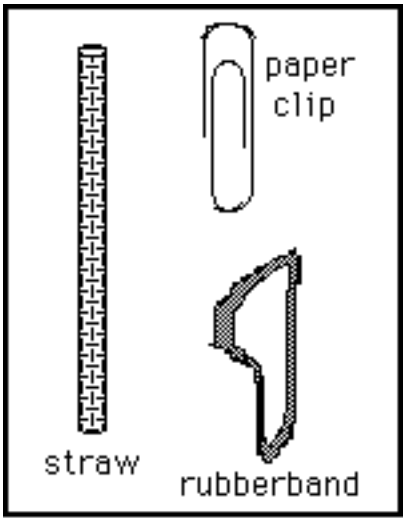
Item: hardware
Cost: $0.03



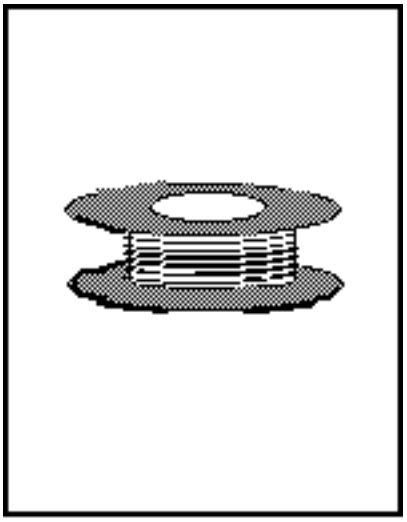
Item: spring
Cost: $3.50

Student Supplement D cont.

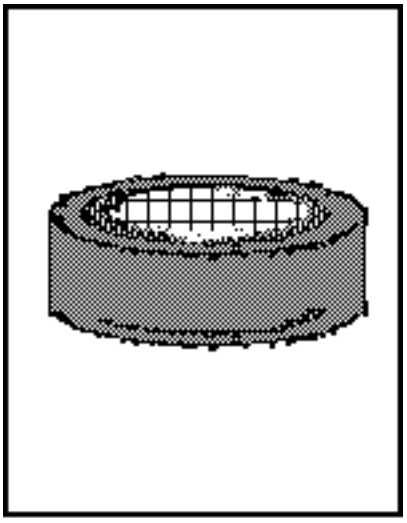
Water Sampler Parts Catalog cont.



