LESSON 1: WHAT COLOR T-SHIRT SHOULD YOU WEAR ON A HOT, SUNNY SUMMER DAY?

Science - Grade 6-8

Objectives

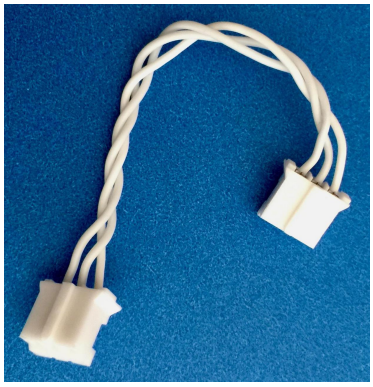
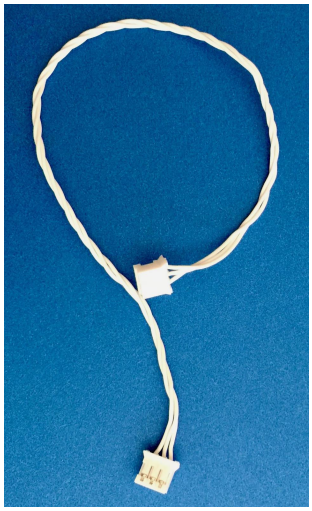
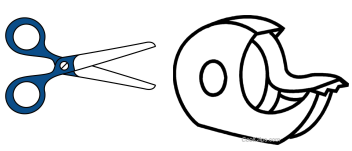
Experimentally measure the relative amount of light absorbed by various colors using the BOSON Temperature Sensor.
Develop an explanation as to why certain color clothing can increase or decrease our perceived degree of warmth or coolness when playing outside.

Standards

Science - Grade 6-8
NGSS - NEXT GENERATION SCIENCE STANDARDS - MIDDLE SCHOOL (MS)
Matter and Its Interactions - MS-PS1-3
Energy - MS-PS3-3
Waves and Their Application in Technologies for Information Transfer - MS-PS4-2
From Molecules to Organisms: Structures and Processes - MS-LS1-8
Engineering Design - MS-ETS1-3
COMMON CORE STATE STANDARDS
ELA/Literacy: RST.6-8.3, RST.6-8.7
Mathematics: MP.2, MP.4, 6.SP.B.5, 7.EE.3
COMMON CAREER TECHNICAL CORE STANDARDS
Science & Mathematics Career Pathway (ST-SM)
Apply science and mathematics to provide results, answers and algorithms for engineering and technological activities.
Apply science and mathematics concepts to the development of plans, processes and projects that address real world problems.
Analyze the impact that science and mathematics has on society.
Apply critical thinking skills to review information, explain statistical analysis, and to translate, interpret and summarize research and statistical data.
INTERNATIONAL SOCIETY FOR TECHNOLOGY IN EDUCATION STANDARDS
Empowered Learner 1a, 1b; Knowledge Constructor 3a, 3b, 3c, 3d; Innovative Designer 4a, 4d; Computational Thinker 5c

Materials

BOSON Science Kit Materials	*Diagram*
Battery Holder w/3x AAA batteries installed	
MainBoard-1IO (m2)	
Temperature Sensor (i11)	
Display Modulen(o11)	

1x short BOSON cable	
1x long BOSON cable	
Additional Materials	*Supplies & Materials*
6-8 sheets of different colored construction paper	
Scissors Tape and/or glue sticks	 

Timing Device	

Activity

Imagine it's a hot summer day. The sun is shining, there's no breeze and there are no clouds in sight. You wonder which of your many short-sleeved t-shirts you should wear today as you will be playing outside all day. Will you choose your favorite navy-blue t-shirt with dragons, your multi-colored striped one, white-colored one with pale pink polka dots, or a bright yellow one? Too many decisions!

- Explore this question by taking a poll of students in your class.
- Copy the chart below into your notebook.
- When completed, discuss the poll results with students sitting near you.
- Why do you think the t-shirt with the most votes would be the best t-shirt to wear outside?
- List a few reasons from your discussion which support the results of the poll.

T-Shirt Description	Number of students who think this is the best t-shirt to wear outside on a hot, sunny, summer day.
Navy blue with dragons	
Multi Colored striped	
White with pale pink polka-dots	
Bright yellow	
Possible reasons for poll results:	

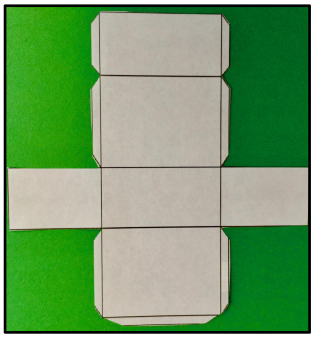
Explore

In this activity your group will use a variety of colored pieces of paper and measure the amount of light absorbed with the BOSON Temperature Sensor. The group will then work together to graph the data from your experiment and develop a set of guidelines which will explain how clothing color can help to keep you cool or warm when you are outside.

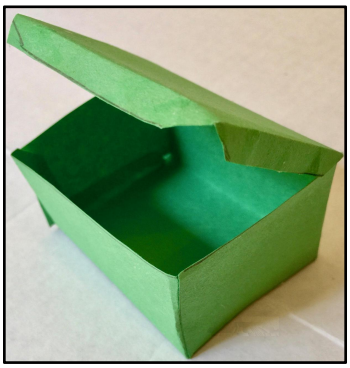
Activity Procedure:

Setup:

1. Using the rectangular prism net template in the Student Resources section, cut out one net for each colored sheet of construction paper.

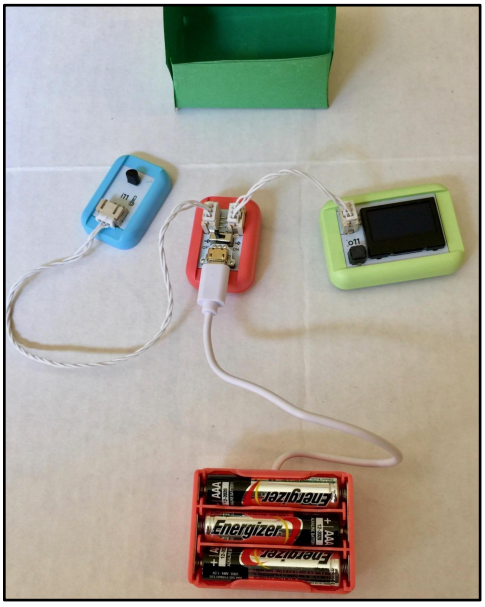


2. Assemble a rectangular prism for each colored sheet of construction paper leaving one of the ends open.



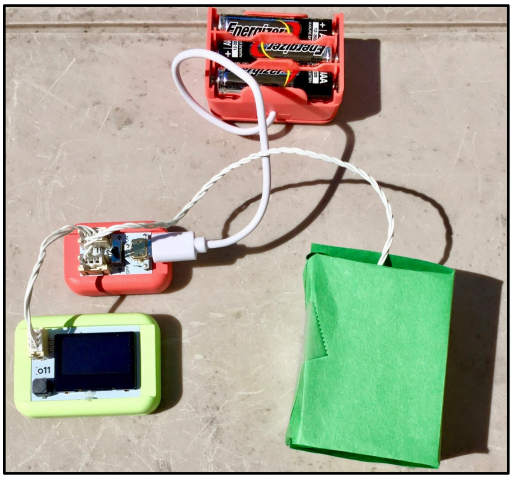
3. Set the rectangular prisms aside.
4. Attach the BOSON Battery Holder to the BOSON MainBoard-110. (Make sure the BOSON MainBoard-110 is turned off.)
5. Use 1x small BOSON cable and connect the BOSON MainBoard-110 to the BOSON Display Module.

6. Use 1 long BOSON cable and connect the BOSON MainBoard-110 to the BOSON Temperature Sensor.



Experiment

1. Rectangular prisms must remain in the shade until they are being used for testing.
2. Move your first rectangular prism into the sunlight.
3. Place the BOSON Temperature Sensor inside the prism and tape the lid shut.



4. Turn on the BOSON MainBoard-110 and adjust the Display Module to display Temperature in ℉.
5. Start the timer and record the temperature at the end of the 1st minute, 2nd minute and 3rd minute.
6. Turn off the BOSON MainBoard-110 and move to the shade for a minute.
7. Repeat Steps 2-6 for each additional rectangular prism.

8. Disconnect all BOSON equipment and place it back in the BOSON box.

Data Record

Copy the Data Table below into your notebook.

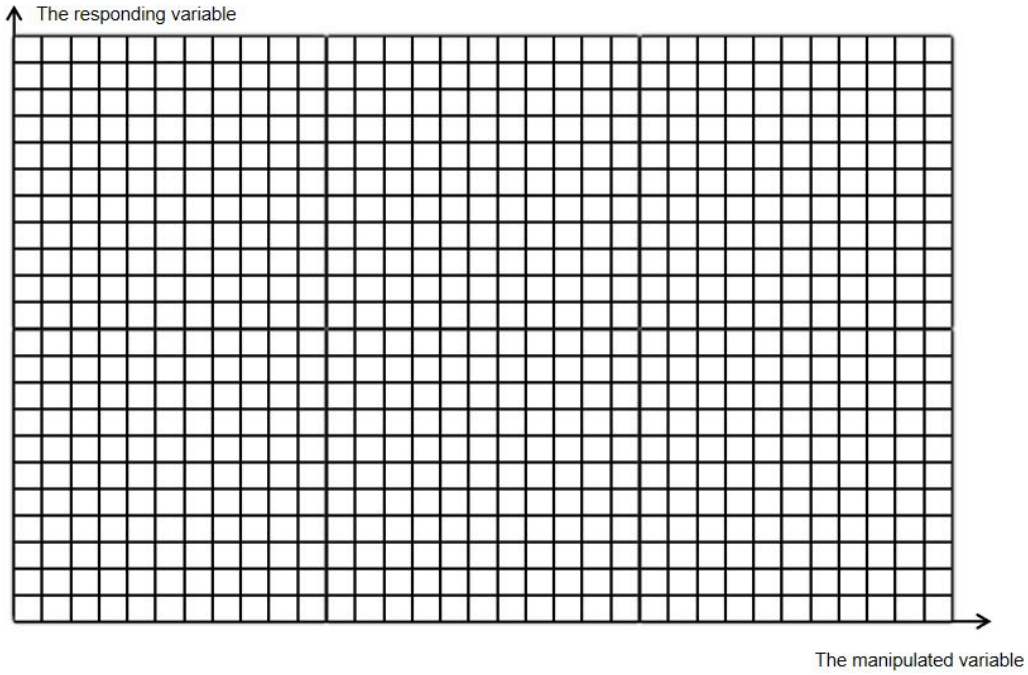
Color of Construction Paper Prism	Temperature (℉) at 1 minute	Temperature (℉) at 2 minutes	Temperature (℉) at 3 minutes

Explain

Making Sense of the Data:

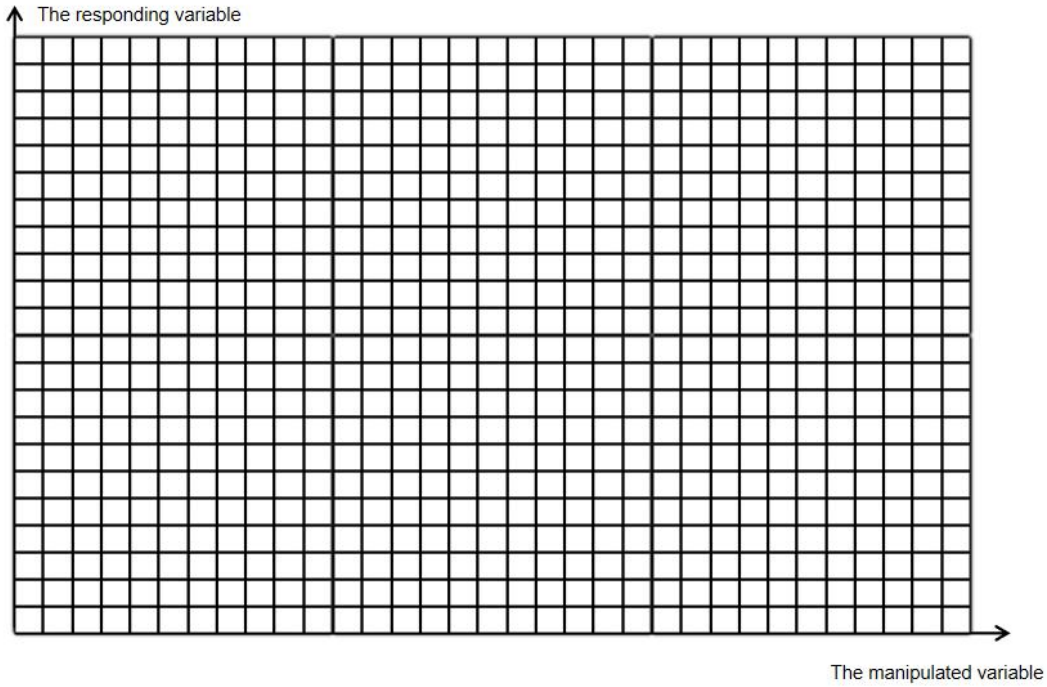
Create a Multi-Colored Line Graph according to the directions below:

1. Use graph paper and plot your results for each color. Use a different color that matches the color of the construction paper for each line. The manipulated variable is the color and the responding variable is the temperature.
2. The manipulated variable is graphed along the X axis and the responding variable is graphed along the Y axis.
3. Use the variables to give your graph a title.
4. Include a legend for your graph.



Create a Bar Graph according to the directions below:

1. Use the temperature data for all colors at the 3-minute reading.
2. The manipulated variable is the time and the responding variable is the temperature.
3. The manipulated variable is graphed along the X axis and the responding variable is graphed along the Y axis.
4. Use the variables to give your graph a title.
5. Include a legend for your graph.



Data Analysis:

In your groups discuss the following questions:

1. Examine the the various lines on the Multi-Colored Line Graph.
    a. Identify and discuss two similarities and two differences from the data.
    b. Which two lines appeared to be the farthest apart? Which two lines seemed to be the closest together?

2. Examine your Bar Graph.
    a. Which color recorded the highest temperature reading at 3 minutes?
    b. Which color recorded the lowest temperature at 3 minutes?
    c. Were there any colors for which the temperatures were close together at 3 minutes?

3. How might your results have changed if you repeated your experiment on a day when the temperature was the same but the sky was overcast?

Elaborate

Vocabulary:

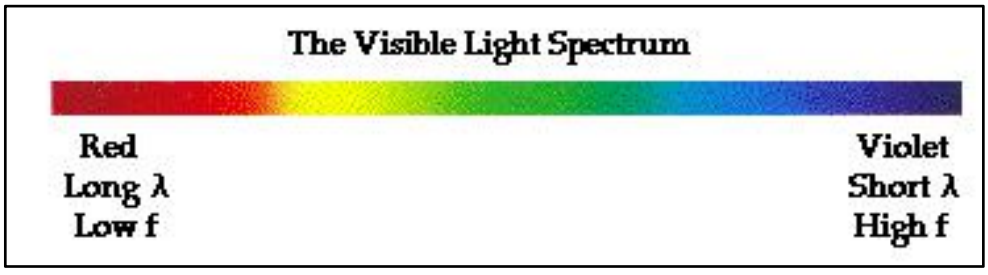
- Electromagnetic Waves - the entire range of wavelengths or frequencies of electromagnetic radiation extending from gamma rays to radio waves and including visible light
- Visible Light - the narrow band of wavelengths of the electromagnetic spectrum which is visible to the eye
- Absorption - the process by which light is taken in and converted into energy
- Reflection - the process by which light bounces off of an object

Science Background:
The First Law of Thermodynamics states that energy can be neither created or destroyed, only changed in form. Where do you think the energy comes from to cause the temperature to increase as shown on your graphs? If you answered the sun then you were correct. Light energy emitted from the sun strikes the rectangular prism and is changed to heat energy. How does this happen? Why was not the temperature increase the same for the different colors?

Read the following information to help you further understand your data and graphs.

When light strikes an object it can do one of three things: it can be absorbed by the object, it can be reflected by the object, or it can be transmitted through the object. In this experiment you looked at how much heat was absorbed by the rectangular prisms.

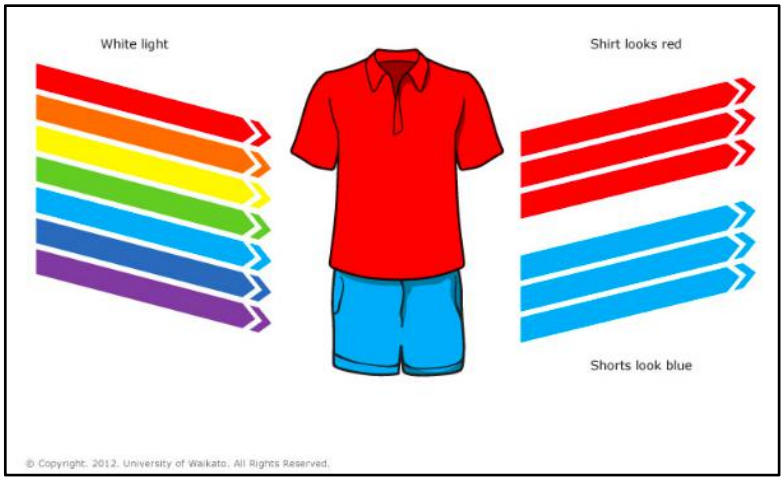
Visible light is a small part, a narrow band of electromagnetic waves within the entire electromagnetic spectrum. Wavelengths of visible light include the light we are able to see and are known as the ROYGBIV (red, orange, yellow, green, blue, indigo, violet) band of electromagnetic waves. Each color is associated with a unique wavelength.



Every object absorbs some light. The rest of the light is reflected back off the object and we see the object as a certain color. When we perceive an object as white we are really looking at an object that is reflecting all the wavelengths of the visible light spectrum. Conversely,

when we perceive an object as black we are really looking at an object of which absorbs all wavelengths from the visible light spectrum and no light is reflected back to our eyes.

An object that appears blue to us is an object that absorbs all visible light except blue light which is reflected off the object. An object that appears red to us is an object that absorbs all visible light wavelengths, except the red light wavelengths which are reflected off the object.
Light energy that is absorbed by an object is changed to heat energy. The more light energy that is absorbed, the more heat energy is produced.



Evaluate

Consider the following questions:

1. After reading the material above, explain why some colors tested resulted in higher temperatures than others when exposed to light.
2. You notice a person wearing a green and blue striped shirt. In terms of light absorption and light reflection explain why the shirt appears green and blue when sunlight strikes the shirt.

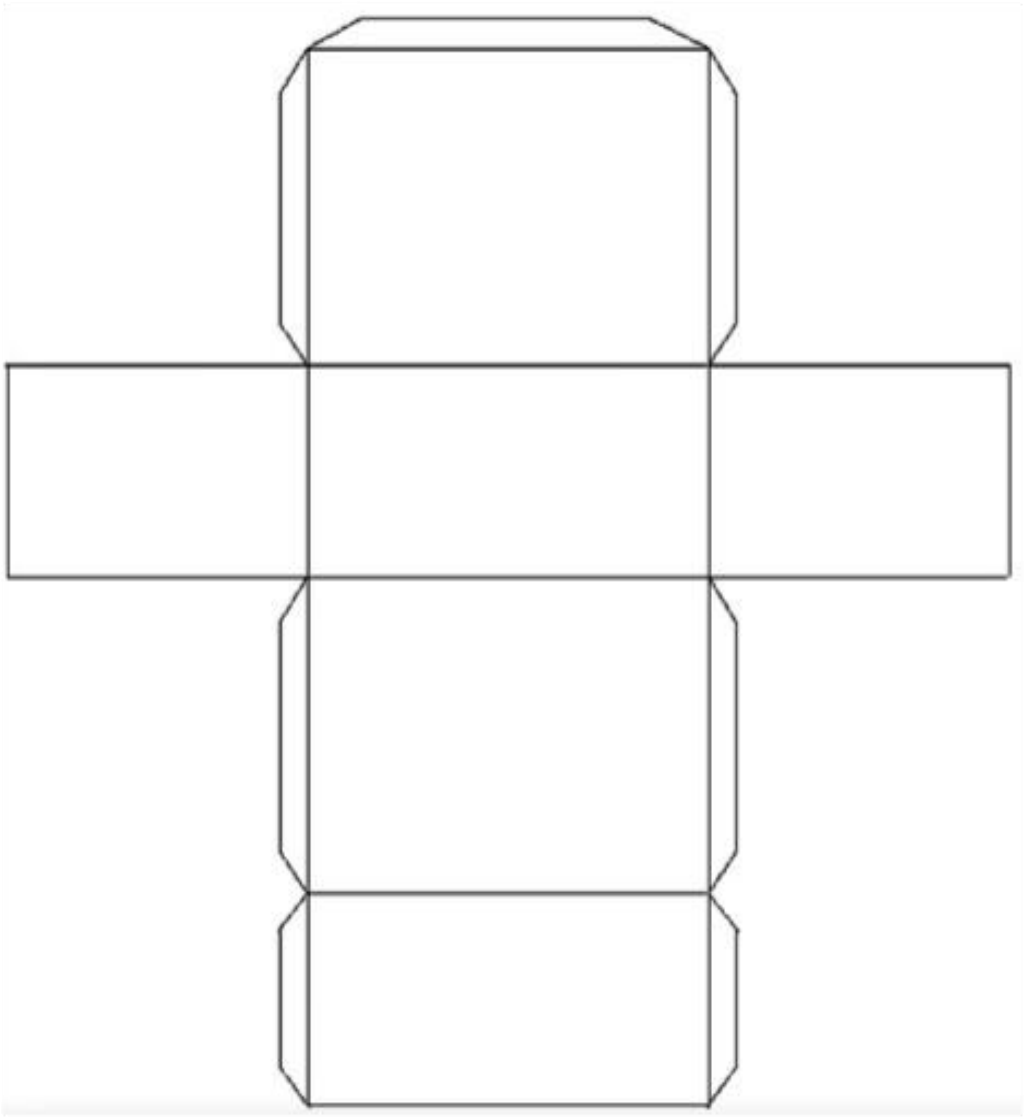
Extend

- Using the information from this lesson write an audio script, create a comic strip or a short video, or create a skit which will help a 5-year-old child choose a t-shirt to wear.

- Research new technologies associated with materials that claim to keep a person warm on a cold day or cool on a hot day. Many of these technologies are used in athletic apparel. How do these materials work?
- Research how light is absorbed or reflected by other materials. Design a chocolate candy bar wrapper which would keep the chocolate from melting when exposed to the heat of a summer's day.

Student Resources:

Rectangular Prism Net



LESSON 2: Which Coffee Cup is BEST?

Science - Grade 6-8

Objectives

Not all coffee cups are created equal in terms of materials and how those materials affect energy transfer. In this lesson you will construct a temperature sensor with the Boson Kit. Using the waterproof temperature sensor, you will be able track temperature changes in various kinds of coffee cups. The materials in each cup will affect energy transfer differently. Will students be able to guess which cup keeps their teacher's coffee hottest for the longest period of time?

Standards

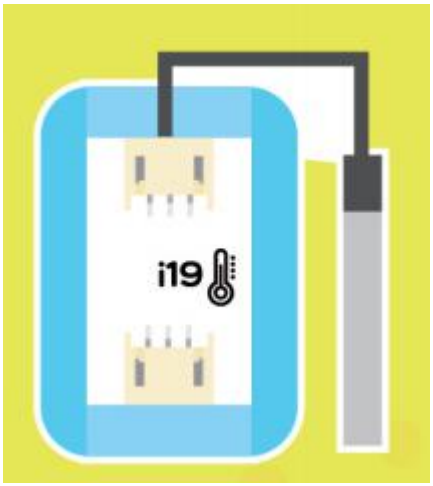
NGSS - NEXT GENERATION SCIENCE STANDARDS - MIDDLE SCHOOL (MS)

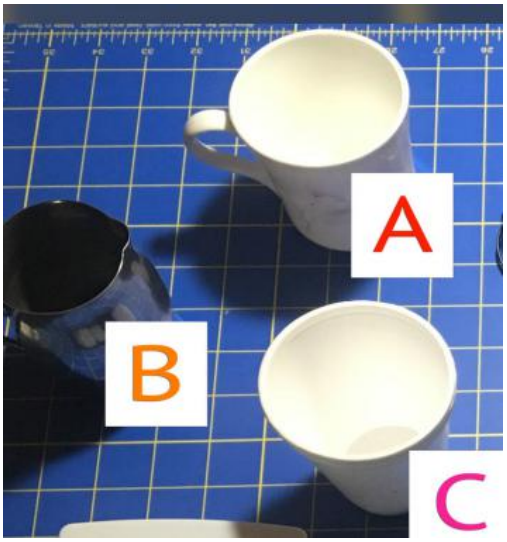
MS-PS3-4 Energy

Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

Materials

BOSON Science Kit Materials	*Diagram*
Battery Holder w/3x AAA batteries installed	

MainBoard-1IO (m2)	
Waterproof Temperature Sensor&Cable	
Display Modulen(o11)	
1x short BOSON cable	

1x long BOSON cable	
Additional Materials	*Supplies & Materials*
Ceramic coffee cup Metal coffee cup Styrofoam coffee cup	
ice	

Hot coffee	
plastic plate metal plate	

Activity

In order to get a better understanding of how energy is transferred have students observe this surprising phenomenon.

1. Have the students place their hands on a piece of metal and a piece of plastic at the same time.Ask the students which object feels warmer and which feels colder. When the students reply that the plastic feels warmer. Ask them if they believe that the 2 objects are at the same temperature. If available, use an infrared thermometer to show them that they are indeed the same temperature
2. Put a piece of ice on each and ask which students think will melt the ice faster. There is always surprise in the room when the “cooler” metal melts the ice more quickly. If you do not have access to these materials, you can show a video in which the same experiment is performed.

plate	Tactile	Which melts the ice faster
plastic plate		
metal plate		

Why does the metal plate melt the ice faster?

There are 2 concepts that students often confuse: temperature and heat. While they seem very similar, they are not the same. These 2 concepts make the results of this experiment surprising.

What is temperature really?

Temperature is the “degree” of hotness of an object. It can be determined from the motion of the particles. If the particles are moving fast, then the temperature is high and vice-versa. The movement of the particles in an object, temperature, is only one part of heat.

What is heat?

Heat is the quantity of hotness. Temperature affects heat but there are other factors that affect heat too. The mass of the particles and quantity of particles in an object also affect heat.

How is heat transferred?

Heat is transferred when warmer objects like your hand touch cooler objects like the metal plate. The plate pulls out heat from your hand.

When you touch an object, you are not feeling its temperature, rather you are feeling the rate at which heat is being pulled out of your body. When you touch an object you feel heat transfer.

Why does the metal plate melt the ice faster?

As we learned on the last page, heat is affected by more than one factor. Heat is transferred at different rates based on what the object is made of and the characteristics of that object’s particles.

The metal plate is able to transfer heat faster to the ice cube because the particles in a metal are much closer together. The metal plate “feels cooler” because it pulls heat from your hand faster than the plastic plate.

When your hand touches the metal plate, the metal pulls heat from your hand faster than plastic. When ice touches the metal plate, the metal pushes heat to the ice faster than plastic. Metal transfers heat faster because the particles in a metal are much closer together than the particles in plastic.

Explore

Based on the phenomenon, have students make some educated guesses about different materials and how they transfer heat.

Activity Procedure:

Setup:

1. Ask students to come up with a list of good and bad conductors. The list should include materials but can also include properties of those materials.

Good Heat Conductors	Poor Heat Conductors
Metal Heavy Dense Shiny Cold to touch ...	Light Plastic Warm to touch ...

2. Next you should take out the 3 types of cups. Ask students how you could find which cup is the best cup at keeping the coffee warm.

Experiment

Discuss the different things we will measure, change, and try to keep constant so that we can make intelligent conclusions.

Dependent Variable

The temperature would be the dependent variable. The dependent variable is what is measured.

Independent Variable

The type of cup would be the independent variable. The independent variable is what the experimenter purposefully changes.

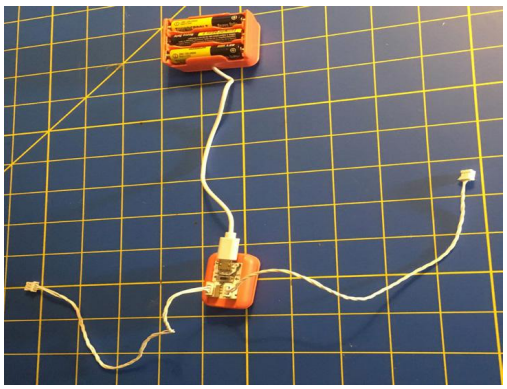
Controlled Variables

The time that passes before a temperature measurement is taken, the amount of water in the cups, and the starting temperature of the water should be the controlled variables. Controlled variables are held constant or the same for all the cups.

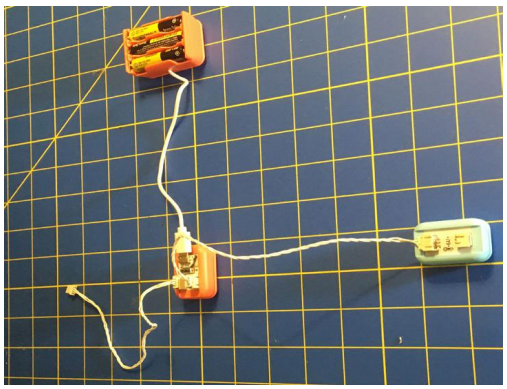
Then we need to build their own temperature sensor using the Boson Kit.

In order to measure the temperature change over time, you can build a temperature sensor using the Boson Kit.

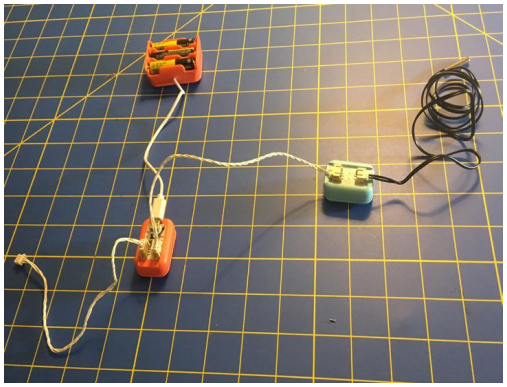
1. Connect the Battery Holder (I) and two Module Cables (K) to the Mainboard (H)



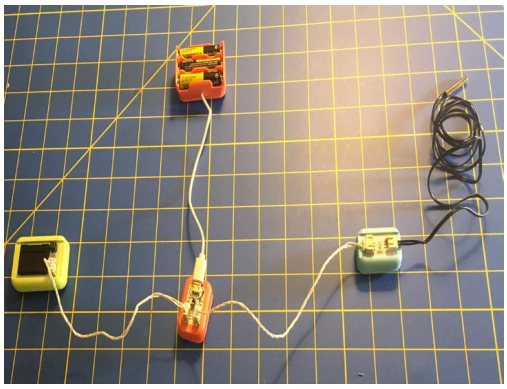
2. Connect the Waterproof Temperature Sensor (F) to the input side of the Mainboard (H) with a Module Cable (K)



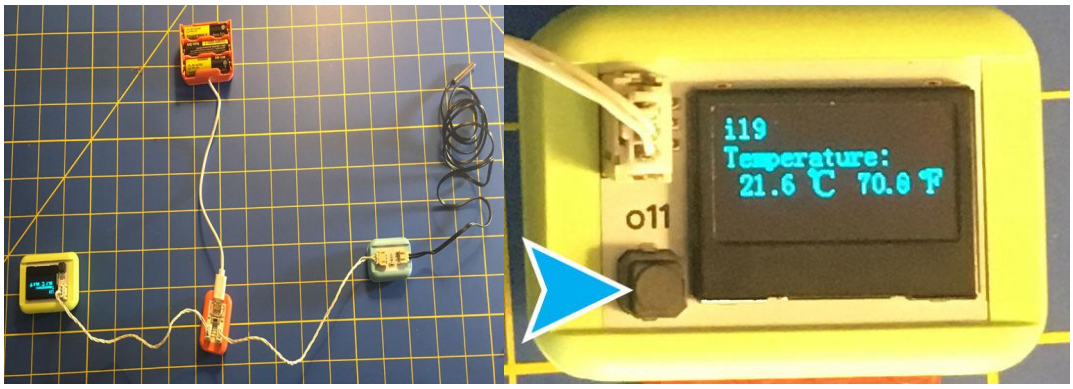
3. Connect the Waterproof Temperature Sensor Cable (E) to the Waterproof Temperature Sensor (F)



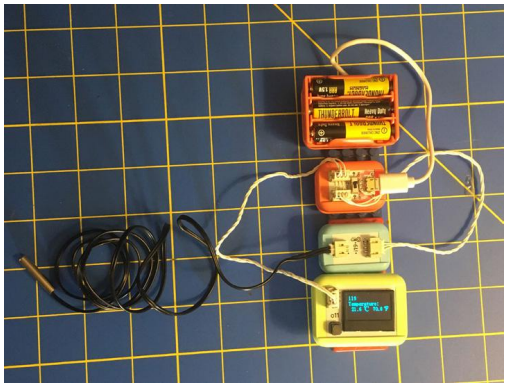
4. Connect the OLED Module (G) to the output side of the Mainboard (H) with a Module Cable (K)



5. Press the button on the OLED Module (G) until the screen turns on



6. Keep all the modules from sliding around during the experiment by attaching the modules to Legos (L)



Data Record

Copy the Data Table below into your notebook.

Time	ceramic coffee cup(F)	metal coffee cup(F)	styrofoam coffee cup(F)
Initial value			
1min			
2min			
3min			
4min			
5min			
6min			
7min			
8min			

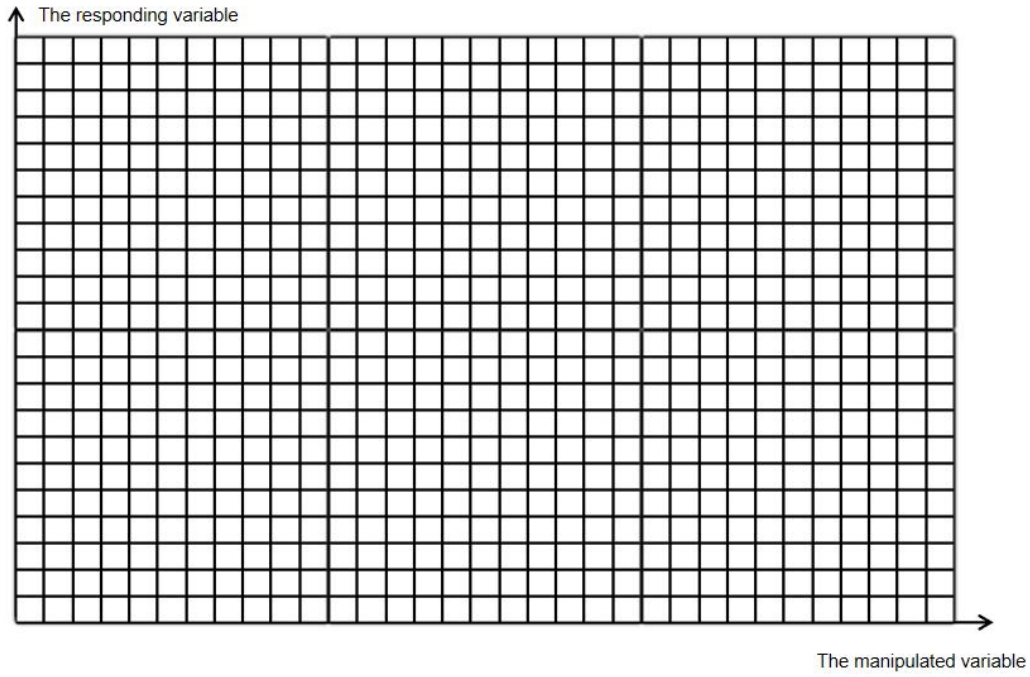
Explain

Making Sense of the Data:

Create a Multi-Colored Line Graph according to the directions below:

1. Use graph paper and plot your results for each color. Use a different color that matches the time of the construction paper for each line. The manipulated variable is the color and the responding variable is the temperature.

2. The manipulated variable is graphed along the X axis and the responding variable is graphed along the Y axis.
3. Use the variables to give your graph a title.
4. Include a legend for your graph.



Data Analysis:

In your groups discuss the following questions:

1.Examine the the various lines on the Multi-Colored Line Graph.

a. Identify and discuss from the data whether it is consistent with the expected data.

b. Is there a regular change in temperature? Why?

2.whether your hypotheses were correct and justify their conclusions with your data.

as well as discussion questions that your should fill in.

Elaborate

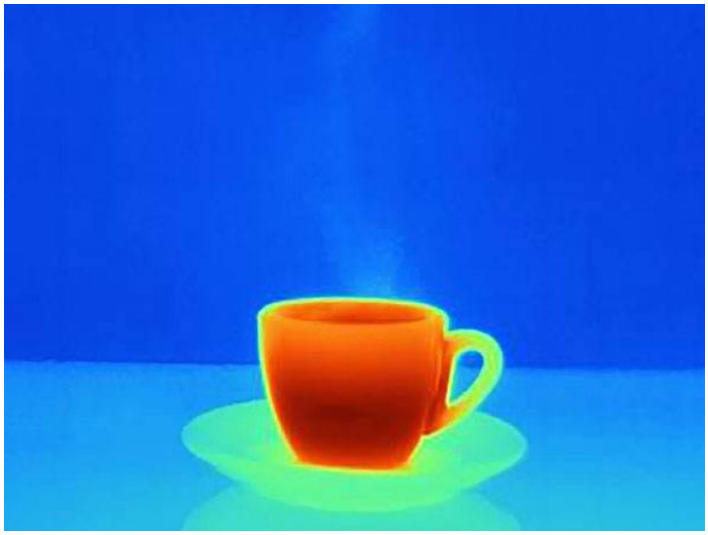
Vocabulary:

- Energy transferred - Heat transfer, the exchange of thermal energy via conduction, convection and radiation.
- The type of matter - Different materials have different thermal conductivity.
- Kinetic energy - The particles and the nature of kinetic energy transfers during collisions is strictly thermal.

Science Background:

Heat conduction, also called diffusion, is the direct microscopic exchange of kinetic energy of particles through the boundary between two systems. When an object is at a different temperature from another body or its surroundings, heat flows so that the body and the surroundings reach the same temperature, at which point they are in thermal equilibrium. Such spontaneous heat transfer always occurs from a region of high temperature to another region of lower temperature, as described in the second law of thermodynamics.

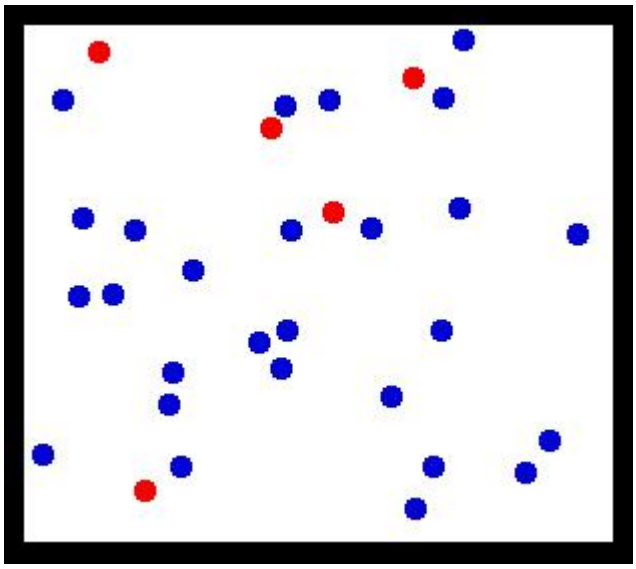
Heat convection occurs when bulk flow of a fluid (gas or liquid) carries heat along with the flow of matter in the fluid. The flow of fluid may be forced by external processes, or sometimes (in gravitational fields) by buoyancy forces caused when thermal energy expands the fluid (for example in a fire plume), thus influencing its own transfer. The latter process is often called "natural convection". All convective processes also move heat partly by diffusion, as well. Another form of convection is forced convection. In this case the fluid is forced to flow by use of a pump, fan or other mechanical means.



The kinetic theory of gases is a historically significant, but simple model of the thermodynamic behavior of gases with which many principal concepts of thermodynamics were established. The model describes a gas as a large number of identical submicroscopic particles (atoms or molecules), all of which are in constant, rapid, random motion. Their size is assumed to be much smaller than the average distance between the particles. The particles undergo random elastic

collisions between themselves and with the enclosing walls of the container. The basic version of the model describes the ideal gas, and considers no other interactions between the particles and, thus, the nature of kinetic energy transfers during collisions is strictly thermal.

The kinetic theory of gases explains the macroscopic properties of gases, such as volume, pressure, and temperature, as well as transport properties such as viscosity, thermal conductivity and mass diffusivity. The model also accounts for related phenomena, such as Brownian motion.



Evaluate

Consider the following questions:

1. Why metal coffee cups dissipate heat faster?
2. What is temperature really?
3. What is heat?

LESSON 1: WHAT COLOR T-SHIRT SHOULD YOU WEAR ON A HOT, SUNNY SUMMER DAY?

Science - Grade 6-8

Objectives

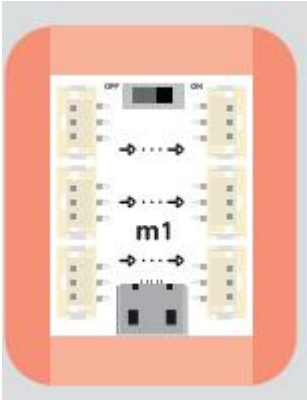
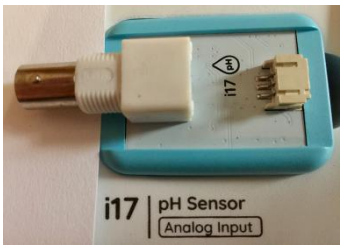
In this chapter, the experiment will guide you to use a pH sensor to find out what kind of acidic or alkaline aqueous solutions are there in life. Moreover, the measured values can even be displayed on a small screen!

Standards

NGSS - NEXT GENERATION SCIENCE STANDARDS - MIDDLE SCHOOL (MS)
From Molecules to Organisms: Structures and Processes - MS-LS1-5
Earth and Human Activity - MS-ESS3-3, MS-ESS3-4, MS-ESS3-5
Matter and its Interactions,MS-PS1-2

Materials

BOSON Science Kit Materials	*Diagram*
Battery Holder w/3x AAA batteries installed	

MainBoard-3IO (m1)	
Display Modulen(o11)	
pH Sensor (i17)	
pH Probe	

1x short BOSON cable	
1x long BOSON cable	
Clear Plastic Cups	
Different liquids	

Activity

When eating food or drinking water, all kinds of tastes like sweet, sour, bitter and salty are experiences through our tongue. So, is there a method to measure the acidity or alkalinity of aqueous solution? Today we will introduce a unit used to express the degree of acidity or alkalinity - pH value.

PH value is an indicator of hydrogen ion concentration in aqueous solution, which is also commonly used to measure the acidity or alkalinity of solution. Under standard conditions (25 degrees Celsius and 1 atmosphere), the aqueous solution with pH=7 (e.g., pure water) is neutral; the solution with pH less than 7 indicates a elatively high concentration of hydrogen (H+)ions, so the solution tends to be acidic; while pH greater than 7 means a relatively low hydrogen ion concentration, so the solution tends to be alkaline. Therefore, the smaller the pH value, the stronger the acidity of the solution; the higher the pH value, the stronger the alkalinity of the solution.

Let's guess how acidic and alkaline these four liquids are.

- Explore this question by taking a poll of students in your class.
- Copy the chart below into your notebook.
- When completed, discuss the poll results with students sitting near you.
- List a few reasons from your discussion which support the results of the poll.

Liquids	acid-base	strength
Vinegar		
Baking soda		
Cola		
Soapy		
How do you judge their acid-base?		

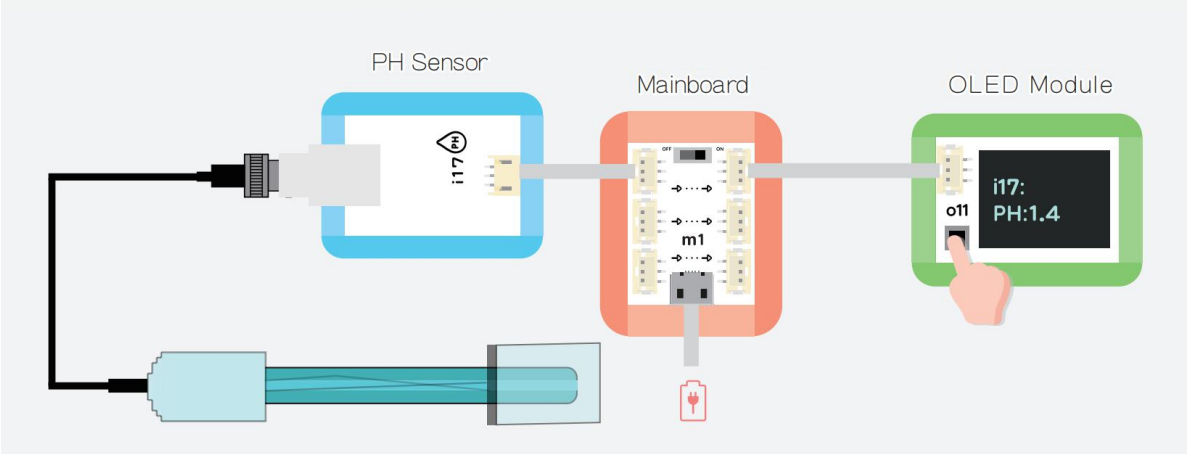
Explore

In this activity, your group will use a pH sensor to detect the pH of each liquid.

Activity Procedure:

Setup:

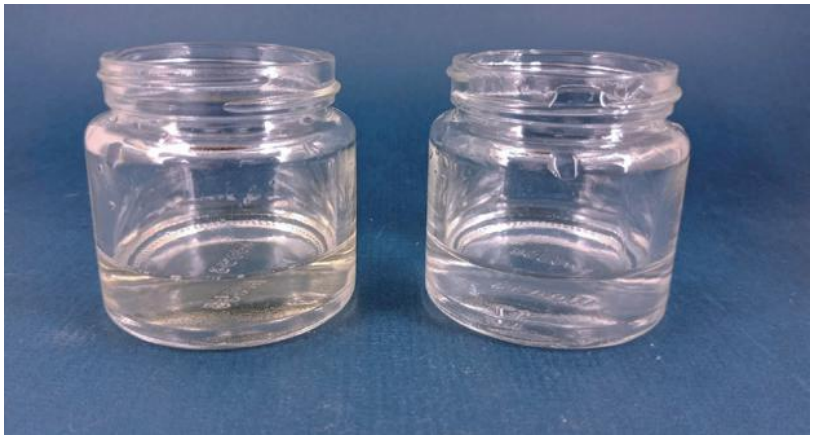
Please connect the pH sensor, the main board and the OLED module as shown in the diagram, and then switch the OLED module to i17, so that the pH value measured by the pH sensor can be displayed on the OLED module.



Experiment

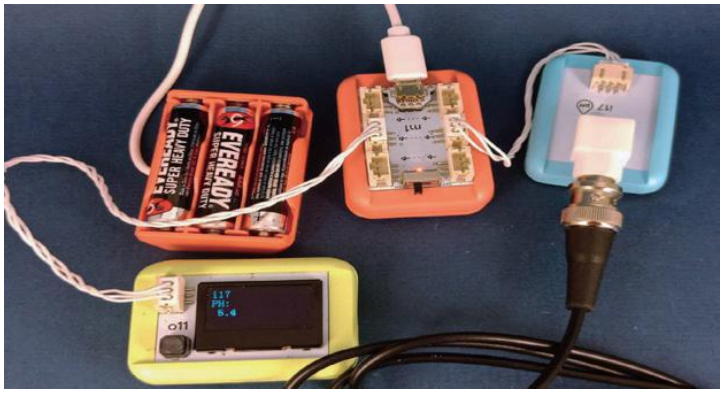
1. Pour the solution into the container

Take two containers, pour white vinegar and baking soda water into the containers respectively, and then stir them evenly. (The capacity shall be based on the height that can be measured by the pH sensor.)



2. Connect pH sensor and OLED module

Connect pH sensor and OLED module to mainboard. This means the value of pH sensor will be displayed on the OLED module.



3. Remove the front cover of pH sensor

Remove the cover with standard solution at the front end of the pH sensor.

Tips: Be careful to avoid pouring out the standard solution when taking it off.

4. Clean the front glass bead with pure water

Flush the front end of pH sensor with pure water for about 5 seconds. (Here, pure water is recommended, and the front glass bead is where to flush.)

5. Measure the pH value of white vinegar

Attach the pH sensor into the solution for about 30 seconds to measure the pH value of white vinegar and record in the table. As can be seen from the right picture, the pH value of white vinegar is 1.4, which belongs to a strong acid!

Tips: Before each measurement of different solutions, flush pH sensor with pure water again, otherwise the measurement results will be less accurate.

6. Measure the pH value of baking soda water

Using the same procedure, measure the pH value of baking soda water and then record it in the table.

Tips: Before measuring different solutions, flush the sensor again with pure water, otherwise the measurement results will be less accurate.

Tips:

Calibration method of pH sensor

The reason why the pH value of pure water under the standard condition is set at 7 is that the product of the concentration of hydrogen ions (H+) and hydroxide ions (OH-) naturally ionized by water under the standard temperature and pressure is always 1×1014, and the concentration of both ions is 1× 107 mol/L. However, in the case of non-water based solution or non-standard condition, the solution with pH 7 is not necessarily neutral.

The pH meter must be switched on in the standard solution (KCl solution of 3M).When the switch on and switch-off are stopped at the same number for two consecutive times, record the number as A, and then record the measured number as B. The figure obtained by using b× (7/a) is the calibrated pH value. PH meter can only be used in aqueous solution.

Data Record

Copy the Data Table below into your notebook.

	Vinegar	Baking soda	Cola	Soapy	
The pH value I measured					
Acidity					

Alkalinity					
The pH value measured by teacher	1.4 (Strong Acidity)	8.7 (Weak Alkalinity)	1.9 (Strong Acidity)	9(Strong Acidity)	

Explain

Data Analysis:

In your groups discuss the following questions:

1. Which source of liquid had the highest pH?
2. Which source of liquid had the lowest pH?
3. Was there any correlation between a high or low pH and your observations of the liquid source? (For example, did a liquid source with a strong odor have a pH distinctly different from a source of liquid with no odor?)

Elaborate

Vocabulary:

- Acid - a chemical substance with a pH less than 7. Acids can dissolve metals, turn blue litmus paper red, have a sour taste, are corrosive and can neutralize a base
- Base - a chemical substance with a pH greater than 7 - Bases can turn red litmus paper blue, have a bitter taste, feel slippery, and can neutralize an acid.
- Alkaline – synonyn for base; having the properties and/or conbtaining alkalin (metal);
- Neutral - with regards to acids and bases - a substance which is neither acidic or basic
- pH - a measurement of whether a substance is acidic or basic

Science Background:

The following information below will help you to understand characteristics of acids and bases, the pH scale, and how pH can be used as an indicator of water quality.

Lemons taste sour. Soap is slippery. All substances have specific properties depending on their composition. Substances such as lemons are termed acidic. Including a sour taste, characteristics of acids include being able to dissolve metals, being able to turn blue litmus paper red. They can be corrosive and have the ability to neutralize bases.

On the other hand, besides being slippery, substances which are bases characteristically taste bitter, turn red litmus paper blue and have the ability to neutralize acids.

How does a substance become classified as an acid or a base?

A small portion of water molecules, H_2O interact and split apart to produce two types of ions; H^+ (hydrogen ion) and OH^- (hydroxide ion). Simply put, a substance becomes acidic when there are more hydrogen ions than hydroxide ions. A substance becomes basic when there are more hydroxide ions than hydrogen ions.

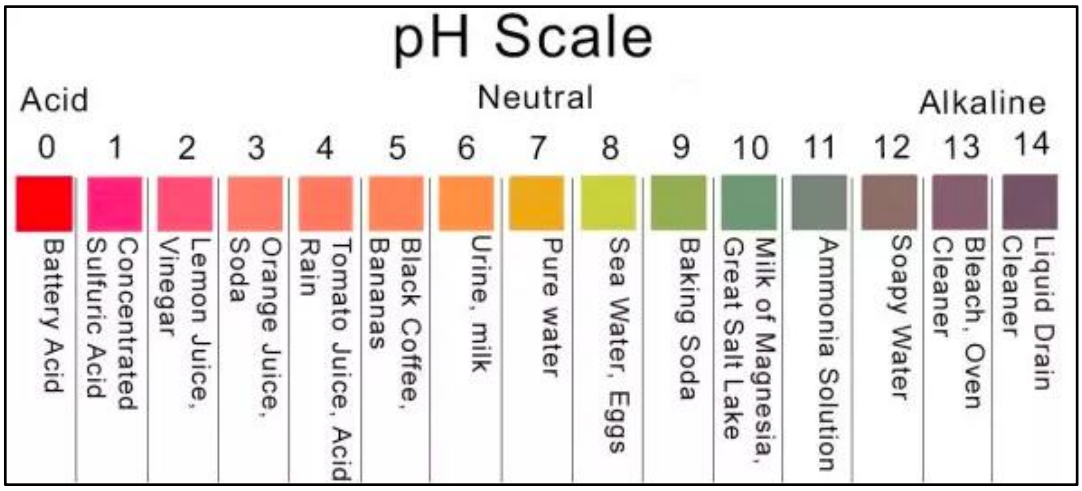
How can you tell is a substance is an acid or a base?

You can't actually and count these ions but there is a way to tell whether a substance is an acid or base. A substance can be tested to determine whether it is an acid or a base by using what is known as litmus paper. Litmus paper is paper which has been prepared with either a red indicator dye or a blue indicator dye. An acid will turn blue litmus paper red and a base will turn red litmus paper blue.

Can you measure the strength or weakness of acids and bases?

The relative amounts of the ions producing acids and bases can be measured using what is known as the pH scale. A piece of paper known as pH paper, which has been prepared with an indicator dye will turn a certain color when dipped in a substance. This color is compared to a standard and the strength of the acid or base can be determined.

The pH of a substance can be measured on a scale from 0-14. pH readings less than 7 indicate the substance is an acid; 0 being the strongest acid. pH readings greater than 7 indicate the substance is a base (also know as alkaline); 14 being the strongest base. A pH reading of 7 means that the substance is neutral, neither acidic or basic.



Evaluate

Consider the following questions:

1. Will the temperature of solution affect the pH value? Try attaching the pH sensor into a solution at different temperatures, and then measure it.
2. 20ml of white vinegar without water, then add 10ml of water, add 30ml water more, will pH value be different?

LESSON 4: Observe the acid-base neutralization reaction

Science - Grade 6-8

Objectives

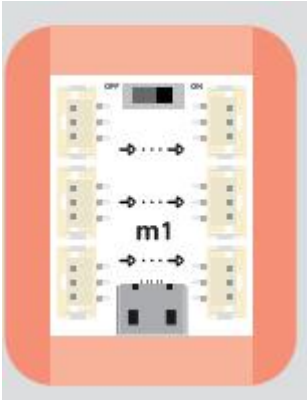
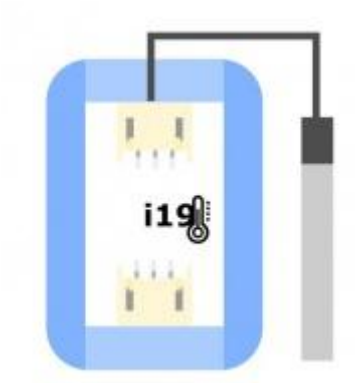
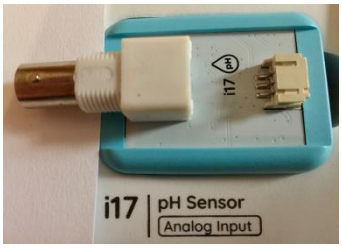
In this chapter, we will use the BOSON to check whether the pH is approximately 7 and represents an aqueous solution neutral.
Except for the pH sensor used in the previous chapter , a waterproof temperature sensor is also used device to further learn about the temperature change of the aqueous solution in this chapter.

Standards

NGSS - NEXT GENERATION SCIENCE STANDARDS - MIDDLE SCHOOL (MS)
From Molecules to Organisms: Structures and Processes - MS-LS1-5
Ecosystems: Interactions, Energy and Dynamics - MS-LS2-5
Earth and Human Activity - MS-ESS3-3, MS-ESS3-4, MS-ESS3-5
Engineering Design - MS-ETS1-1, MS-ETS1-3

Materials

BOSON Science Kit Materials	*Diagram*
Battery Holder w/3x AAA batteries installed	

MainBoard-3IO (m1)	
Waterproof Temperature Sensor (i19)	
Display Modulen(o11)	
pH Sensor (i17)	

pH Probe	
1x short BOSON cable	
1x long BOSON cable	
Clear Plastic Cups	

dropper	
Different liquids	

Activity

We can use BOSON pH sensor to detect the pH of a liquid, so what happens if we mix liquids of different pH?

- Pour four different liquids into four containers
- Use pH sensor and display modulen to detect the pH of these liquids
- Record the detected values in a table
- Discuss the acidity and alkalinity of these liquids
- Discuss what happens when you mix acidic and alkaline liquids?

Liquids	pH Value	Acidity
Vinegar		
Baking soda		
Lemonade		
Bleach		

The acidity and alkalinity of these liquids:
What happens when you mix acidic and alkaline liquids?

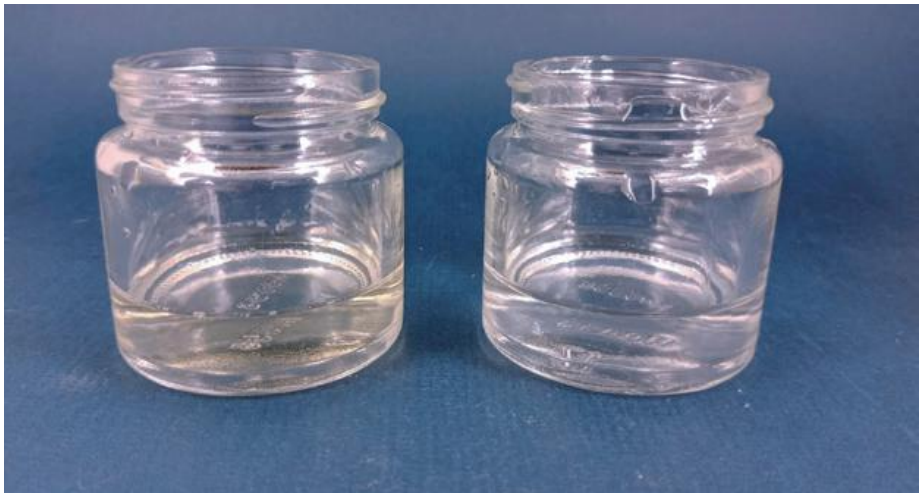
Explore

In this activity, your group needs to mix acidic and alkaline liquids together and use BOSON waterproof temperature sensor to detect temperature changes as they are mixed.

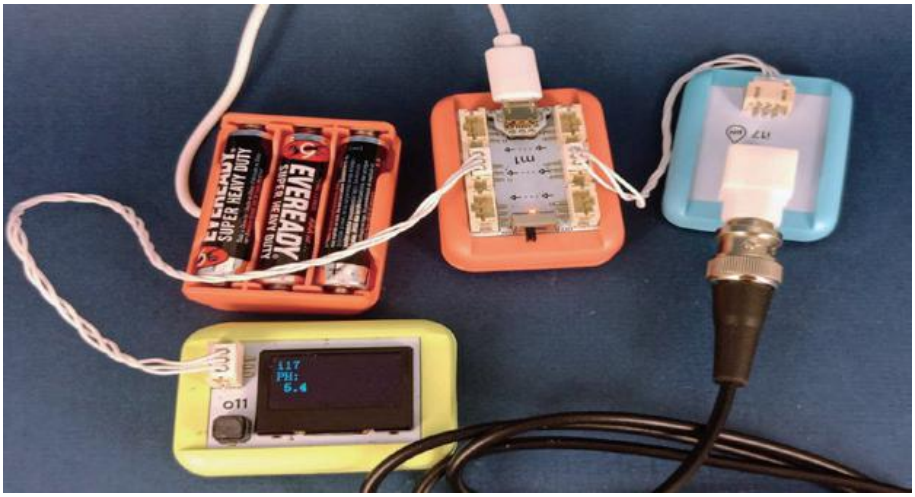
Activity Procedure:

Setup:

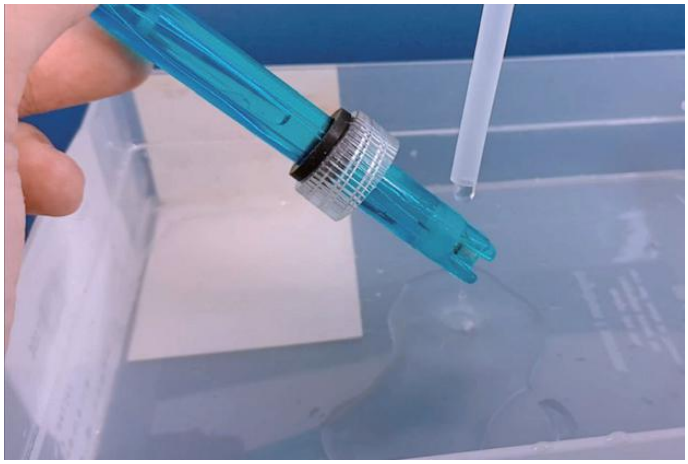
1. Take two containers, pour white vinegar and baking soda into the containers respectively, and stir well. The capacity is based on the height that the pH sensor can measure.



2. Connect the pH sensor,MainBoard, and display module. This means that we want to display the value of the pH sensor on the display module

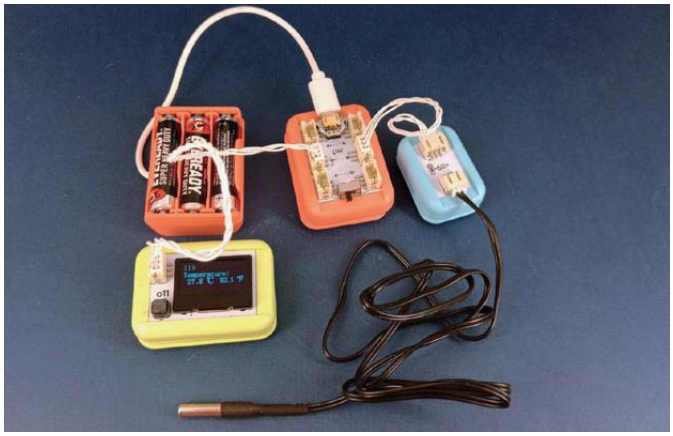


3. Remove the front cover of the pH sensor and clean the front glass beads with pure water.



4. Put the pH sensor in the solution for about 30 seconds to measure the pH of white vinegar. From the figure, you can see that the pH value of white vinegar is 1.4, which is a strong acid.

5. To measure the temperature, remove the pH sensor, replace it with a waterproof temperature sensor, and switch the display module switch to i19 to display the temperature.



6. Put the metal tip of the waterproof temperature sensor in white vinegar and let it stand for 30 seconds.Obtain a stable value and record it in a table. The figure shows that the temperature of white vinegar is 25.8 degrees Celsius.

7. Next, use baking soda to neutralize the white vinegar. Take an appropriate amount of baking soda with a dropper, drip it into the white vinegar solution, and leave it for 30 seconds before recording the new temperature. Then replace the waterproof temperature sensor with a pH sensor, and after leaving it for 30 seconds, observe the pH value on the display module again. Is there any change? Please record the changed values in the table. Repeat this step to complete the form below.

Experiment

1. The amount of baking soda added should be the same each time.
2. Clear pH sensor and waterproof temperature sensor are required before each test.
3. Each test needs to stand for 30 seconds before recording data.

Data Record

Copy the Data Table below into your notebook.

Number of times added baking soda	Temperature (℉)	pH Value

Explain

Making Sense of the Data:

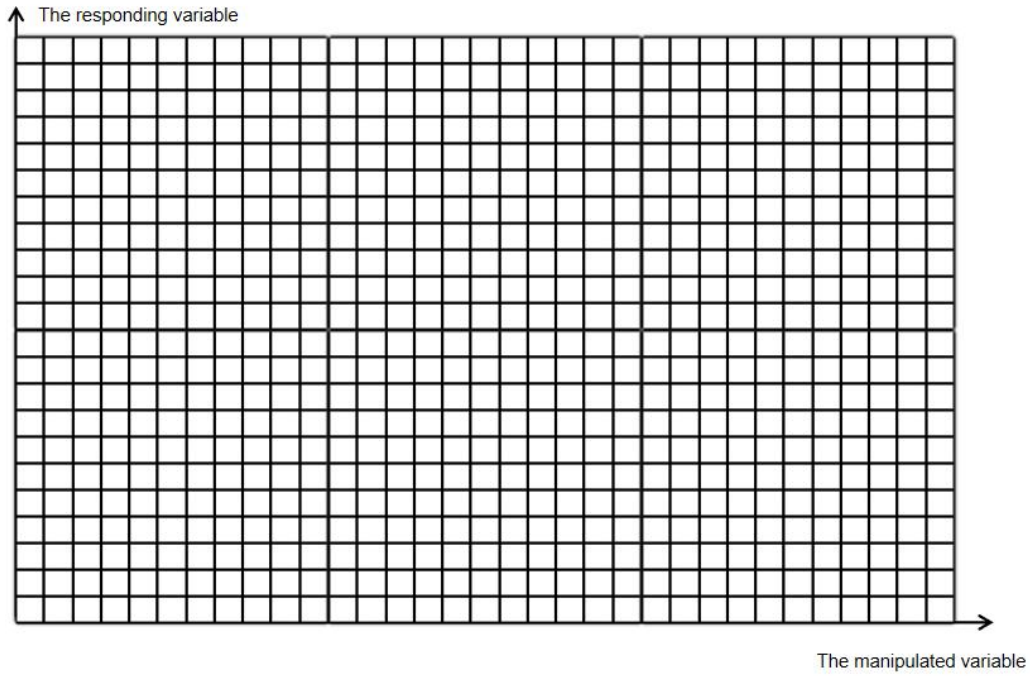
Create a Multi-Colored Line Graph according to the directions below:

1. Use graph paper and draw the results for each color. For each line, use a different color that matches the color of the worksheet. The operating variable is the number of times the liquid is added, and the response variable is temperature.

2. The manipulated variable is plotted along the X axis, and the response variable is plotted along the Y axis.

3. Use variables to name the graph.

4.Add a legend to the diagram.



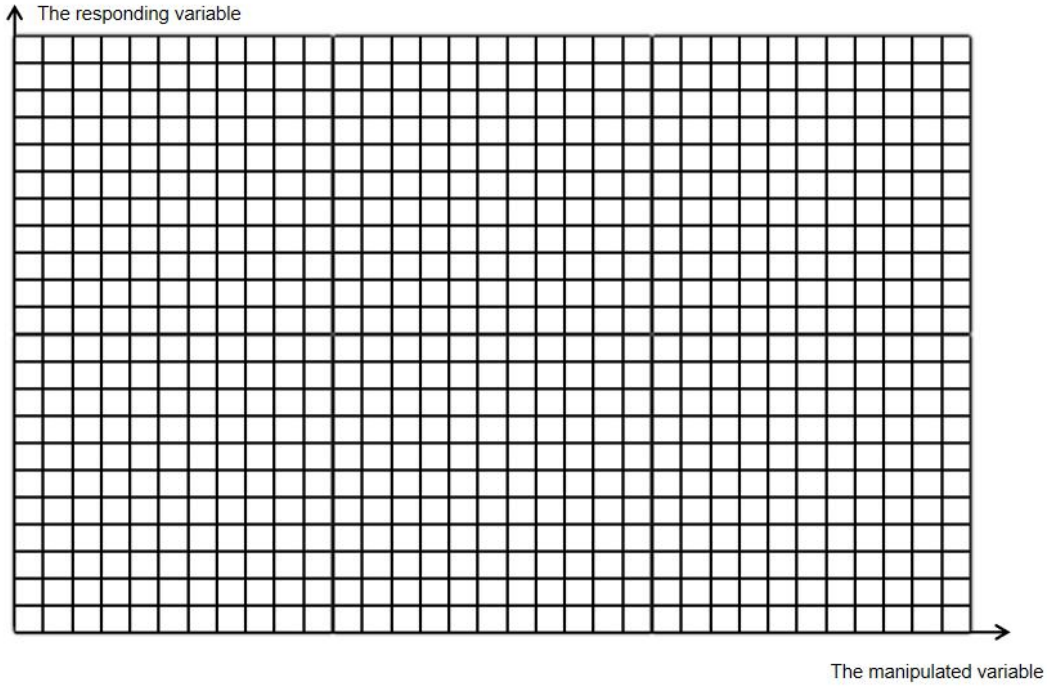
Create a Bar Graph according to the directions below:

1. Use graph paper and draw the results for each color. For each row, use a different color that matches the worksheet color. The operating variable is the number of times the liquid is added, and the response variable is the pH value.

2. Manipulated variables are plotted along the X axis, and response variables are plotted along the Y axis.

3. Use variables to name the graphics.

4.Add a legend to the diagram.



Data Analysis:

In your groups discuss the following questions:

1. Examine the the various lines on the Multi-Colored Line Graph.
    a. What are the trends in temperature and pH values?.

2. If I add more baking soda to white vinegar at one time (for example, 2 drops to 4 drops), will the temperature change speed be different? Please write down what you observed.

Elaborate

Vocabulary:

- Meaning of neutralization
- Acid-base neutralization
- Neutralization heat

Science Background:

In the context of a chemical reaction the term neutralization is used for a reaction between an acid and a base or alkali. Historically, this reaction was represented as

$$\text{acid + base (alkali)} \rightarrow \text{salt + water}$$

For example:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

The statement is still valid as long as it is understood that in an aqueous solution the substances involved are subject to dissociation, which changes the substances ionization state. The arrow sign, →, is used because the reaction is complete, that is, neutralization is a quantitative reaction. A more general definition is based on Brønsted–Lowry acid–base theory.

$$AH + B \rightarrow A + BH$$

Electrical charges are omitted from generic expressions such as this, as each species A, AH, B, or BH may or may not carry an electrical charge. Neutralization of sulphuric acid provides a specific example. Two partial neutralization reactions are possible in this instance.

$$H_2SO_4 + OH^- \rightarrow HSO_4^- + H_2O$$
$$HSO_4^- + OH^- \rightarrow SO_4^{2-} + H_2O$$
$$\text{Overall: } H_2SO_4 + 2OH^- \rightarrow SO_4^{2-} + 2H_2O$$

After an acid AH has been neutralized there are no molecules of the acid (or hydrogen ions produced by dissociation of the molecule) left in solution.

When an acid is neutralized the amount of base added to it must be equal the amount of acid present initially. This amount of base is said to be the equivalent amount. In a titration of an acid with a base, the point of neutralization can also be called the equivalence point. The quantitative nature of the neutralization reaction is most conveniently expressed in terms of the concentrations of acid and alkali. At the equivalence point:

$$\text{volume (acid)} \times \text{concentration } (H^+ \text{ ions from dissociation}) = \text{volume (base)} \times \text{concentration } (OH^- \text{ ions})$$

In general, for an acid AHn at concentration c1 reacting with a base B(OH)m at concentration c2 the volumes are related by:

$$n\,v_1\,c_1 = m\,v_2\,c_2$$

An example of a base being neutralized by an acid is as follows.

$$Ba(OH)_2 + 2H^+ \rightarrow Ba^{2+} + 2H_2O$$

The same equation relating the concentrations of acid and base applies. The concept of neutralization is not limited to reactions in solution. For example, the reaction of limestone with acid such as sulfuric acid is also a neutralization reaction.

$$[Ca,Mg]CO_3(s) + H_2SO_4(aq) \rightarrow (Ca^{2+}, Mg^{2+})(aq) + SO_4^{2-}(aq) + CO_2(g) + H_2O$$

Such reactions are important in soil chemistry.

The heat of reaction in which the acid and base are neutralized in a dilute solution to produce 1 mol of water. The heat of neutralization between a strong monobasic acid and a strong base is about 57kJ, regardless of the type of acid and base, because this is actually the heat of reaction when 1molH + reacts with 1molOH- to form 1molH2O. The heat of neutralization of weak acids, weak bases, and polybasic acids is not a constant value due to the influence of ionization heat.

Evaluate

Consider the following questions:

1. 1. After reading the above material, please explain why pouring soda water into white vinegar will increase the pH value.
2. 2. Why does the temperature rise after I add baking soda?

LESSON 5: Why is the water changing its colour?

Science - Grade 6-8

Objectives

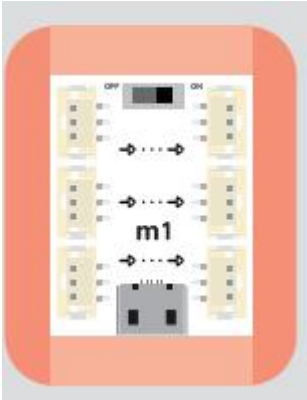
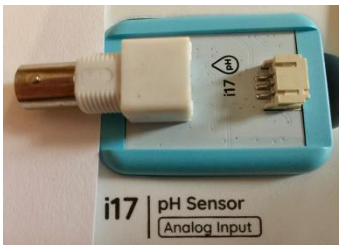
Some liquids will show different colors at different pH values. In this lesson, we will explore what color will appear when the pH of these solutions changes, and try to make a ‘good-looking drink’.

Standards

NGSS - NEXT GENERATION SCIENCE STANDARDS - MIDDLE SCHOOL (MS)
From Molecules to Organisms: Structures and Processes - MS-LS1-5
Ecosystems: Interactions, Energy and Dynamics - MS-LS2-5
Engineering Design - MS-ETS1-1, MS-ETS1-3

Materials

BOSON Science Kit Materials	*Diagram*
Battery Holder w/3x AAA batteries installed	

MainBoard-3IO (m1)	
Display Modulen(o11)	
pH Sensor (i17)	
pH Probe	

1x short BOSON cable	
1x long BOSON cable	
Clear Plastic Cups	
Dropper	

Different liquids	
Butterfly bean flower or purple cabbage juice	

Activity

Warning:

In addition to lemonade, the several experimental liquids in this chapter are like white vinegar, baking soda and bleach are absolutely not allowed to drink! Although the color of white vinegar and butterfly bean juice is very beautiful, shouldn't you want to drink vinegar directly?

Many drinks are sold at night markets or school celebrations, such as black fairy grass honey or orange papaya milk. But have you ever seen a drink containing two or more colors? This colorful drink is usually achieved by using the juice of the special plant such as butterfly bean flower, and then adding different pH solutions to achieve the effect of discoloration.

Children can use the experiments in this chapter to find out which solutions and butterfly bean juice can produce the most beautiful color.

- Pour four different liquids into butterfly bean flower or purple cabbage juice
- Use pH sensor and display modulen to detect the pH of these liquids
- Record the detected values in a table
- Discuss the relationship between the pH and color of these liquids

Liquids	pH Value	Color
Vinegar		
Baking soda		
Bleach		
Bleach		

What happens when you mix the liquids?

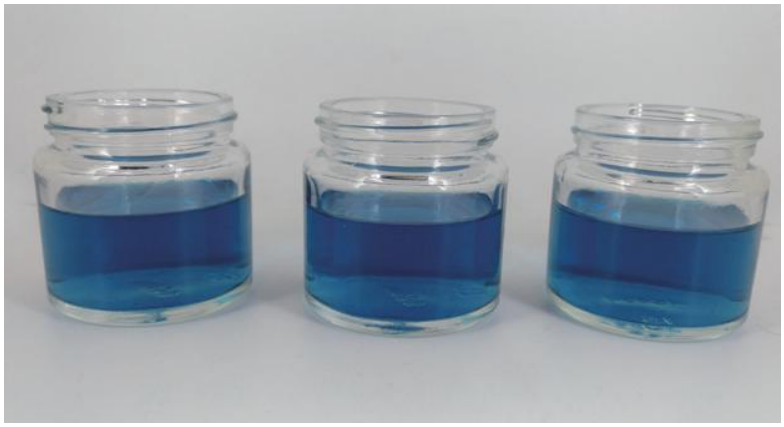
Explore

In this activity, your group needs to mix the liquids together and use BOSON pH sensor to detect pH value when color changed.

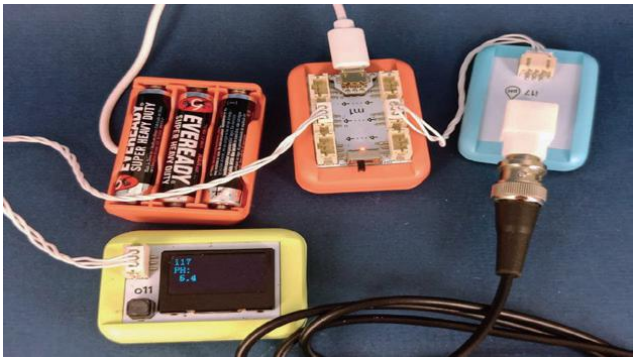
Activity Procedure:

Experiment

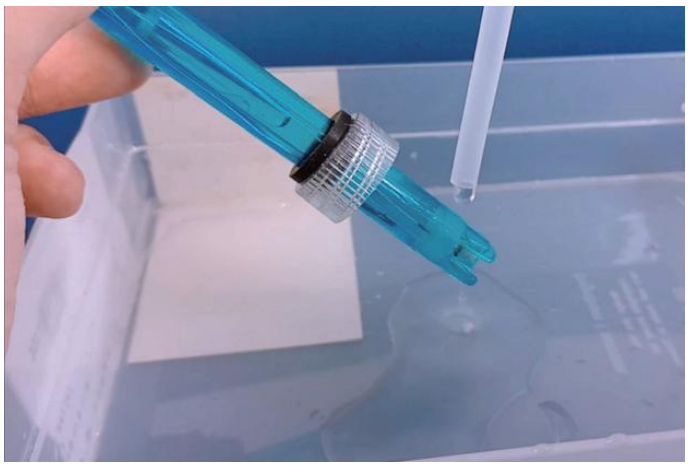
1. Prepare Butterfly Bean Flower Juice.（Or purple cabbage juice, the description will not be repeated later）Immerse the butterfly pea flower in hot water for about 30 minutes, and find three containers to distribute them equally.



2. Connect the pH sensor according to the figure below, control the module and the display module, and switch the display module switch to i17 to display the pH value.



3. Remove the front cover of the pH sensor and clean the front glass beads with pure water.



4. First use the pH sensor to measure the pH value of butterfly bean flower juice, and record it in the table below. As shown on the right, the measurement result is 7.3, which means butterfly bean flower juice is a neutral solution. In addition, the pH value of white vinegar, baking soda, lemonade, and bleach should be recorded after the initial measurement.

Tips:Before measuring different solutions, flush the sensor with pure water again, otherwise the measurement results will be inaccurate.

5. Slowly pour the white vinegar into the butterfly bean juice and carefully observe the color change. After standing for 30 seconds, measure the pH again.

6. Pour the remaining baking soda, lemon drink, and bleach into the butterfly bean juice, observe the color change, and record it in the table below. Is it colorful ?

From left to right are white vinegar, baking soda, lemonade and bleach

Data Record

Copy the Data Table below into your notebook.

Liquid	Butterfly Bean Flower Juice	Vinegar	Baking soda	Lemonade	Bleach
pH value					
Color					
Acidity&Alkaline					

Explain

Observe and think:

1.Observe, is there a relationship between the acidity and alkalinity of the final mixed solution and the color depth?

2.Take a walk to the market and see if the butterfly bean flower beverage has a common taste?

Elaborate

Vocabulary:

- Anthocyanin
- Acid-base indicator solution

Anthocyanins are water-soluble vacuolar pigments that, depending on their pH, may appear red, purple, blue or black. Food plants rich in anthocyanins include the blueberry, raspberry, black rice, and black soybean, among many others that are red, blue, purple, or black. Some of the colors of autumn leaves are derived from anthocyanins.

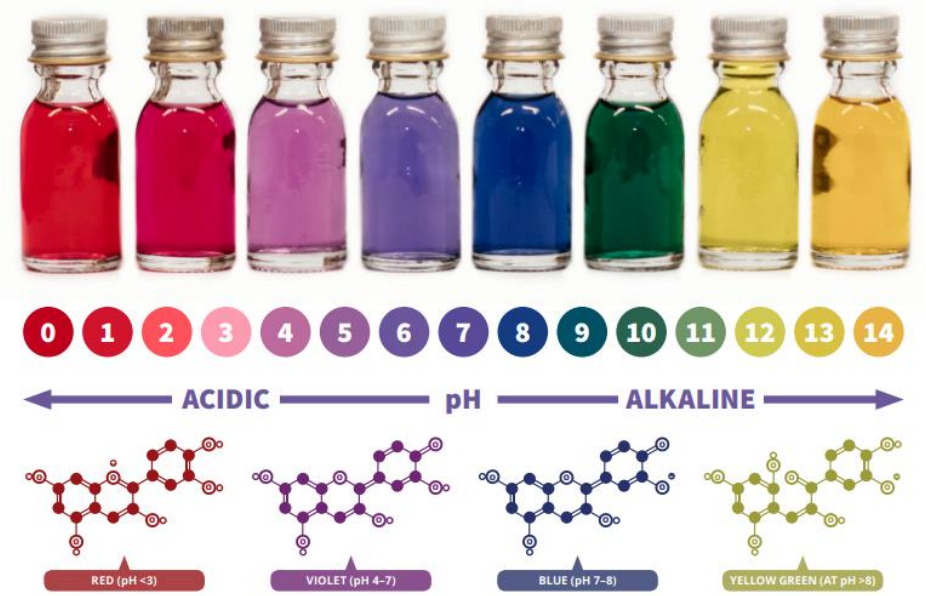
Anthocyanins belong to a parent class of molecules called flavonoids synthesized via the phenylpropanoid pathway. They occur in all tissues of higher plants, including leaves, stems, roots, flowers, and fruits. Anthocyanins are derived from anthocyanidins by adding sugars. They are odorless and moderately astringent.

pH

Anthocyanins generally are degraded at higher pH. However, some anthocyanins, , are resistant to degradation at pH 8 and may be used effectively as a food colorant.

Use as environmental pH indicator

Anthocyanins may be used as pH indicators because their color changes with pH; they are red or pink in acidic solutions (pH < 7), purple in neutral solutions (pH $\approx$ 7), greenish-yellow in alkaline solutions (pH > 7), and colorless in very alkaline solutions, where the pigment is completely reduced.



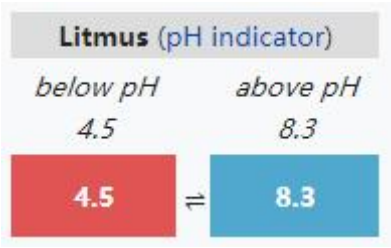
Litmus

Litmus is a water-soluble mixture of different dyes extracted from lichens. It is often adsorbed onto filter paper to produce one of the oldest forms of pH indicator, used to test materials for acidity.

The main use of litmus is to test whether a solution is acidic or basic. Blue litmus paper turns red under acidic conditions and red litmus paper turns blue under basic or alkaline conditions, with the color change occurring over the pH range 4.5–8.3 at 25 °C (77 °F). Neutral litmus paper is purple.Litmus can also be prepared as an aqueous solution that functions similarly. Under acidic conditions, the solution is red, and under alkaline conditions, the solution is blue.

Wet litmus paper can also be used to test for water-soluble gases that affect acidity or alkalinity; the gas dissolves in the water and the resulting solution colors the litmus paper. For instance, ammonia gas, which is alkaline, turns red litmus paper blue.

Chemical reactions other than acid–base can also cause a color change to litmus paper. For instance, chlorine gas turns blue litmus paper white – the litmus dye is bleached,[2] because of presence of hypochlorite ions. This reaction is irreversible, so the litmus is not acting as an indicator in this situation.



Evaluate

Consider the following questions:

1. Investigate the safety of anthocyanins as food additives.
2. Why lemonade is an alkaline solution, although it tastes sour.

LESSON 6：Will Soil pH and Fertilizers Affect Plant Growth?

Science - Grade 6-8

Objectives

This chapter will guide you to set up controlled experiments to explore how different soil pH and fertilizers impact on the growth of plants. A pH sensor is used to detect the pH of different soils here.

Standards

NGSS - NEXT GENERATION SCIENCE STANDARDS - MIDDLE SCHOOL (MS)

From Molecules to Organisms: Structures and Processes - MS-LS1-5

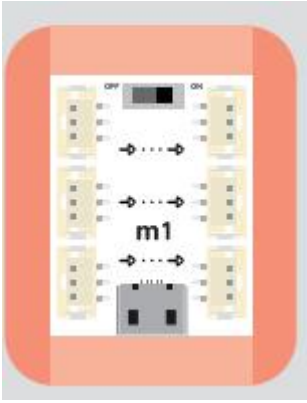
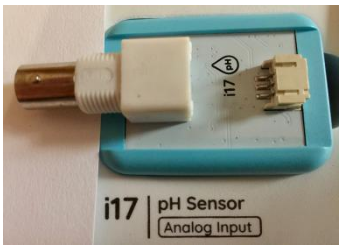
Ecosystems: Interactions, Energy and Dynamics - MS-LS2-5

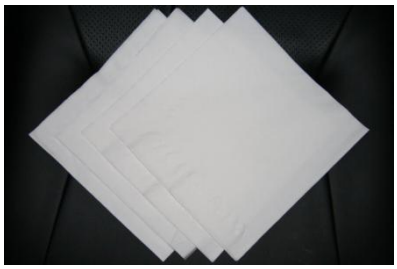
Earth and Human Activity - MS-ESS3-3

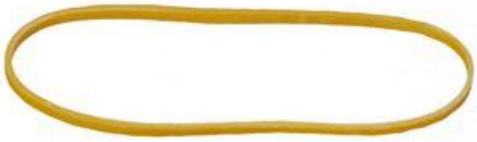
Engineering Design - MS-ETS1-1, MS-ETS1-3

Materials

BOSON Science Kit Materials	*Image*
Battery Holder w/3x AAA batteries installed	

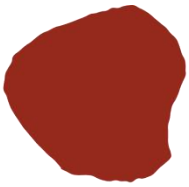
MainBoard-3IO (m1)	
Display Module (o11)	
pH Sensor (i17)	
pH Probe	

1x short BOSON cable	
1x long BOSON cable	
Clear Plastic Cups	
Toilet Paper	
Gauze Filter	

	
Rubber Band	
Different Types of Soil	

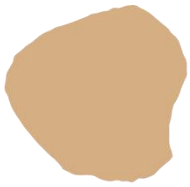
Activity

Imagine you are sent to outer space as a farmer someday and you need to grow plants on that new planet. There are three different types of soils (A, B, C), and you have measured their pH using BOSON sensors. The problem here is that how to choose the suitable soil for different kinds of plants, and do you have any plan to make these plants grow faster and stronger?



A
PH<6

B
6.5<PH<7.5



C
PH>7.5

Pea

Watermelon

Cotton

Wheat

Potato

●Explore this question by taking a poll of students in your class.

●Copy the chart below into your notebook.

●When completed, discuss the poll result with your classmates sitting next to you.

●Why do you choose this area as the place where you grow the most plants?

●List a few reasons from your discussion which support the results of the poll.

Plants	Soil A	Soil B	Soil C
Pea			
watermelon			
cotton			
wheat			
potato			
Please give reasons for your judgment:			
Do you think fertilizer is helpful to plant growth? Why?			

Explore

In this activity, your group will use a pH sensor to detect the pH of different soils and choose one to carry out controlled experiments so as to explore the effects of fertilizer on plant growth.

Activity Procedure:

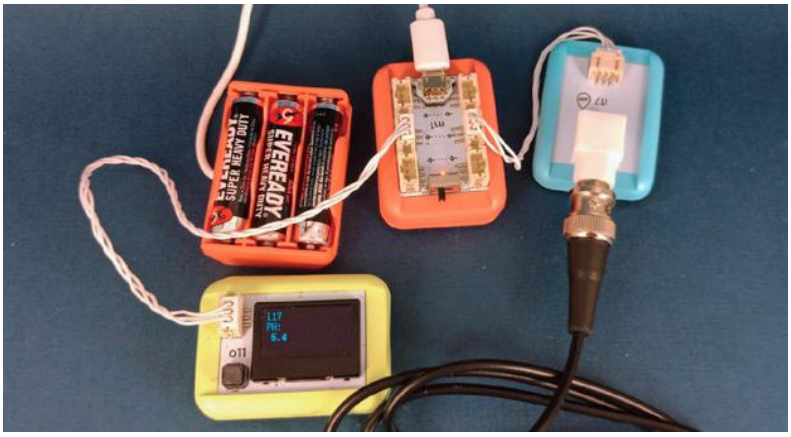
Experiment 1：Measure Soil pH

1. **Prepare soil:** get soil from different places, like nutrient soil from market, or normal soil from parks, flower pad, etc.

2. **Put soil in water and stir:** put the soil in a container, add water in it and stir for a while.

3. **Stand and settle:** let it stand still until the soil settled at the bottom of the container.

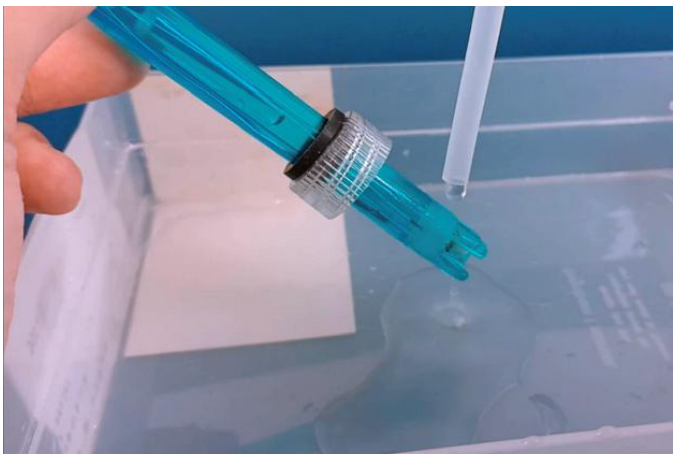
4. **Connect all parts:** connect the pH Sensor, controller module, and display module as the figure shown below.



5. **Remove the sensor cap:** remove the front sensor cap (There is a standard solution in the cap).

Tips: Please do **NOT** let the standard solution pour out.

6. **Wash the pH electrode:** wash the pH electrode for about 5 seconds (recommend washing with pour water).



7. **Measure the pH of the solution:** put the pH sensor into the solution for 30 seconds to detect the pH. Check the results and see if the soils from different places have the same pH values, and is there a difference between soils with different colors in pH.

Data Record 1

Copy the Data Table below into your notebook.

Soil	Nutrient soil from market	Soil from flowerbed	Soil from other place _____			
PH Value						
Color						

Experiment 2：Apply Fertilizer

1. **Prepare materials:** plastic bottle, toilet paper, rubber band, gauze filter (Cut the plastic bottle in half).

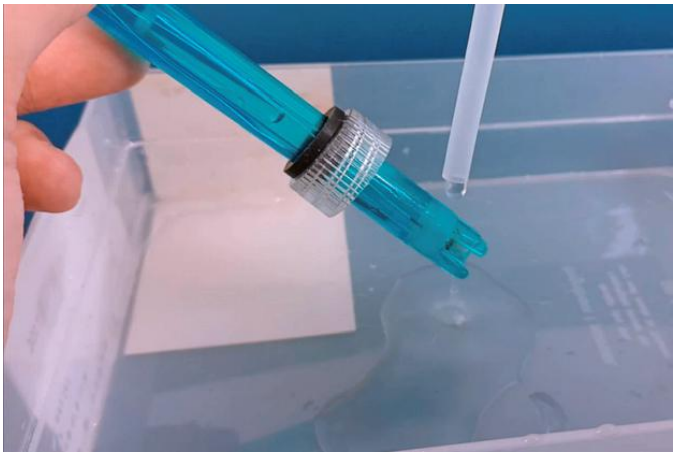
2. **Put toilet paper into bottle mouth:** put the scrunched up piece of toilet paper into the mouth of the bottle.

3. **Fix the gauze filter:** cut the gauze filter in a suitable size, wrap the bottle mouth with the gauze and fix it with a rubber band.

4. **Put soil into the bottle:** fill the bottle to the half with soil and then place it onto another half of the bottle as shown in figure below.

5. **Sow the seeds:** put some seeds on the soil, (the number of seeds depends on the soil range, about 5~10 here), pour some soils to cover the seeds.

6. **Wash the pH electrode:** prepare another plastic bottle, repeat steps 1 to 5 and mark the bottle (Apply fertilizer after the seeds sprout). Clean up the pH sensor.



7. **Measure the pH value:** water the plants every day, and detect the pH of the solution in the bottle below (The watering time and water quantity for the plants

in the two bottles should be the same). Record the detected pH and the growth situation, fill the form.

Data Record 2

Copy the Data Table below into your notebook.

		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Without fertilizer	PH							
	Growth situation							
With fertilizer	PH							
	Growth situation							

Explain

Observe and think:

1. Will the growth situation be different for the seeds planted in different soils?

2. Will the growth speed be the same for plants with and without fertilizer?

Elaborate

Vocabulary:

- Soil pH
- Fertilizer
- Plant Growth

Science Background:

Soil pH(acidity and alkalinity), the basic characteristic of soil, is one of the most important factors affecting soil fertility and plant growth. Too much acidity or alkalinity will reduce the availability of plant nutrients in varying degrees, specifically in the following five aspects:

1. Reduce the availability of plant nutrients. P(phosphorus)in the soil is directly affected by soil pH. When the pH is over 7.5 or lower than 6, phosphoric acid and calcium or iron, aluminum form a delayed effect state, which greatly impacted on the availability. Ca(calcium), Mg(Magnesium) and K(potassium) can easily be lost or be substituted in acid soil. At alkaline pH values, greater than pH 7.5 for example, phosphate ions tend to react quickly with calcium (Ca) and magnesium (Mg) to form less soluble compounds. The availability of boron, manganese, copper and other microelements is more likely to be reduced in alkaline soil, while molybdenum will combine with free iron and aluminum into precipitate in strong acid soil.

2. Harmful to the development of soil and damage the soil structure. There are too much H(hydrogen) and Na(sodium) in strong acid or alkaline soil, meanwhile, the lack of Ca(calcium) in these kinds of soil makes it difficult to form a good soil structure, bad for the plant growth.

3. Have a bad effect on the activities of microorganisms in soil. The ideal soil pH for the microorganisms is considered to be around 6.5~7.5. Soil pH exceeding this range could severely inhibit the activities of microorganisms, thus affecting the transformation and supply of nitrogen and other nutrients.

4. Go against plants development. The most suitable soil pH for plant growth is neutral or close to neutral. In slightly (over) acidic or alkaline soil, it will be difficult or even unable for plants to grow up.

5. May produce a variety of toxic substances. Free Al^{3+} and organic acids can be easily produced in over acid soil. Besides, when the soluble salt in alkaline soil reaches a certain amount, the germination and growth of crops will be directly influenced. What's more, alkalized soil with more sodium carbonate even has a toxic effect on plants.

pH Range		
5.0 – 5.5	**5.5 – 6.5**	**6.5 – 7.0**
Blueberries	Barley	Alfalfa
Irish Potatoes	Bluegrass	Some Clovers
Sweet Potatoes	Corn	Sugar Beets
	Cotton	
	Fescue	
	Grain Sorghum	
	Peanuts	
	Rice	
	Soybeans	
	Watermelon	
	Wheat	

NPK are the most needed nutrient elements for plants among the basic necessary elements (hydrocarbon, oxygen, nitrogen, phosphorus, potassium, calcium and magnesium). Most of them will be taken away when the plants are harvested, and the amount they are returned to soil in the form of stubble and root is relatively less.

Effects of P, K and N on plants:

All plants need nitrogen, phosphorus and potassium to grow. Without enough of any one of these nutrients, a plant will fail to grow.

Nitrogen (N) – nitrogen is largely responsible for the growth of leaves on the plant.

Phosphorus (P) – Phosphorus is largely responsible for root growth and flower and fruit development.

Potassium (K) – Potassium is a nutrient that helps the overall functions of the plant perform correctly.

Knowing the NPK values of a kind of fertilizer can help you select one that is appropriate for the type of plant you are growing. For example, if you are growing leafy vegetables, you may want to apply a fertilizer that has a higher nitrogen number to encourage leafy growth. If you are growing flowers, you may want to apply a fertilizer that has a higher phosphorus number to encourage more blooms.

Evaluate

Consider the following questions:

1. After reading the above material, please explain why different plants are needed to be planted in different types of soils.
2. Does applying fertilizer help plants grow better?

LESSON 7：Do plants need light?

Science - Grade 6-8

Objectives

In this lesson, we are going to find out the most suitable light intensity range for plant growth, and get to know the relationship between plant growth and light.

Standards

NGSS - NEXT GENERATION SCIENCE STANDARDS - MIDDLE SCHOOL (MS)
From Molecules to Organisms: Structures and Processes MS-LS1-4, MS-LS1-5
Ecosystems: Interactions, Energy and Dynamics MS-LS2-1, MS-LS2-4, MS-LS2-5 MS-ESS3
Earth and Human Activity MS-ESS3-3
Engineering Design MS-ETS1-1, MS-ETS1-3

Materials

BOSON Science Kit Materials	*Diagram*
Battery Holder w/3x AAA batteries installed	

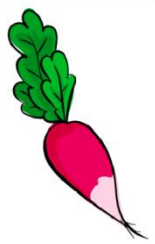
MainBoard-1IO (m2)	
Light Sensor (i4)	
Display Modulen(o11)	
1x short BOSON cable	

1x long BOSON cable	
Additional Materials	*Supplies & Materials*
Pothos (leaves should be the same in size and quantity)	
Potting Soil	
Plastic Cups	
Water	

Permanent Marker	

Activity

If someday, human activities make the extreme weather more frequent, and in a place, the sunshine hasn't been seen for a very long time. Guess, which kind of plant in the following will suffer more? Which of them will live longer?

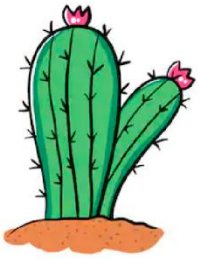


Radish

Mushroom

Sunflower

Onion



Cactus

- Explore this question by taking a poll of students in your class.
- Copy the chart below into your notebook.
- When completed, discuss the poll results with students sitting near you.
- Why do you choose these plants?
- List a few reasons from your discussion which support the results of the poll.

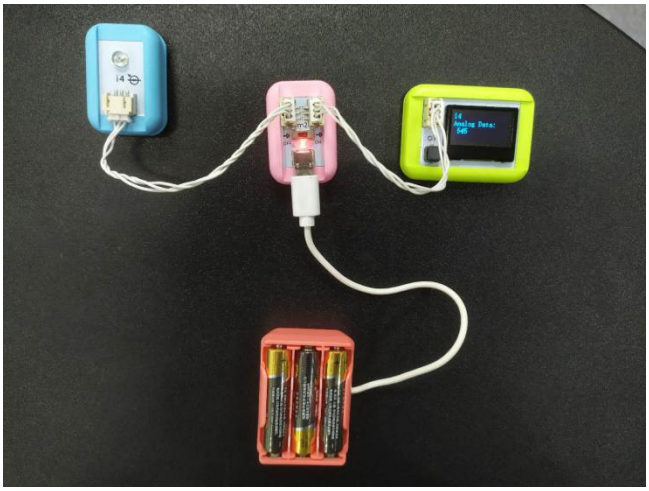
Plants	Suffer a lot when no light there	Live as usual when no light there
Radish		
Mushroom		
Sunflower		
Onion		
Cactus		
Please give reasons for your judgment		
Would plants die if there is no sunlight?		

Explore

In this activity, your group will use a light sensor to detect intensity of light, and set up controlled experiments to explore the effect of light intensity on plant growth.

Activity Procedure Setup:

1. Connect the Battery Pack to the MainBoard-110. Ensure the MainBoard-110 is turned OFF.
2. Use a short BOSON Cable to connect the Display Module with the MainBoard-110.
3. Use a long BOSON Cable to connect the Light Sensor with the MainBoard-110.



4. Set the BOSON equipment aside.
5. Use a permanent marker to label the three plastic cups as A, B, and C.

Experiment：

1. Fill each plastic cup 1/2 full with potting soil. Pat the soil down gently.
2. Divide the pothos into three parts and plant them in three pots.

3. Put the three parts of pothos at different positions of a room.

Low **Intermediate** **High**

Tips: light intensity value from the light sensor

Low(0-50) intermediate(450-600) high(900-1000)

4. Water plants with the same amount of water at regular intervals.
5. Read the value of the light sensor.
6. Observe the leaf quantity, color, and growth situation.
7. Repeat steps 4 to 6 in two weeks and record what you observed.

Data Record

Copy the Data Table below into your notebook.

Plants	Light intensity, number of green leaves, number of yellow leaves

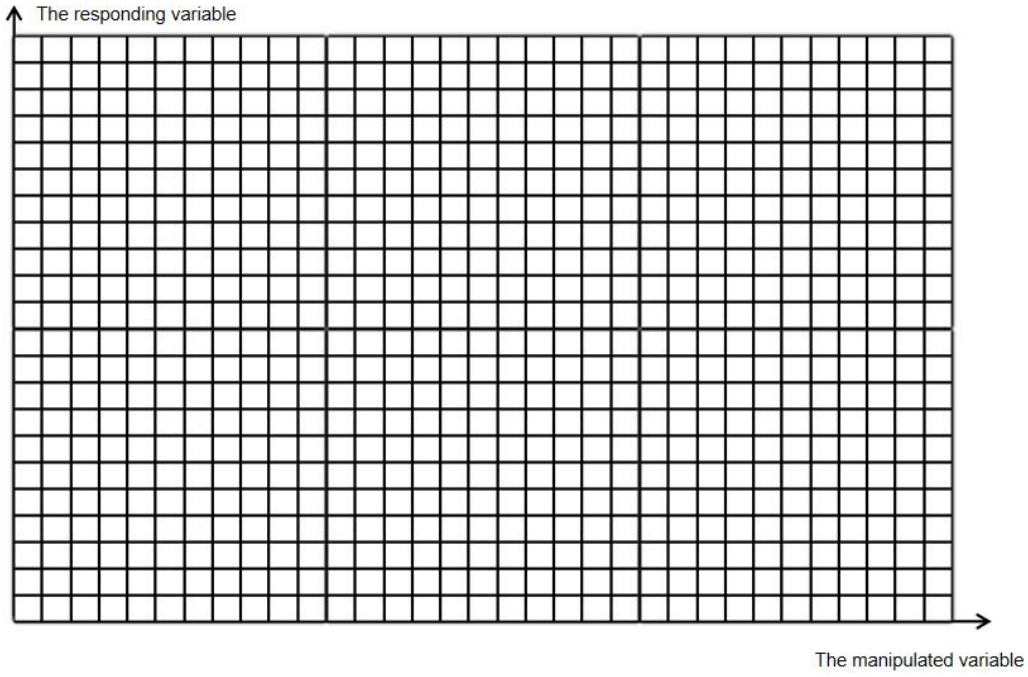
Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A														
B														
C														

Explain

Making Sense of the Data:

Summarize the collected data in the line chart below.

1. Plot date on the X-axis
2. Plot the numbers of green leaf, yellow leaf on the Y-axis respectively
3. Use three colors to represent plants in pot A, B and C



Observe and think:

1. Will plants grow differently under different light intensities?

2. What's the most suitable light intensity range for plant growth?

Elaborate

Vocabulary:

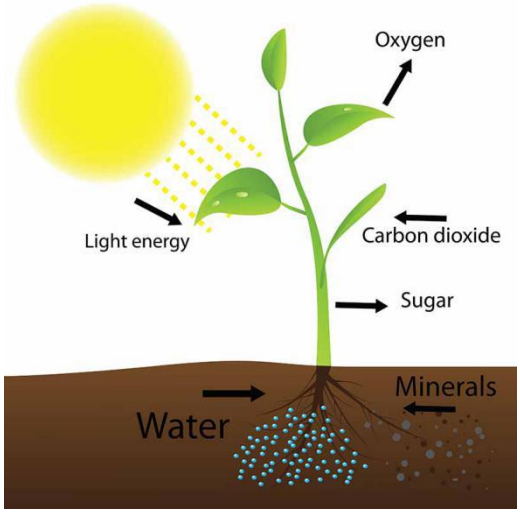
- Plant Growth
- Photosynthesis

Science Background:

Light is something we all take for granted unless you live in the arctic circle or something! But if you get into gardening, or more specifically, indoor hydroponics, you start to appreciate how valuable sunlight truly is.

You cannot grow anything in the darkness. Mushrooms and fungi are an exception of course, but for any plants with green chlorophyll coursing through their leaves, light is mandatory.

Why Plants Need Light?



Let's refresh that memory with a few basic concepts. Asking why plants need light is like asking why we need fire or heat to cook our food.

Plants are autotrophs, which means that they are capable of creating nutrition (read carbs, proteins, and fats) in their bodies. To create these foods they absorb the following ingredients from the environment:

- Nutrients and Minerals from the soil via routes
- Water, again through the roots
- Carbon Dioxide, through the pores in the leaf.

To combine these ingredients and cook up some food, plants need energy. This they derive from the sunlight, using the green chemical called chlorophyll in their leaves.

The recipe reads something like this:

$6CO_2 + 6H_2O$ --- Chlorophyll & Sunlight ---> $C_6H_{12}O_6 + 6O_2$

Carbon Dioxide and water, in the presence of Chlorophyll & Sunlight, combine to produce Glucose and Oxygen molecules. The glucose is used by the plants for growth and bearing fruit, while the oxygen is released into the atmosphere as a by-product.

This is a simple definition of the process of photosynthesis that happens in a plant leaf in the presence of chlorophyll and sunlight. You may have noted the absence of any minerals in the equation.

But minerals like magnesium and phosphorus are essential for photosynthesis. Without magnesium, plants cannot create chlorophyll in the leaves. And phosphorus is essential for creating proteins.

How Does Light Affect Plant Growth?

Direction of Growth

The survival of a plant is entirely dependant on the source of light. In the case of all outdoor plants, the sun is the only source of light.

When the first leaves appear on the plant, it will try to grow towards the light source, to ensure that maximum light is received by the leaves for photosynthesis.

Some plants take this to its extreme and follow the sun as it traverses the sky in the day. The sunflower is the most famous example of these plants, called heliotropic by botanists.

The rest of the plants are called phototropic, which means that they respond to light. The stems of these plants try to grow towards the direction of the source of the light.

Consider a garden plant which is partially in the shade. When light shines on a part, it stimulates the secretion of growth hormones called auxins in that area of the stem.

These auxins cause that part of the stem cells to elongate, forcing the stem to grow towards the sunlight. These are changes that occur continuously through the life cycle of a plant.

Seasonal Effects

If there is one disadvantage to sunlight, it is the fact that it is not constant all through the year. The duration and intensity of sunlight received fluctuate with the changing seasons.

So plants have adapted to these changing seasons as well. In the summer and spring, with light being plentiful, most plants focus on growth, blooming of flowers, and bearing of fruit.

When the light intensity and duration reduces as winters approach, the plants put more emphasis on conserving energy and reducing growth.

Photosynthesis is reduced in the fall, and leaves start losing chlorophyll. This is why leaves tend to turn brown, yellow, or red in autumn.

Evaluate

Consider the following questions:

1. After reading the above material, please explain why plants grow differently in different light level.
2. Do plants grow better with higher light intensities?

LESSON 8： Do plants grow better with more water?

Science - Grade 6-8

Objectives

Experimentally determine the optimum amount of soil moisture needed for optimal plant growth.
Identify aspects of human activity which can negatively impact crop productivity.

Standards

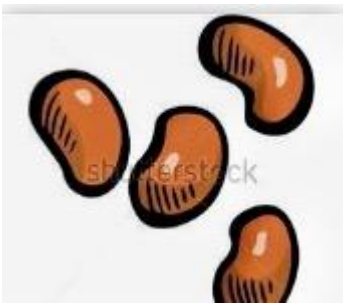
NEXT GENERATION SCIENCE STANDARDS - MIDDLE SCHOOL (MS)

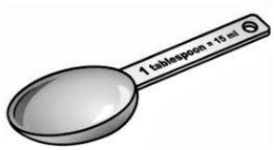
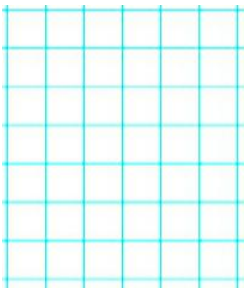
From Molecules to Organisms: Structures and Processes MS-LS1-4, MS-LS1-5
Ecosystems: Interactions, Energy and Dynamics MS-LS2-1, MS-LS2-4, MS-LS2-5 MS-ESS3
Earth and Human Activity MS-ESS3-3
Engineering Design MS-ETS1-1, MS-ETS1-3

Materials

BOSON Science Kit Materials	*Diagram*
Battery Holder w/3x AAA batteries installed	
MainBoard-1IO (m2)	

Soil Moisture Sensor	
Display Modulen (o11)	
1x short BOSON cable	

1x long BOSON cable	
Additional Materials	*Supplies & Materials*
12-18 Bean Seeds	
Potting Soil	
4-6 Clear Plastic 18 oz. Cups	
Permanent Marker	

1 Tablespoon Measuring Spoon	
Water	
Ruler	
Popsicle Stick	
Paper Towels	
Graph Paper	
Scissors	

Activity

Create a chart like the one below in your journal.

Amount of Water Added to Soil (Tablespoons)	Observations: Sight and Touch of Soil
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

1. Fill a plastic cup 3/4 full with potting soil. Carefully stir the soil with a popsicle stick. Look closely at the soil. Scoop up a little bit of the soil in your hand. What does the soil look like? What does it feel like? Record your observations in the chart.
2. Add a tablespoon of water. Carefully stir the soil with a popsicle stick. Look closely at the soil. Scoop up a little bit of the soil in your hand. What does the soil look like? What does it feel like? Record your observations in the chart.
3. Continue adding water, stirring the soil. Looking at, touching the soil and recording your observations.

Discuss the following questions with your group:

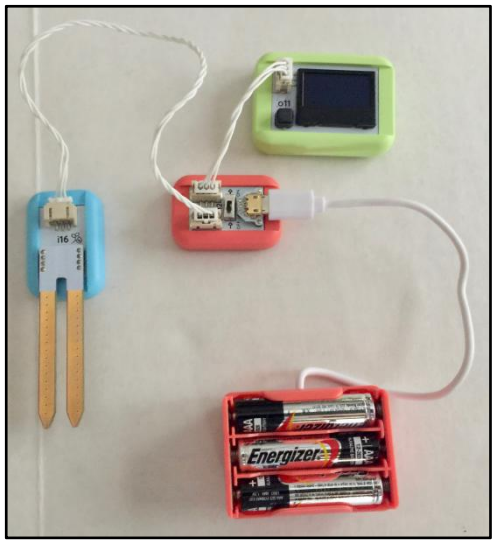
1. Discuss how the soil looked and felt with each addition of water.
2. Was there a point when the soil felt “muddy” as opposed to “wet dirt”?
3. At what point (how many tablespoons of water) did the soil become completely saturated and was able to “pour” like water?
4. Do you think the amount of water in soil can affect plant growth? Explain.

Explore

In this activity your group will use the BOSON Soil Moisture Sensor to collect data as you plant, water and grow bean plants. The purpose of this activity is to determine if there is an optimal amount of water which will result in the greatest plant growth. You will then relate this information to how some aspects of human activity can have a negative impact on crop production.

Activity Procedure Setup:

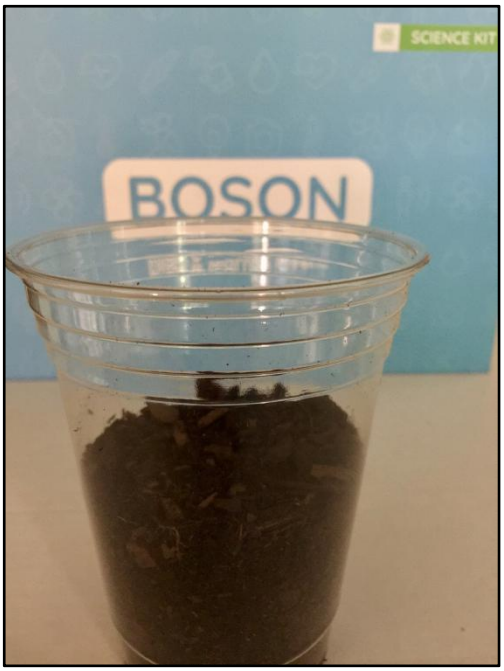
1. Connect the Battery Pack to the MainBoard-110. Ensure the MainBoard-110 is turned OFF.
2. Use a short BOSON Cable to connect the Display Module with the MainBoard-110.
3. Use a long BOSON Cable to connect the Soil Moisture Sensor with the MainBoard-110.



4. Set the BOSON equipment aside.
5. Use a permanent marker to number individual clear plastic cups 1-6.
6. Create a data table in your journal.
    a. Note: You will add rows of data for approximately 3 weeks.
    b. Note: For the first few rows there will be no height data to record because the beans will not have broken through the surface of the soil.

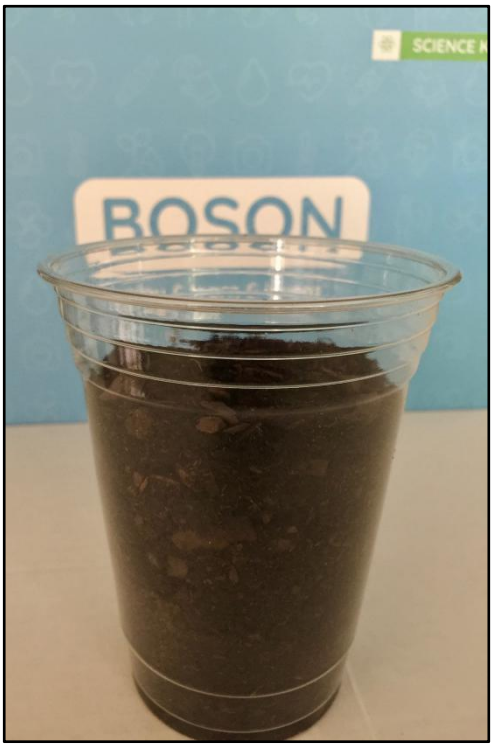
Experiment

1. Fill each plastic cup 1/2 full with garden soil. Pat the soil down gently.



2. Place 3 beans, spaced apart, on top of the soil.

3. Add more garden soil to the cup leaving about an inch to the top. Pat the soil down gently.



4. Add water to each cup as indicated in your data table. Enter the date in the left-hand column.
5. Measure and record the soil moisture according to the instructions below:
   a. Turn on the BOSON MainBoard-110.
   b. Press the black button on the Display Module until the display shows “Analog Data” for the Soil Moisture Sensor i16.
   c. Place the Soil Moisture Sensor into the soil of cup #1.

d. Record the analog data displayed.
e. Wipe off the soil moisture sensor with a paper towel.
f. Repeat steps c-e for each cup.

6. Place the cups near a window which receives sunlight during at least some of the day. Make sure all cups receive the same amount of light.
7. Water the plants daily. Measure and record the soil moisture daily.
8. Note: 3 beans were planted in each cup in order to ensure you have a plant to measure growth for each cup. However, you will only measure the growth of one plant. Keep the healthiest looking plant and remove the other two plants from the cup.
9. Measure and record the plant's height to your chart daily for one to two weeks.

Data Record

Copy the Data Table below into your notebook.

Date	Soil Moisture (Analog Data) and Plant Height (inches)					
	Cup 1 No Water	Cup 2 1 Tbsp. Water	Cup 3 2 Tbsp. Water	Cup 4 3 Tbsp. Water	Cup 5 4 Tbsp. Water	Cup 6 5 Tbsp. Water

Explain

Making Sense of the Data:

Create a Bar Graph according to the directions below:

1. Calculate the average soil moisture for each cup over the testing period.
2. The manipulated variable is the cup number and the responding variable is the average soil moisture reading.
3. The manipulated variable is graphed along the X axis and the responding variable is graphed along the Y axis.
4. Use the variables to give your graph a title.
5. Include a legend for your graph.

Create a Multi-Colored Line Graph according to the directions below:

1. Use a different color to plot your results of plant growth for each cup.
2. The manipulated variable is the date and the responding variable is the measured height of the plant.
3. The manipulated variable is graphed along the X axis and the responding variable is graphed along the Y axis.
4. Use the variables to give your graph a title.
5. Include a legend for your graph.

Data Analysis:

In your group discuss the following questions:

1. Which plant grew the highest? What was the average soil moisture reading for this plant?
2. Which plant grew the least? What was the average soil moisture reading for this plant?
3. Were there any plants which did not sprout and/or died during the experiment?
4. Looking at your data, what seems to be the optimal amount of soil moisture for plant growth?

Elaborate

Vocabulary:

- Soil moisture - the quantity of water contained in a soil sample
- Optimal - best or most favorable
- Root - the structural part of a plant, usually found underground that grows downward, is responsible for plant support and absorption of water and nutrients
- Root hair - thin hair like projections of the root which increase the overall root surface area and responsible for absorption of nutrients and water
- Diffusion - the movement of a substance from an area of higher concentration to an area of lower concentration
- Vascular - relating to the plant tissues which are responsible for movement of water, nutrient and food substances
- Xylem - the plant tissue responsible for transporting water and nutrients from the roots to other areas of the plant
- Phloem - the plant tissue responsible for the downward movement of food substances from the leaves to other areas of the plant

Science Background:

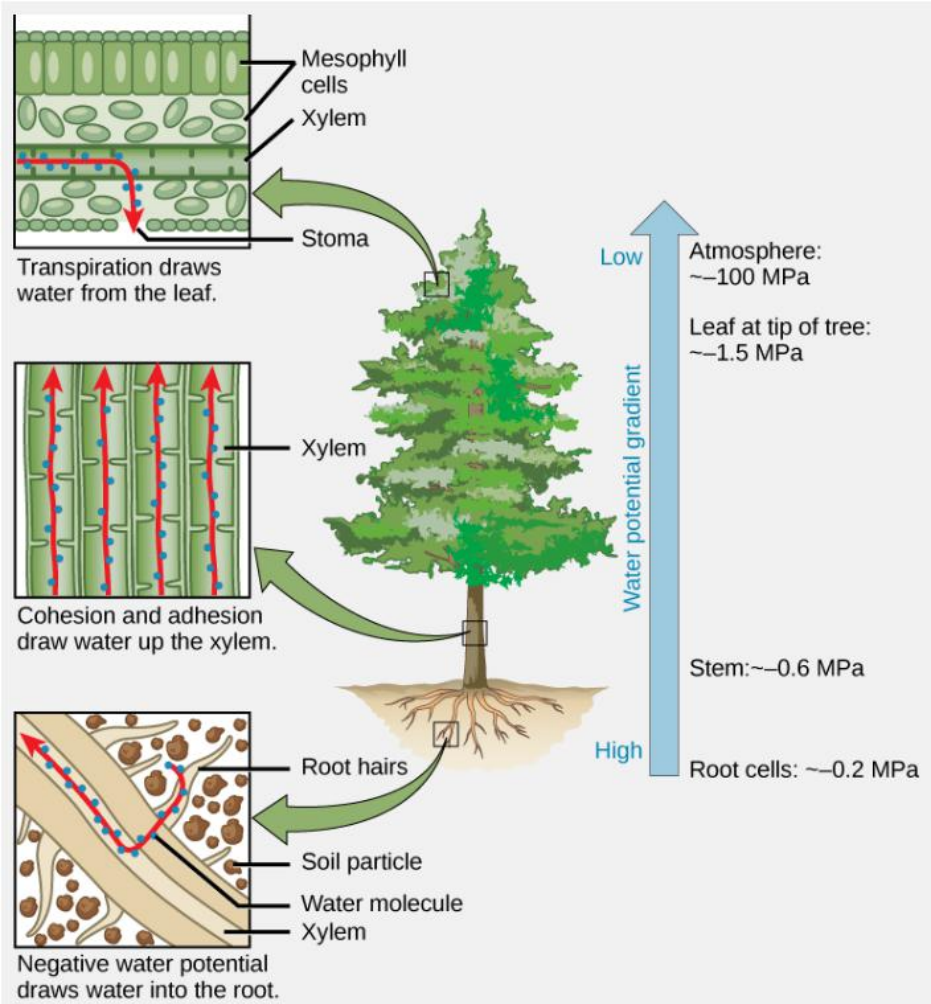
Along with sunlight and nutrients from the soil, all plants need moisture to grow. Plants develop adaptations to survive in various ecosystems. Each species of plant has a range of tolerance for moisture and will grow best when the optimal amount of moisture is available. Too little moisture can result in plant death. Too much moisture can cause root disease which will also result in plant death.

How do plants take in moisture?

The root system of a plant is responsible for structural support as well as the uptake of water from the soil. Most of a plant's root system remains hidden below in the soil. Part of the root is made up of fine root hairs. Water from the soil enters the plant through the root hairs. Because the cells of roots contain more solutes than in the soil, water will move into the root by the process of diffusion. From the roots water is moved and distributed to all parts of the plant. In general, the more extensive the root system, the more water it is able to absorb.

How does water move within a plant?

Plants stems have a vascular system which connects the roots of a plant to the leaves. The vascular system is made up of two types of tissue, xylem tissue and phloem tissue. Xylem tissue transports water from the roots to all other parts of the plant. Phloem tissue is responsible for transporting sugars made by the process of photosynthesis in the leaves to the non-photosynthetic parts of the plant.



The cohesion-tension theory of sap ascent is shown. Evaporation from the mesophyll cells produces a negative water potential gradient that causes water to move upwards from the roots through the xylem. Image credit: OpenStax Biology

Can plants survive periods of drought and periods of excess moisture?

While some plants have a narrow range of tolerance for soil moisture, other plants have developed adaptations which help them survive periods of drought or periods of excess moisture. These adaptations include modifications to root depth and spread, adaptations of the stem to help a plant remain upright during limited or excessive periods of moisture, and adaptations of leaves to retain or release water.

Evaluate

1. After analyzing your experimental data and discussing the information above cut down the side of two or three cups and carefully remove the plants. Keep note of which cup each plant came from.
2. Carefully remove plants from the soil and lay them on a paper towel.
3. Make and note observations of the plants with regards to structure and color. Note differences in the root, stem and leaves.
4. Create a diagram for each plant. Identify the amount of water each plant received, the structure and function of the plant parts. Include your observations with your diagram.

Extend

Research and develop a project based on one of the following:

- How can El Niño and La Niña weather events affect crop growth and yield?
- What are some specific plant adaptations for dealing with drought? With surviving in wet ecosystems?
- Compare and contrast the range of tolerance for water of desert plants vs. wetland plants.
- In what ways can human activity have an impact on the amount of soil moisture available for plant growth? How can people work to mitigate possible negative impacts?

LESSON 9： What’s the best environment for a plant?

Science - Grade 6-8

Objectives

Search the best PH, light level, and soil humidity of a plant online. Set up contrast experiments using the control variables method to check if the plant grows best when the optimal growth requirements are met.

Standards

NEXT GENERATION SCIENCE STANDARDS - MIDDLE SCHOOL (MS)

From Molecules to Organisms: Structures and Processes MS-LS1-4, MS-LS1-5

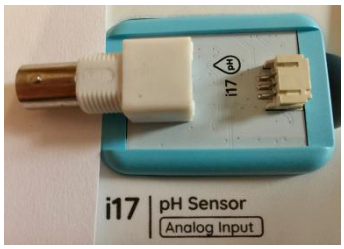
Ecosystems: Interactions, Energy and Dynamics MS-LS2-1, MS-LS2-4, MS-LS2-5 MS-ESS3

Earth and Human Activity MS-ESS3-3

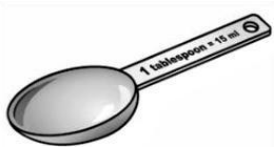
Engineering Design MS-ETS1-1, MS-ETS1-3

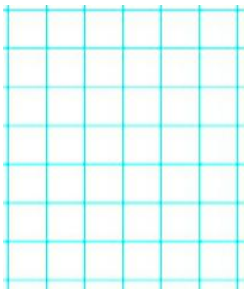
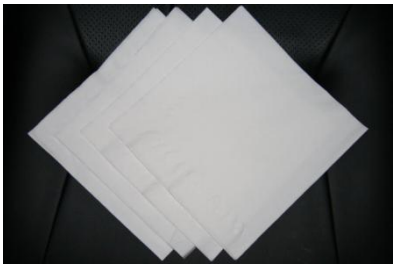
Materials

BOSON Science Kit Materials	*Diagram*
Battery Holder w/3x AAA batteries installed	
MainBoard-1IO (m2)	

Soil Moisture Sensor	
pH Sensor (i17)	
pH Probe	
Display Modulen (o11)	

1x short BOSON cable	
1x long BOSON cable	
Additional Materials	*Supplies & Materials*
Pothos (leaves should be the same in size and quantity)	
Potting Soil	

4-6 Clear Plastic 18 oz. Cups	
Permanent Marker	
1 Tablespoon Measuring Spoon	
Water	
Ruler	
Popsicle Stick	
Paper Towels	

Graph Paper	
Scissors	
Toilet Paper	
Gauze Filter	
Rubber Band	

Activity

We have explored the three factors affecting plant growth: pH, light level, soil humidity. Search the best growth parameters for Pothos online, and fill the form below:

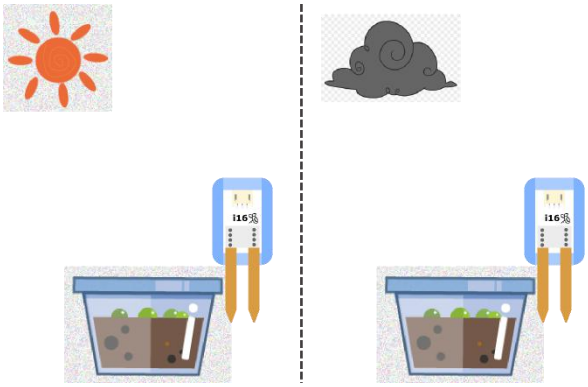
PH	Light Level	Soil Humidity

If we control the Potho's condition in the optimal growth data range, will that be the best environment for its growth?

To find out the answer, you may need to think about the following questions:

- Will light influence soil pH?
- Does light affect soil humidity?
- Will soil humidity affect soil pH?

Design experiments to explore these questions. Take the second one as an example:



- Mark two plastic cups as A and B.
- Fill two cups 3/4 full with potting soil.
- Add the same quantity of water in two cups, wait for a while, then measure their humidity. Spray water onto the soil until the humidity difference of two cups of soil stays in a very small range.
- Put cup A outdoor in sunlight, cup B indoor in shade.
- Measure the soil humidity in two cups at regular intervals.

	Initial soil humidity	1 day later	2 days later	3 days later
Without sunlight				
With sunlight				

Explore

In this activity your group will use BOSON pH sensor, light sensor, Soil Moisture Sensor to collect data as you plant, water and grow Pothos. The purpose of this activity is to determine whether the best growth environment for Pothos can be constructed when multiple optimal growth requirements are met.

Experiment

1. Plant 4 pots of Pothos with a similar initial state as the way in the previous activity. Use BOSON pH sensor, light sensor, and soil moisture sensor to detect the corresponding values.

2. Set optimal-condition group: for Pothos pot 1, control the three factors affecting Pothos growth in the best range(the data you got online).

3. Set control group 1: for Pothos pot 2, adjust the soil pH lightly(increase or decrease by 1) and keep the other two factors as the same of the pot 1.
4. Set control group 2: for Pothos pot 3, adjust the light level to 1/2 of the Pot 1, and keep other factors as the same of Pot 1.
5. Set control group 3: for Pothos pot 4, adjust the soil humidity to 1/2 of the Pot 1, other factors are the same as Pot 1.
6. Observe and record the growth situation of Pothos daily for one week.

Data Record

Copy the Data Table below into your notebook.

	PH	Light level	Soil humidity	Growth situation
Optimal-condition Group				
Control group 1				
Control group 2				
Control group 3				

Explain

Making Sense of the Data:

Create a Multi-Colored Line Graph according to the directions below:

1. Use a different color for each cup to plot your results for plant growth.
2. The manipulated variable is the date and the responding variable is the growth situation(plant height, leaf number).
3. The manipulated variable is graphed along the X axis and the responding variable is graphed along the Y axis.
4. Use the variables to give your graph a title.
5. Include a legend for your graph.

Data Analysis:

In your group discuss the following questions:

1. Which pot of Pothos grows best? Is it the optimal-condition group(Pot 1)?
2. Which pot of Pothos grows worst? Whether the corresponding control variable is the most important factor for Pothos growth?
3. According to the data you recorded, if the best growth environment for Pothos can be constructed when multiple optimal growth requirements are met.

Elaborate

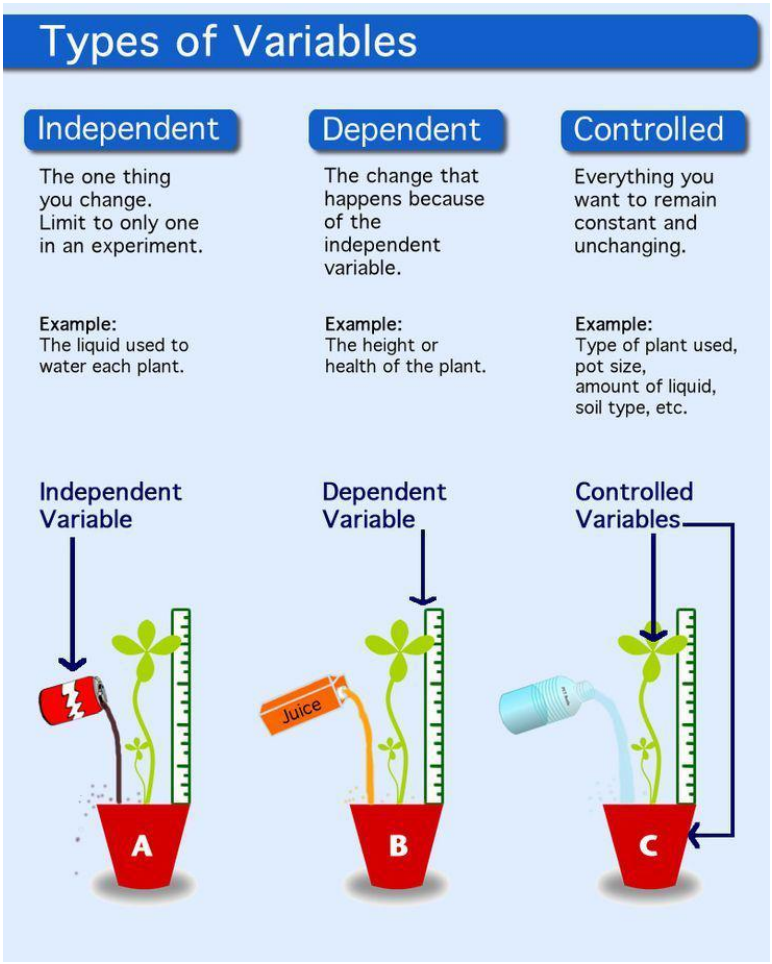
Vocabulary:

- Control Variable
- Independent Variable
- Dependent Variable

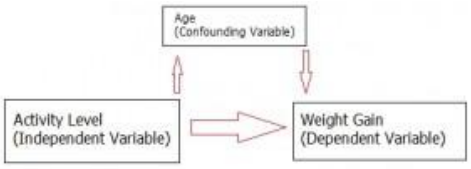
Simple Definition:

An experiment has several types of variables, including a control variable (sometimes called a controlled variable). Variables are just values that can change; a good experiment only has two changing variables: the independent variable and dependent variable. Let's say you are testing to see how the amount of light received affects plant growth:

- The independent variable, in this case the amount of light, is changed by you, the researcher.
- As you change the independent variable, you watch what happens to the dependent variable. In this case you see how much the plants grow.
- A control variable is another factor in an experiment; it must be held constant. In the plant growth experiment, this may be factors like water and fertilizer levels.



The Control Variable and Experimental Design



A confounding variable can have a hidden effect on your experiment's outcome.

If control variables aren't kept constant, they could ruin your experiment. For example, you may conclude that plants grow optimally at 4 hours of light a day. However, if your plants are receiving different fertilizer levels, your experiment becomes invalid. As a researcher, you should identify any variables that may affect the outcome of your experiment and you must take steps to keep them constant ("control" them). If you do not, your experiment compromises internal validity, which is just another way of saying your experimental results will not be valid. When control variables run amok and aren't controlled, they turn into confounding variables, which affect your results and ruin your experiment.

Control Variables vs. Control Groups

In any experiment or research, it can be virtually impossible to account for all variables that may affect the outcome of your experiment. If it's difficult to identify and control all potential confounding variables, it may be necessary to make a control group. A control group provides a baseline measurement for your experiment.

Evaluate

1. In the experiment, where did we use the control variables method?
2. What are the independent variable and the dependent variable in this experiment?

LESSON 10： Can pure water conduct electricity?

Science - Grade 6-8

Objectives

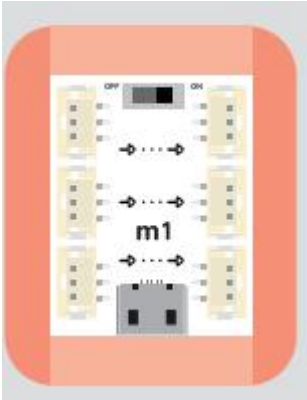
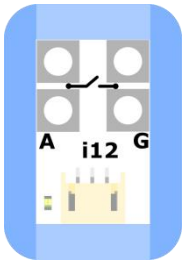
In this lesson, we are going to explore the conductivity of different liquids, discuss whether pure water can conduct electricity, and find out which kind of liquid in our daily life has the best electrical conductivity.

Standards

NGSS - NEXT GENERATION SCIENCE STANDARDS - MIDDLE SCHOOL (MS)
Matter and its Interactions- MS-PS1-2
Engineering Design - MS-ETS1-1, MS-ETS1-3

Materials

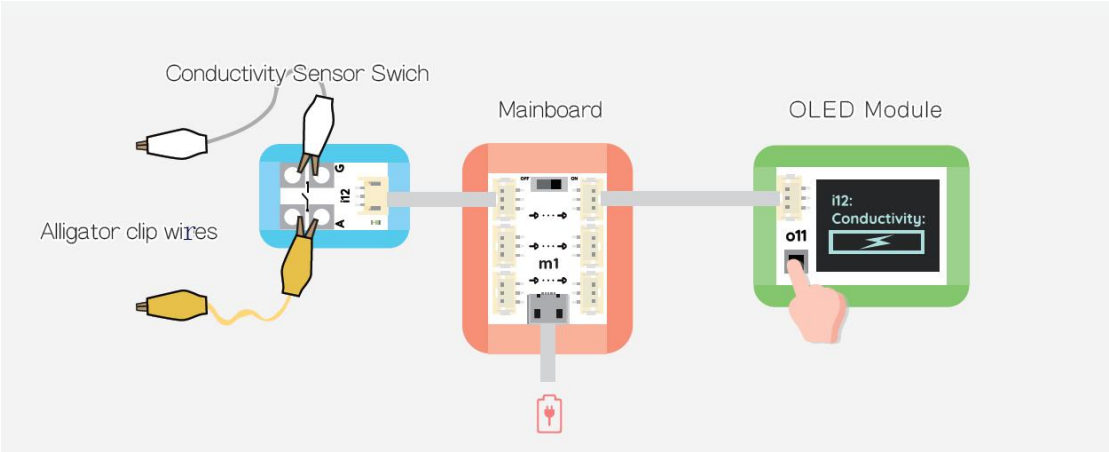
BOSON Science Kit Materials	*Diagram*
Battery Holder w/3x AAA batteries installed	

MainBoard-3IO (m1)	
Display Module(o11)	
Conductivity Switch (i12)	
Alligator Clip Test Cables	

1x short BOSON cable	
1x long BOSON cable	
Glass	
Water	
Different liquids	

Activity

To know whether an object is conductive, we can use a Conductivity Sensor Switch to check it out. Connect the conductivity switch, Mainboard, and OLED module as the way shown below. Switch the display module to “i12”, and connect two Alligator Clip Test Cables with the Conductivity Sensor.



1. Explore whether some daily-used stuff has electrical conductivity, like tissue, scissors, wood, etc. (There will be a lightning bolt symbol displayed on the OLED module if the object is conductive.)
2. Will the result be different when the tissue is wet?
3. Try to figure out some conductive liquids in our daily life.

Explore

In this activity, your group will use a conductivity switch to detect the conductivity of different liquids. Meanwhile, try exploring whether the distance of two Alligators clips will influence the conductivity of a solution.

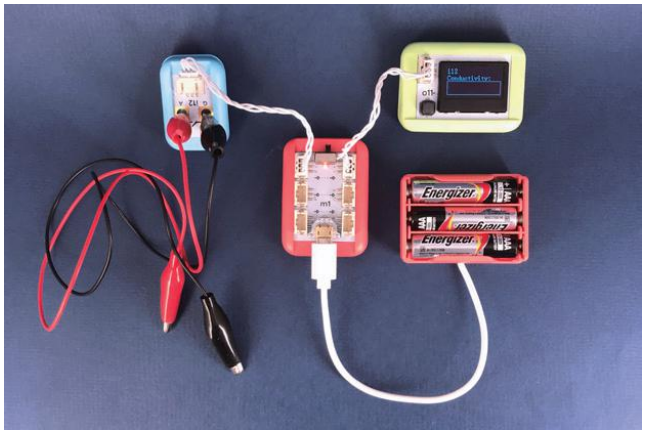
Experiment

1. Prepare Solutions

Prepare 5 cups(glass, plastic, or disposable cups) and then pour 50ml vinegar, baking soda, soapy water, distilled water and rice wine into the cups respectively.

2. Connect the Conductivity Switch

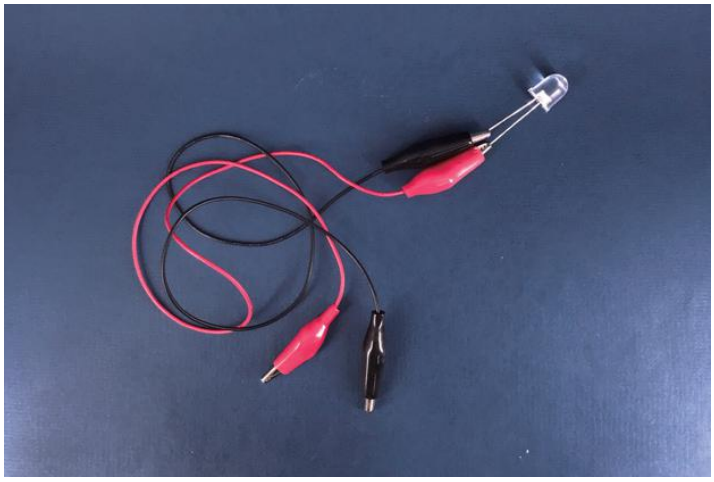
Connect the conductivity switch with the OLED module, power source(4.5V) and power-mainboard. Attach the two alligators clips on the conductivity switch. The hardware connection for detecting liquid electric conductivity is done.



3. Connect an LED with two Alligator Clips

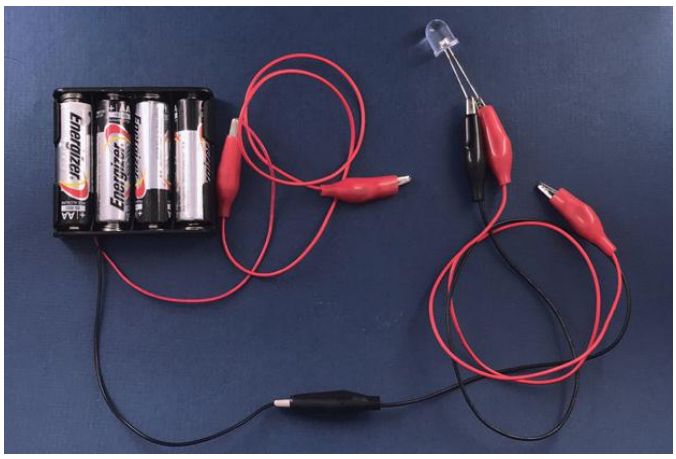
To detect the effect of distance of alligator clips on liquid conductivity, we have to connect another set of tools.

Connect the LED long lead to red alligator clip cable, the short lead goes to the black cable.



4. Connect LED with Battery Box

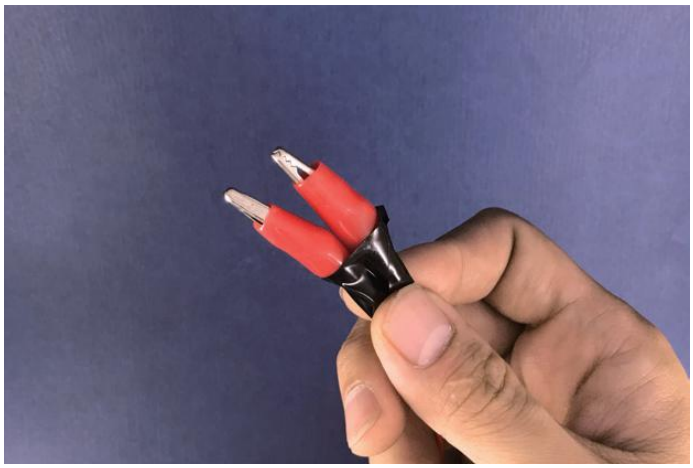
Connect a red alligator clip cable to a 6V battery box's red wire, then connect the box's black wire to the black alligator clip cable on the LED's short lead.



5. Fix the Alligator Clips cable

Use tape to fix the alligator clip cables.

Tips: The front end of the alligator clips should not be touched together, or it will be dangerous!



6. Put the Alligator clips into the Liquids

Place the fixed alligator clip cables into a liquid, observe and record.

Tips:

To improve the detection accuracy, please wipe the alligator clips with clean tissues before you put them into different liquids, and try to remove all the remained liquids.

Data Record

Now, place the alligator clips into different liquids, and see if there is a lightning bolt symbol appearing on the OLED module, at the same time, observe the brightness change of the LED, will the LED' s brightness be different for various liquids?

Copy the Data Table below into your notebook.

	Vinegar	Baking soda	Soapy	Distilled Water	Rice Wine	Others

Electrical conductivity						
LED Brightness						
LED brightness when the distance between Alligator clips is 5cm						
LED brightness when the distance between Alligator clips is 10cm						

Explain

Data Analysis:

In your groups discuss the following questions:

1. Can every cup of liquid conduct electricity? Which liquid has the best electrical conductivity?
2. Is the LED brightness all the same for different liquids?
3. Will the water temperature affect its electrical conductivity? Set up an experiment and explore.
4. Does the distance between the alligator clips influence the brightness of the LED? Try Separating them by 5cm or 10, then record data in the table above.

Elaborate

Vocabulary:

- Dissociation - physical process accompanying the dissolution of an ionic compound in which the compound's constituent ions are solvated and dispersed throughout the solution
- Electrolyte - substance that produces ions when dissolved in water
- Nonelectrolyte – substance that does not produce ions when dissolved in water
- strong electrolyte – substance that dissociates or ionizes completely when dissolved in water
- weak electrolyte – substance that ionizes only partially when dissolved in water

Science Background:

When some substances are dissolved in water, they undergo either a physical or a chemical change that yields ions in solution. These substances constitute an important class of compounds called electrolytes. Substances that do not yield ions when dissolved are called nonelectrolytes. If the physical or chemical process that generates the ions is essentially 100% efficient (all of the dissolved compound yields ions), then the substance is known as a strong electrolyte. If only a relatively small fraction of the dissolved substance undergoes the ion-producing process, it is called a weak electrolyte.

Substances may be identified as strong, weak, or nonelectrolytes by measuring the electrical conductance of an aqueous solution containing the substance. To conduct electricity, a substance must contain freely mobile, charged species. Most familiar is the conduction of electricity through metallic wires, in which case the mobile, charged entities are electrons. Solutions may also conduct electricity if they contain dissolved ions, with conductivity increasing as ion concentration increases. Applying a voltage to electrodes immersed in a solution permits assessment of the relative concentration of dissolved ions, either quantitatively, by measuring the electrical current flow, or qualitatively, by observing the brightness of a light bulb included in the circuit (Figure 1).

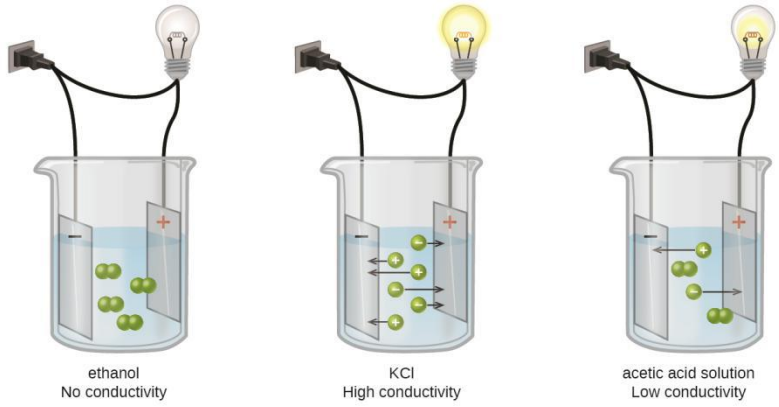


Figure 1. Solutions of nonelectrolytes such as ethanol do not contain dissolved ions and cannot conduct electricity. Solutions of electrolytes contain ions that permit the passage of electricity. The conductivity of an electrolyte solution is related to the strength of the electrolyte.

Pure water is an extremely poor conductor of electricity because it is only very slightly ionized—only about two out of every 1 billion molecules ionize at 25 °C. Water ionizes when one molecule of water gives up a proton to another molecule of water, yielding hydronium and hydroxide ions.

$$\mathrm{H_2O}(l) + \mathrm{H_2O}(l) \rightleftharpoons \mathrm{H_3O^+}(aq) + \mathrm{OH^-}(aq)$$

Evaluate

Consider the following questions:

1. Why the LED's brightness is different for different liquids?
2. Can you explain the relation between the distance of alligator clips and the LED brightness according to the experiment result?

LESSON 11: Are we able to 'see' conductivity?

Science - Grade 6-8

Objectives

In this lesson you will investigate how different materials and states of matter have different abilities to carry positive and negative charges. These charges attract each other. The attraction or movement of charged particles can be measured.
We will start with the phenomenon of static electricity and then move to the conductivity of different substances when they are dissolved in water. You will then use the Boson Kit to measure the change in conductivity as more salt ions are added to water. This lesson will get you charged up!

Standards

NGSS - NEXT GENERATION SCIENCE STANDARDS

5-PS1-3 Matter and its Interactions

Make observations and measurements to identify materials based on their properties.

Materials

BOSON Science Kit Materials	*Diagram*
Battery Holder w/3x AAA batteries installed	

MainBoard-1IO (m2)	
Display Module(o11)	
Soil Moisture Sensor	
Module Velcro	

1x short BOSON cable	
1x long BOSON cable	
Cup of Distilled Water	
Balloon	

Salt	
Scooper （or spoon）	

Activity

Why does your hair “stick“ to the balloon?

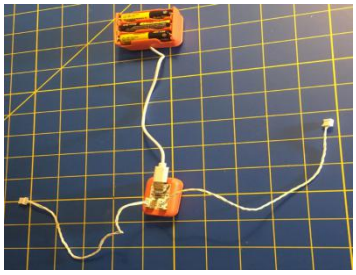
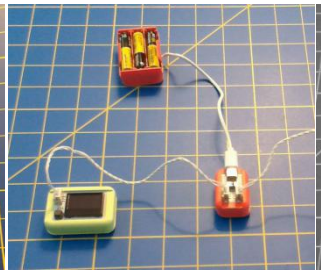
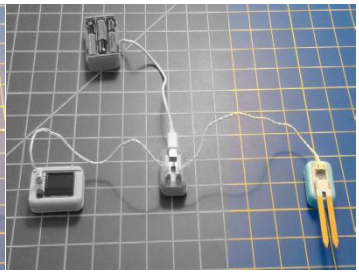
- Have the students charge a balloon by rubbing it on their hair.
- Next, have them pull the balloon slowly away. Some of their hair should “stick“ to the balloon. If not, have them rub longer.
- After they have fun with this for a while, start a discussion about why this is happening. Someone may know it is because of static electricity but can they explain how static electricity works?

Explore

To measure the number of ions in the saltwater solution, we will be using the soil moisture sensor in the Boson Kit. The soil moisture sensor works by putting opposite charges on the two prongs (electrodes) of the device. The soil moisture sensor is an analog voltage sensor that can be used to measure a continuous spectrum of different conductivities.

Setup:

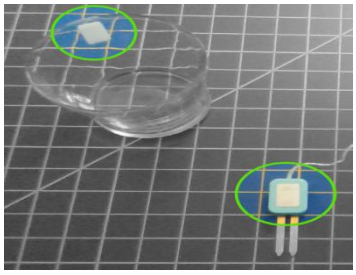
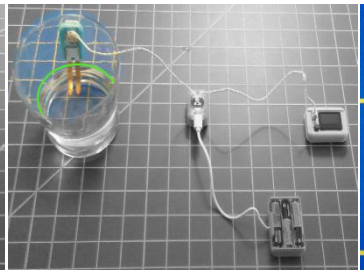
1. Connect the Battery Holder and two Module Cables to the Main Board.
2. Connect the OLED Module to the output side of the Main Board with a Module Cable.
3. Connect the Soil Moisture Sensor to the input side of the Main Board with a Module Cable.

4. Attach the Soil Moisture Sensor to the Cup with the Module Velcro.

5. Add the Distilled Water to the Cup. Fill the Cup so the water covers the bottom half of the legs of the Soil Moisture Sensor.

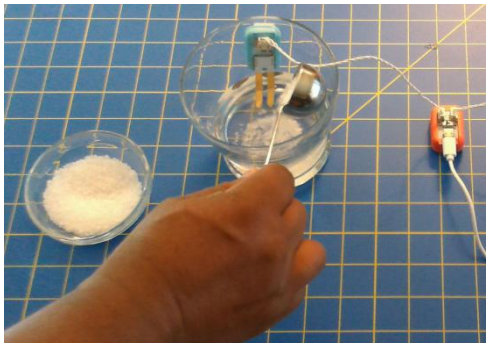
6. Turn on the OLED and turn it to the analog screen.


Experiment

1. Add scoops of Salt to the Distilled Water. Record the analog reading, which is the voltage reading.

2. Repeat Step 1 and gather data.



Data Record

Copy the Data Table below into your notebook.

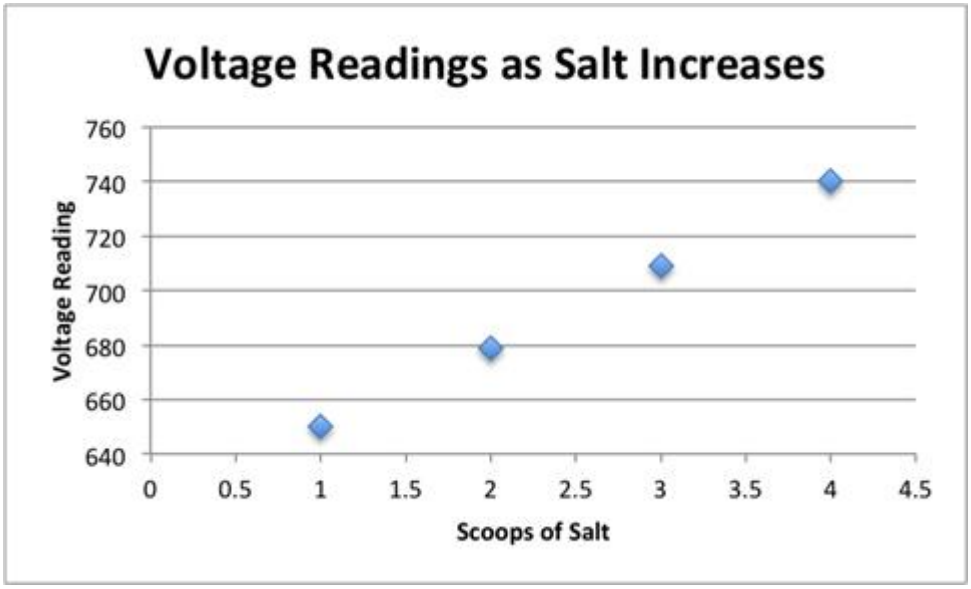
Scoops of Salt	Measured Voltage Reading(V)
1	
2	

3	
4	

Explain

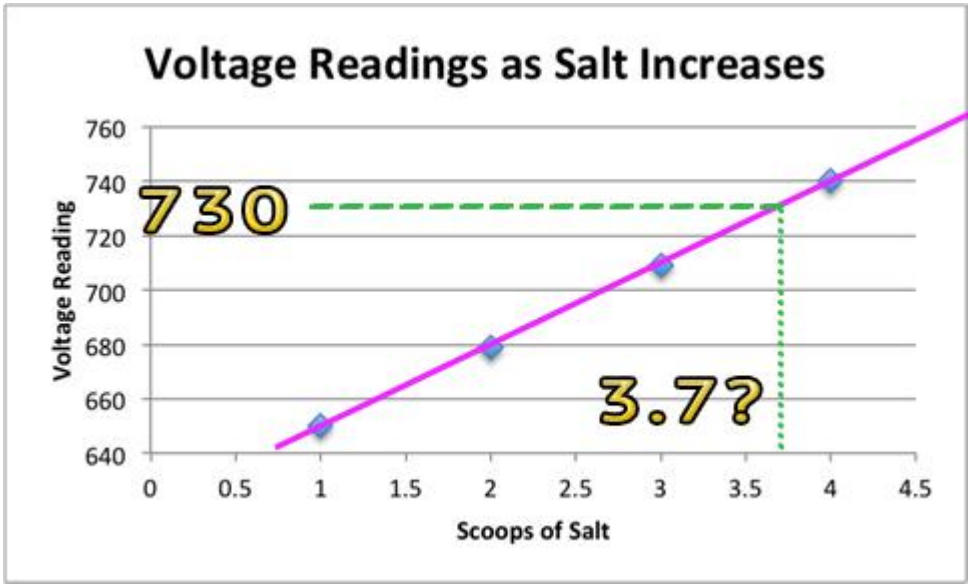
Data Analysis:

Have students graph the results. We recommend students make the graphs by hand, but you could also use free software like Google Sheets.



Students can make a line of best fit and find the linear equation. This will allow them to determine the number of scoops in a solution of unknown concentration.

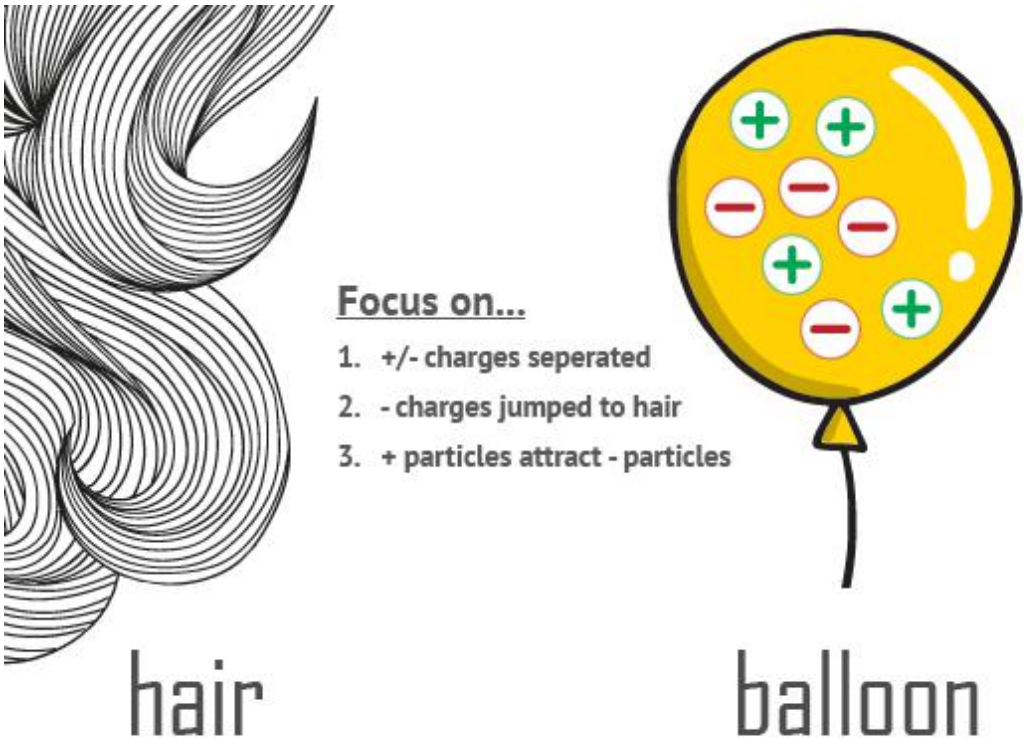
They use the conductivity meter to determine the voltage and then plug it into the equation as the y- value. Then they can then determine the amount of salt in the solution by solving for x.

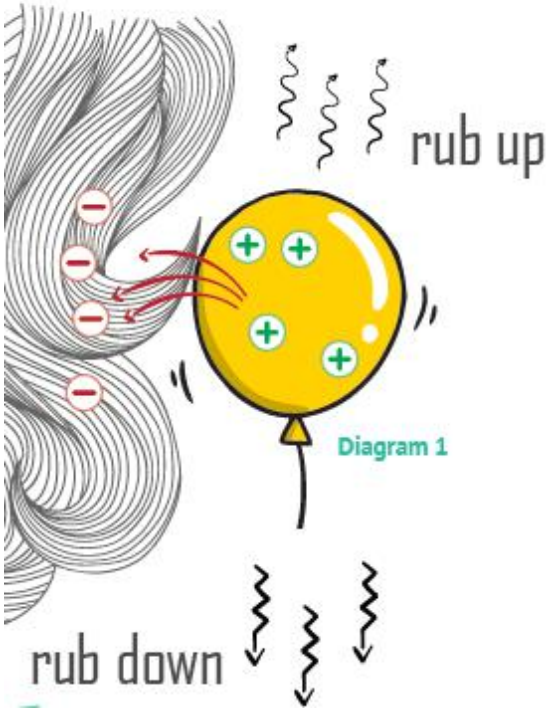


Students test a solution's voltage and get 730 volts. By looking at their graph they can determine this is about 3.7 scoops of salt.

Elaborate

Conductivity and the Flow of Ions





When the balloon is rubbed on the hair, the negative charges jump onto the hair, leaving the positive charges on the balloon. The friction from the rubbing seperated the charges. The balloon and hair become attracted to each other because they are oppositely charged. This is static electricity and why the hair "sticks" to the balloon.

This shows us that matter can be charged!

Ions = Charged Particles

Charged particles are called ions. Matter can be charged do to some change like the rubbing with the balloon. Other materials or matter innately carries a charge with it. The salt used in the Experiment is a material that carries a charge with it innately.

Conductivity = how much a material allows ions to flow through it

Ions(+/-) are attracted to their opposites. Ions attempt to move towards each other. The flow of ions to different places depends on the material they are in or the material the ions come into contact with. Some materials allow ions to move more freely while other materials resist that flow.

Voltage = how many negative charges "want" positive charges

Ions are charged and "want" their opposite. When a positive charge is near a negative charge, they will attract. This causes them to flow or move towards each other.

We can measure the flow of ions. A common way of doing this is to measure the voltage. Voltage is simply a measurement of how many negative charges "want" to combine with positive charges. The conductivity meter we build in Experiment measures voltage or the flow of charged particles.

To be "charged up" means to separate positive from negative charges

In Activity, we again get charged particles to separate by using friction. We prepare the balloon by rubbing it on our hair. Once the balloon is positively charged it is "looking for " some negative charges.

Oppositely Charged Particles Attract

In Activity, the balloon was able to find negative charges in our hair so they were attracted to each other.

Evaluate

Consider the following questions:

1. If we rub a balloon on our hair and then place it near a thin stream of water, what will happen? And why is this happening?
2. Can you explain the data line graph in the experimental results from a micro perspective?

LESSON 12：What happens to your body during a workout?

Science - Grade 6-8

Objectives

What happens to our bodies when we exercise? In this chapter we will use BOSON modules to make a heart rate detector to monitor our heartbeat, by which to explore the internal balance during the process of exercise.

Standards

NGSS - NEXT GENERATION SCIENCE STANDARDS

HS-LS1-3 From Molecules to Organisms: Structures and Processes

Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

Materials

BOSON Science Kit Materials	*Diagram*
Battery Holder w/3x AAA batteries installed	

MainBoard-1IO (m2)	
Display Modulen(o11)	
Heart Rate Sensor (i20)	
Module Velcro	

1x short BOSON cable	
1x long BOSON cable	

Activity

The human body is a complex system that is kept healthy and survives through a mechanism called homeostasis. Homeostasis is the body making adjustments to keep us safe and comfortable. For example, your body likes to be in a "Goldie Locks" temperature range that is not too hot and not too cold. To stay in this comfortable temperature range, your body will shiver when it is cold and sweat when it is hot. This is just one example of a negative feedback loop the body uses to maintain homeostasis. Negative feedback loops work to minimize the effect of a change to the system. For your body, they are safety mechanisms that are used to keep your body in ideal conditions. Temperature is one factor the body must keep constant but there are others as well.

What will happen to your body if you do some exercise?

When you exercise, you are increasing the demand for oxygen and decreasing the oxygen concentration in your blood. The body responds by breathing faster and deeper, thereby taking in more oxygen and countering the decrease in oxygen. The blood also starts to

circulate faster in order to get rid of the extra carbon dioxide produced by cellular respiration. This means the heart will start beating faster.

What will happen to your heart rate if you do some exercise?

1. Find your heartbeat with your fingers. You can place them on your carotid artery in your neck, or the artery in your wrist.
2. Find a stopwatch and time the number of beats in 10 seconds.
3. Multiply the number of beats by 6 to find your beats per minute.
4. Now, jump up and down for 1 minute.
5. Repeat steps 1-3.
6. Compare the 2 values: Which one is higher?

Explore

Building a heart rate monitor with the Boson Kit will give you a much clearer picture of your heart rate by automatically counting your heart beats for you.

Setup:

1.Connect the Battery Holder and two Module Cables to the Mainboard.

2. Connect the Heart Rate Sensor to the input side of the Mainboard with a Module Cable.

3. Connect the OLED Module to the output side of the Mainboard with a Module Cable.

4. Press the button on the OLED Module until the screen turns on.

Experiment

1. Press a finger on the heart rate sensor, measure data three times and take the average value.

Tip: please apply moderate pressure on the sensor. Take the average value from multiple measurements can ensure the accuracy of the recorded data.

2. Do an exercise, and measure the heart rate in 3, 6 and 9 minutes.
3. Repeat steps 1-2, and select different sports every time.

Data Record

Copy the Data Table below into your notebook.

Exercise	0min			3min			6min			9min		
Run												
Swim												

Explain

Data Analysis:

In your groups discuss the following questions:

1. What was the effect of increased exercise on heart rate? Was there a positive/negative correlation?
2. Justify your results with the information from the activity and from what you know about exercise and your heart.
3. Compare your results with the rest of your class. Did they match up?
4. What would you say is your greatest source of error and how would you improve next time?

Elaborate

Vocabulary:

- Homeostasis
- Metabolism
- