Environmental Science with Vernier

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HANDS-ON ACTIVITIES

Investigating Dissolved Oxygen
- Optical DO Probe

Acid Rain and its Effect on Surface Water
- pH Probe

Freezing of Ocean Water
- Stainless Steel Temperature Probe
- Go Direct Temperature

Insulation Study
- Stainless Steel Temperature Probe
- Go Direct Temperature

Environmental Science Lab Books from Vernier

Book	Grade Level	Features
Investigating Environmental Science Through Inquiry	▪ High school ▪ College	▪ Correlated to AP and IB Standards ▪ 34 inquiry based investigations ▪ Available as an iBook
Renewable Energy with Vernier	▪ High school ▪ College	▪ NGSS aligned ▪ 26 experiments ▪ Includes experiments in wind energy and solar energy
Earth Science with Vernier	▪ Middle school ▪ High school ▪ College	▪ 33 experiments ▪ Includes experiments in soil analysis, water quality, meteorology, and energy
Water Quality with Vernier	▪ Middle school ▪ High school ▪ College	▪ 18 water quality tests, including pH, TDS, and dissolved oxygen ▪ Determing the Water Quality Index (WQI) of a local body of water ▪ comprehensive introduction providing important background information
Investigating Wind Energy	▪ K–8	▪ NGSS aligned ▪ 10 experiments and a culminating engineering project ▪ Investigate variables that affect power output of wind turbines
Investigating Solar Energy	▪ K–8	▪ NGSS aligned ▪ 9 experiments and 2 culminating engineering projects ▪ Explore variables that affect solar panel output

Dissolved Oxygen in Water

(Optical Dissolved Oxygen Probe)

Aquatic life depends upon oxygen dissolved in water, just as organisms on land rely upon oxygen in the atmosphere. Molecular oxygen is used by organisms in aerobic respiration where energy is released during the combustion of sugar in the mitochondria. Without sufficient oxygen, they suffocate. Some organisms, such as salmon, mayflies, and trout, require high concentrations of oxygen in the water. Other organisms, such as catfish, midge fly larvae, and carp can survive with much less oxygen.

Oxygen dissolves at the interface between the water and the air or when aquatic autotrophs release oxygen as a byproduct of photosynthesis. Abiotic factors including temperature and pressure influence the maximum amount of oxygen that can be dissolved in pure water. Biotic life also influences the amount of oxygen that is dissolved.

The following table indicates the oxygen and temperature tolerance level of selected animals. The quality of the water can be assessed with fair accuracy by observing the aquatic animal populations in a stream. These assessments are based on known dissolved oxygen tolerance. If a stream has only species that can survive at low oxygen levels, it is expected to have low oxygen levels.

Table 1

Animal	Temperature range (°C)	Minimum dissolved oxygen (mg/L)
Trout	5–20	6.5
Smallmouth bass	5–28	6.5
Caddisfly larvae	10–25	4.0
Mayfly larvae	10–25	4.0
Stonefly larvae	10–25	4.0
Catfish	20–25	2.5
Carp	10–25	2.0
Water boatmen	10–25	2.0
Mosquito	10–25	1.0

OBJECTIVES

- Measure the concentration of dissolved oxygen in water using an Optical DO Probe.
- Determine the effect of temperature on the amount of dissolved oxygen in water.
- Apply the results to predict the effect of water temperature on aquatic life.

MATERIALS CHECKLIST

LabQuest
LabQuest App
Optical DO Probe
Temperature Probe
two 250 mL beakers
100 mL beaker
polystyrene foam cup
1-gallon plastic milk container
hot and cold water
ice
goggles

PROCEDURE

1. Set the switch on the Optical DO Probe to the mg/L setting. The switch is located on the box containing the microSD card.

2. Connect the Optical DO Probe and the Temperature Probe to LabQuest. Choose New from the File menu.

3. Set up the data-collection mode.

   a. On the Meter screen, tap Mode.
   b. Change the data-collection mode to Selected Events.
   c. Select Average over 10 seconds.
   d. Select OK.

4. Start data collection.

5. Obtain two 250 mL beakers. Fill one beaker with ice and cold water. Place the polystyrene foam cup into the second, empty beaker.

6. Place approximately 100 mL of cold water and a couple small pieces of ice, from the beaker filled with ice water, into a clean plastic one-gallon milk container.

7. Seal the container and vigorously shake the water for a period of 2 minutes. This will allow the air inside the container to dissolve into the water sample.

8. Pour the shaken water into the polystyrene foam cup.

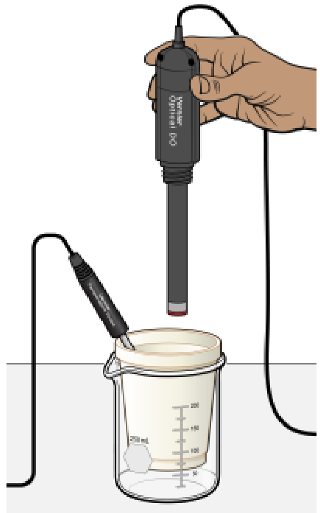

Figure 1

9. Place the Temperature Probe in the polystyrene foam cup as shown in Figure 1.

10. Place the shaft of the Optical DO Probe into the water. Make sure the silver dot on the side of the probe is submerged.

11. Monitor the dissolved oxygen readings displayed on the screen. Give the dissolved oxygen readings ample time to stabilize (90–120 seconds).

12. When the readings have stabilized, tap Keep. **Important**: Do not remove the probes until the 10-second averaging period is complete.

13. Remove the probes from the water sample.

14. Pour the water from the polystyrene foam cup back into the milk container. Seal the container and shake the water vigorously for 1 minute. Pour the water back into the polystyrene foam cup.

15. Repeat Steps 9–14 until the water sample reaches room temperature.

16. Fill a second beaker with very warm water about 40–50 °C. When the water in the polystyrene foam cup reaches room temperature, add about 25 mL of the very warm water prior to shaking the water sample.

17. Repeat Steps 9–14 until the water temperature reaches 35°C.

18. When all samples have been taken, stop data collection.

19. Tap the Table tab. Record the dissolved oxygen and temperature readings in Table 2.

20. Create a single graph of dissolved oxygen *vs*. temperature to help you answer the questions.

    a. Tap the Graph tab and choose Show Graph ►Graph 1 from the Graph menu.
    b. Tap the x-axis label and select Temperature.

DATA

Table 2	
Temperature (°C)	Dissolved oxygen (mg/L)

QUESTIONS

1. At what temperature was the dissolved oxygen concentration the highest? Lowest?

2. Does your data indicate how the amount of dissolved oxygen in the water is affected by the temperature of water? Explain.

3. If you analyzed the invertebrates in a stream and found an abundant supply of caddisflies, mayflies, dragonfly larvae, and trout, what minimum concentration of dissolved oxygen would be present in the stream? What maximum temperature would you expect the stream to sustain?

4. Mosquito larvae can tolerate extremely low dissolved oxygen concentrations, yet cannot survive at temperatures above approximately 25°C. How might you account for dissolved oxygen concentrations of such a low value at a temperature of 25°C? Explain.

5. Why might trout be found in pools of water shaded by trees and shrubs more commonly than in water where the trees have been cleared?

LabQuest
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Acid Rain and Its Effect on Surface Water

Acid rain can be very harmful to the environment. It can kill fish by lowering the pH of lakes and rivers. It can harm trees and plants by burning their leaves and depriving them of nutrients. It can also weather away stone buildings and monuments. But why is it more of a problem in some places than others?

To answer this question, let's first look at how rain becomes acidic. Carbon dioxide, CO_2, is a gas found naturally in the air. When CO_2 dissolves into rain droplets, it produces a weak acid called carbonic acid, H_2CO_3. This makes rain slightly acidic naturally. Rain of pH 5 to 6 is common and does not generally cause any problems. When fossil fuels are burned, however, gases such as sulfur dioxide, SO_2, are released into the air. When sulfur dioxide dissolves into rain droplets, sulfuric acid, H_2SO_4, is formed. This rain can be as acidic as pH 4. Figure 1 shows the trend of rain pH in the United States in a typical year. Notice that the most acidic rain occurs over and downwind from heavily populated and industrialized areas.

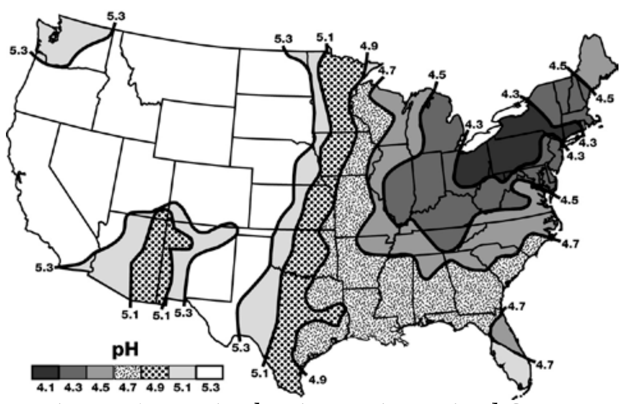

Figure 1: Typical rain pH in United States.

Acid rain is more harmful to some areas than others. This is because some water resists changes in pH better than others. Water that resists a change in pH is said to be *buffered*. Depending on the *buffering capacity* of the surface water, one area could be heavily damaged by acid rain that does not seem to harm another at all.

In Part I of this experiment, you will study how rain naturally becomes acidic due to CO_2 in the air. You will monitor the pH of water as you add CO_2 by blowing through a straw. In Part II, you will study the effect of acid rain has on the pH of different water types. The pH will be recorded as sulfuric acid is added dropwise to several different types of water.

OBJECTIVES

In this experiment, you will

- Use a pH Sensor to measure pH.
- Study the effect of dissolved CO_2 on the pH of distilled water.
- Study the effect on pH of dissolving H_2SO_4 in various waters.
- Learn why some bodies of water are more vulnerable to acid rain than others.

MATERIALS

LabQuest	ring stand
LabQuest App	utility clamp
Vernier pH Sensor	straw
100 mL beaker	wash bottle with distilled water
dilute H_2SO_4	soft water
waste beaker	hard water
dropper	buffer solution

PROCEDURE

Part I CO_2 and Water

1. Obtain and wear goggles! **CAUTION:** The sulfuric acid used in Part II of this experiment is a strong acid. Contact with sulfuric acid will damage your skin, eyes, and clothing!

2. Connect the pH Sensor to LabQuest and choose New from the File menu. If you have an older sensor that does not auto-ID, manually set up the sensor. **Important:** For this experiment your teacher already has the pH Sensor in pH soaking solution in a beaker; be careful not to tip over the beaker when connecting the sensor to the interface.

3. On the Meter screen, tap Rate. Change the data-collection rate to 1 sample/second and the data-collection length to 60 seconds. Select OK.

4. Add 50 mL of distilled water to a clean 100 mL beaker.

5. Lower the pH electrode into the beaker so that the water is covering the glass bulb.

6. Give a straw to the group member who will be blowing into the water.

7. Start data collection. After one data pair have been collected, begin blowing through the straw into the distilled water. You may take breaths as needed, but try to keep a fairly constant stream of air going into the water. Data collection will stop after 60 seconds.

8. Determine the maximum and minimum pH values.
   a. Choose Statistics from the Analyze menu.
   b. Record the maximum and minimum pH in the Part I data table.

9. Print the graph as directed by your teacher.

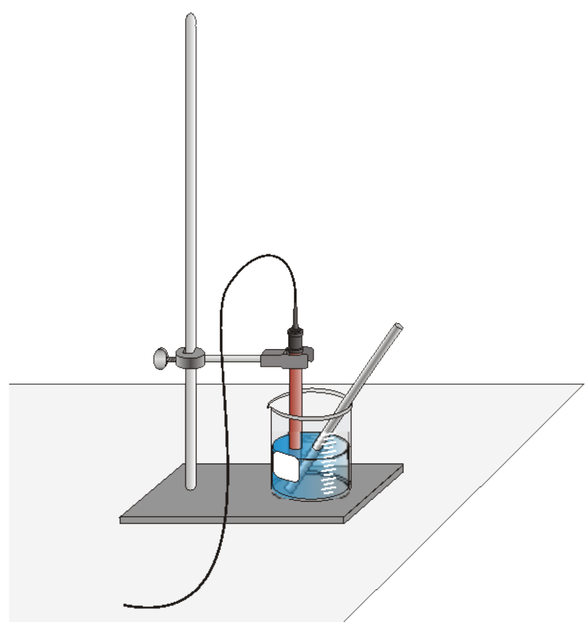

Figure 2

Part II Effects of Acid Rain on Surface Water

Acid Rain in Distilled Water

10. Set up LabQuest for data collection in the Event with Entry mode.
    a. On the Meter screen, tap Mode. Change the data-collection mode to Events with Entry.
    b. Enter the Name (Drops) and leave Units field blank. Select OK.
11. Rinse the pH electrode thoroughly with distilled water.
12. Wash and dry the 100 mL beaker. Get a new 50 mL portion of distilled water. Lower the pH Sensor into the distilled water.
13. Start data collection.
14. When the pH reading displayed on the screen stabilizes, tap Keep. Enter **0** (the number of drops). Select OK to save this data pair.
15. Add 1 drop of sulfuric acid to the water. **CAUTION:** Handle the sulfuric acid with care. It can cause painful burns if it comes into contact with skin, eyes, or clothing.
16. Stir thoroughly. When the pH is stable, tap Keep. Enter the number of drops of acid added to the beaker and select OK.
17. Repeat Steps 15–16, adding 1 drop at a time, until you have added 10 drops of acid.
18. Stop data collection.
19. To examine the data pairs on the displayed graph, tap any data point. As you tap each data point, the pH and drop number values are displayed to the right of the graph.
20. Record the maximum and minimum pH values in the Part II data table.
21. Store the data from the first run by tapping the File Cabinet icon.

Acid Rain in Soft Water

22. Repeat Steps 11–21 using 50 mL of soft water instead of distilled water.

Acid Rain in Hard Water

23. Repeat Steps 11–20 using 50 mL of hard water instead of distilled water. **Important**: Do not store this final run.
24. It is often helpful to view all three runs on one graph for comparison.
    a. Tap Run 3 and select All Runs.
    b. Print the graph or sketch it in the space below, labeling each line with the type of water used.

DATA

Part I CO_2 and Water

Table 1		
Maximum pH	Minimum pH	ΔpH

Part II Effects of Acid Rain on Surface Water

Table II			
	Distilled Water	Soft Water	Hard Water
Maximum pH			
Minimum pH			
ΔpH			

PROCESSING THE DATA

1. Calculate the change in pH (ΔpH) for the water in Part I and record in the Part I data table.
2. Calculate the change in pH (ΔpH) for each of the Part II trials and record in Part II data table.
3. Compare the ΔpH values. Which test gave the largest pH change? Which test gave the smallest pH change?
4. Hard water is said to be "naturally buffered." From the result of this experiment, explain what this means.
5. Many aquatic life forms can only survive in water with a narrow range of pH values. In which type of water—hard or soft—would living things be more threatened by acid rain? Explain.

6. Figure 3 shows the general trend in hard and soft water in the United States. There are numerous coal-burning electric power plants in Illinois that produce sulfur dioxide. As the prevailing winds carry the pollutants northwestward, they contribute to acid rain over the northeast. Based on what you have learned in this lab, do you think that Ohio and New York will be affected the same by this acid rain? Why or why not?

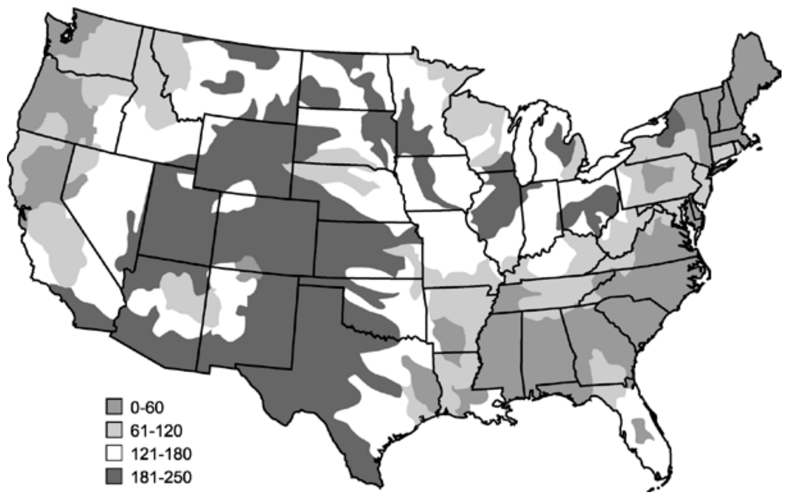

Figure 3: Typical water hardness as mg/L calcium carbonate

7. A similar situation exists in Europe where air pollutants from highly industrialized Germany are more harmful to Scandinavian water life than to water life in Germany. Use the results of this experiment to predict the relative hardness and softness of Germany and Scandinavia's water.

EXTENSIONS

1. Test ocean water in the same way you tested hard and soft water. How does it compare?

2. Do library research to get more information on the effects of acid rain on streams and lakes.

LabQuest
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Freezing Temperature of Ocean Water

During winter in the northern hemisphere, Arctic air temperatures often dip below what we normally think of as the freezing point of water. Yet, while freshwater lakes freeze over, much of the ocean stays in liquid form rather than freezing into ice. Why doesn't ocean water freeze at the same temperature as fresh water?

In this experiment, you will use a Temperature Probe to measure the temperature of water as it cools and then freezes. In Part I, you will collect temperature data as you freeze fresh water and determine its freezing temperature. In Part II you do the same for ocean water. You will then compare the two freezing temperatures and hypothesize why they are different.

OBJECTIVES

In this experiment, you will

- Observe the freezing of fresh water and ocean water.
- Use a Temperature Probe to measure temperature.
- Determine the freezing temperature of fresh and ocean water.

MATERIALS

LabQuest	salt
LabQuest App	ice
Temperature Probe	plastic spoon
test tube	fresh water
400 mL beaker	ocean water
ring stand	

PRE-LAB QUESTIONS

1. Predict at what temperature fresh water will freeze.

   ________ °C

2. Predict at what temperature ocean water will freeze.

   ________ °C

PROCEDURE

Part I Freezing Fresh Water

1. Connect the Temperature Probe to LabQuest and choose New from the File menu. If you have an older sensor that does not auto-ID, manually set up the sensor.

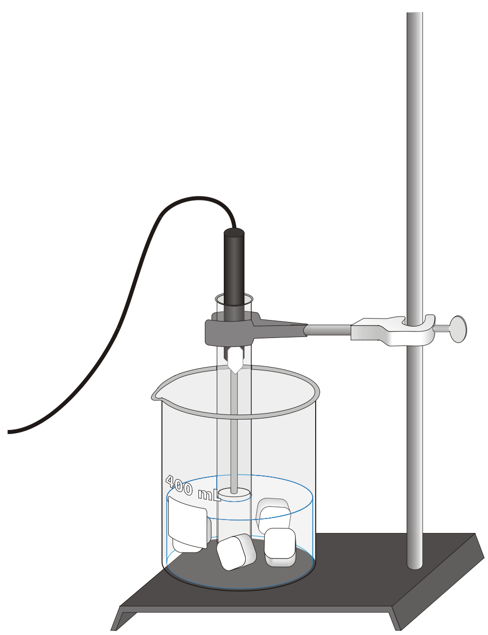

Figure 1

2. On the Meter screen, tap Rate. Change the data-collection rate to 0.1 samples/second and the length to 900 seconds. Data collection will last 15 minutes. Select OK.

3. Fill a 400 mL beaker 1/3 full with ice, then add 100 mL of water as shown in Figure 1.

4. Put 5 mL of fresh water into a test tube and use a utility clamp to fasten the test tube to a ring stand. The test tube should be clamped above the water bath. Place the Temperature Probe into the water inside the test tube.

5. When everything is ready, start data collection. Then lower the test tube into the ice-water bath.

6. Soon after lowering the test tube, add 5 spoons of salt to the beaker and stir with a spoon. Continue to stir the ice-water bath.

7. Slightly, but continuously, move the probe during the first 10 minutes of data collection. Be careful to keep the probe in, and not above, the ice as it forms. When 10 minutes have gone by, stop moving the probe and allow it to freeze into the ice. Continue to stir the ice-water bath. Add more ice cubes as the original ice cubes get smaller.

8. Make and record observations as the water freezes.

9. When 15 minutes have passed, data collection will stop. A graph of temperature *vs.* time will be displayed. To examine the data pairs on the displayed graph, tap any data point. As you tap each data point, the temperature values are displayed to the right of the graph.

10. Analyze the flat part of the graph to determine the freezing temperature of fresh water.
    a. Tap and drag your stylus across the flat portion of the graph to select the data points.
    b. Choose Statistics from the Analyze menu. The program will now calculate and display the statistics for the data in the region.
    c. Record the mean value as the freezing temperature in your data table. Round to the nearest 0.1°C.

11. Store the data from the first run by tapping the File Cabinet icon.

12. Do not attempt to remove the Temperature Probe from the ice! Place the test tube into a beaker of warm water to melt the ice, then remove the Temperature Probe.

Part II Freezing Ocean Water

13. Repeat Steps 3–10, this time using ocean water instead of fresh water. You may find that you need to add more ice and salt to the ice-water bath to freeze the ocean water. **Important:** Do not store this run as you did in the first run—proceed directly to Step 14 after you complete Step 10.

14. A good way to compare the freezing curves is to view both sets of data on one graph. To do this, tap Run 2 and choose All Runs.

15. Do not attempt to remove the Temperature Probe from the ice! Place the test tube into a beaker of warm water to melt the ice, then remove the Temperature Probe.

16. Sketch or print the graph as directed by your teacher. Label the lines "Fresh Water" and "Ocean Water" and write the freezing temperatures on your graph.

OBSERVATIONS

Part I Freezing Fresh Water

Part II Freezing Ocean Water

DATA

	Part I Fresh Water	Part II Ocean Water
Freezing Temperature (°C)		

PROCESSING THE DATA

1. Describe the shape of each graph.

   Part I – Fresh Water

   Part II – Ocean Water

2. What was happening to the water during the flat portion of each graph?

3. Based on your data, which type of water has to get colder in order to freeze, fresh water or ocean water?

4. In some areas, icy roads are “salted” to make them safer for drivers. Use your data to explain why this is an effective method.

EXTENSIONS

1. Ocean water has a salinity of about 35 ppt. Design and conduct an experiment to determine the freezing temperature of water with different concentrations of salt.

2. Freshwater streams and rivers can also stay in liquid form below the normal freezing temperature of water. Design and conduct an experiment to examine this phenomenon.

Experiment
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PRELIMINARY ACTIVITY FOR Insulation Study

Insulation is an important component of energy-efficient buildings. Insulation reduces both the energy required for wintertime heating and summertime cooling. Fiber glass, rock wool, cellulose, polyurethane foam, polystyrene foam, and foil-faced paper, polyethylene bubbles, and plastic film are common insulation materials. Basic insulation forms include blanket (batts or rolls), loose-fill, spray-applied, rigid insulation, and reflective systems.

In the Preliminary Activity, you will monitor the temperature of a bottle of warm water as it cools for three minutes and determine its cooling rate.

After completing the Preliminary Activity, you will first use reference sources to find out more about insulation before you choose and investigate a researchable question. Some topics to consider in your reference search are:

- insulation
- thermal insulation
- R-value
- energy efficiency
- energy-efficient technologies
- superinsulation

Later, you will use the class research results as you insulate the bottle in preparation for a contest to see which group can make the best-insulated bottle, as determined by lowest cooling rate.

PROCEDURE

1. Connect the Temperature Probe and the data-collection interface.
2. Obtain a small bottle and a one-hole rubber stopper that fits the bottle. Insert the Temperature Probe into the rubber stopper.
3. Fill the bottle with hot tap water. Insert the rubber stopper and Temperature Probe into the bottle.
4. Observe the temperature readings. When the readings begin to drop, start data collection.
5. When data collection stops, use the Linear Fit function to determine the cooling rate (slope). Record the cooling rate (in ºC/s).

QUESTIONS

1. What was the cooling rate of your water in the Preliminary Activity?
2. Identify two materials commonly used to insulate homes in your area.
3. List at least one researchable question for this experiment.

Digital Microscope Imaging Options from Vernier

Product Name	Order Code (Price)	Device Compatibility	Use
Celestron Digital Microscope Imager	CS-DMI ($79)	Computer Chromebook LabQuest 2	▪ Existing Microscopes ▪ Replaces an eyepiece
USB Digital Microscope	BD-EDU-100 ($119)	Computer Chromebook LabQuest 2	▪ Stand alone ▪ Independent light source
ProScope Micro Mobile Microscope	BD-PMM ($149)	iPad iPhone iPod Touch Galaxy S4	▪ Uses imaging apps on mobile device ▪ Independent light source ▪ Different sleeve for each device
ProScope 5MP Microscope Camera	BD-PS-MC5UW ($299)	Computer Chromebook iOS Devices Android Devices	▪ Existing Microscopes ▪ Replaces an eyepiece ▪ Connects to iOS and Android devices via Wi-Fi ▪ Connects to computers and Chromebooks via USB