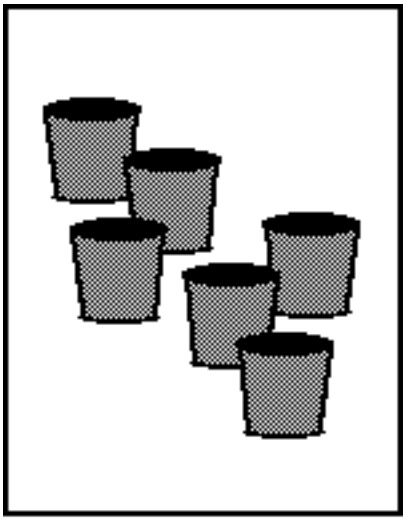
Item: supplies
Cost: $0.03



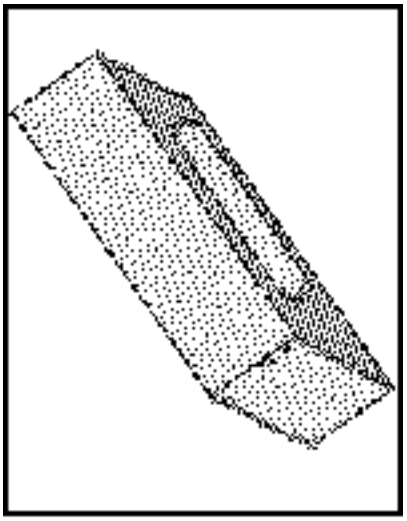
Item: nylon string
Cost: $0.02/ft



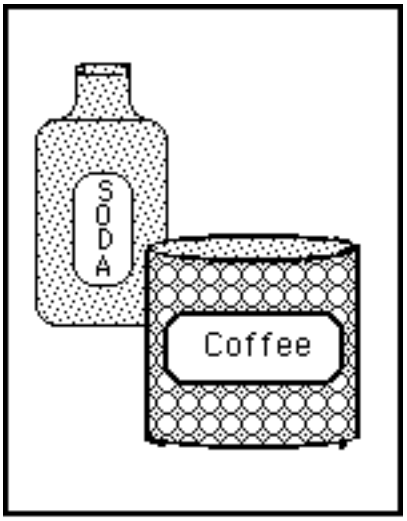
Item: duct tape
Cost: $0.05/ft



Item: stoppers
Cost: $0.15



Item: brick
Cost: $0.50



Item: Recyclables
Cost: $0.05

Student Supplement E

Vertical Water Sampler

Cost Analysis Worksheet

Item	# of pieces	Cost per item	Subtotal
		TOTAL:	

Cost Analysis Instructions

- In column 1, enter the name of the item you will use in your design.
- In column 2, enter the number of pieces or estimated length of the item.
- In column 3, enter the cost per of the specific item obtained from the **Parts List**.
- Multiply column 2 by column 3 to obtain the subtotal for the item.
- Add the subtotals of all items listed to determine the cost of your design.

Student Supplement F

Water Sampler Design Rubric

Alternatives Selection

Numerical scale - Description:
1 -
2 -
3 -
4 -
5 -

Specifications

									TOTAL
Alternatives									

==========

Modifications Selection

Numerical scale - Description:
1 -
2 -
3 -
4 -
5 -

Specifications

									TOTAL
Alternatives									

Student Supplement G

Water Sampler Self-Assessment Rubric

Team Members: _____ _____
_____ _____

Date: _____

Assessment Scale

5 - Exceeds minimum requirement
4 - Satisfies minimum requirements
3 - Minimum requirement questionable
2 - Does not meet minimum requirement
1 - no evidence for assessment

Design Criteria	Evaluation	Wgt.	Pts
The cost of sampler is less than $10.00	1 2 3 4 5	1 3 5	
Building time for the water sampler is less than 30 minutes	1 2 3 4 5	1 3 5	
Sampling trials can be made within 5 minutes	1 2 3 4 5	1 3 5	
The sampler can be used to obtain water samples from different depths with high precision	1 2 3 4 5	1 3 5	
The sampler can be used from shore and extend horizontally to a distance of 10 feet	1 2 3 4 5	1 3 5	
There is no mixing of water from other depths	1 2 3 4 5	1 3 5	
Your sample volume is greater than 100 ml	1 2 3 4 5	1 3 5	
Your water sampler is easy to handle and operate	1 2 3 4 5	1 3 5	
Your water sampler is capable of performing several trials without repair	1 2 3 4 5	1 3 5	
Your water sampler is safe to handle and operate	1 2 3 4 5	1 3 5	
		Total:	

Student Supplement H

Water Sampler Presentation Rubric

Presenters: _____ _____
_____ _____

Assessed by: _____

Date: _____

Assessment Scale

5 - Exceeds minimum requirement
4 - Satisfies minimum requirements
3 - Minimum requirement questionable
2 - Does not meet minimum requirement
1 - no evidence for assessment

Presentation Criteria	Evaluation	Wgt.	Pts
The cost of sampler is less than $10.00	1 2 3 4 5	1 3 5	
Building time for the water sampler is less than 30 minutes	1 2 3 4 5	1 3 5	
Sampling trials can be made within 5 minutes	1 2 3 4 5	1 3 5	
The sampler can be used to obtain water samples from different depths with high precision	1 2 3 4 5	1 3 5	
The sampler can be used from shore and extend horizontally to a distance of 10 feet	1 2 3 4 5	1 3 5	
There is no mixing of water from other depths	1 2 3 4 5	1 3 5	
Your sample volume is greater than 100 ml	1 2 3 4 5	1 3 5	
Your water sampler is easy to handle and operate	1 2 3 4 5	1 3 5	
Your water sampler is capable of performing several trials without repair	1 2 3 4 5	1 3 5	
Your water sampler is safe to handle and operate	1 2 3 4 5	1 3 5	

Overall quality of presentation	1 2 3 4 5	1 3 5	
Overall quality of the presentation	1 2 3 4 5	1 3 5	
		TOTAL	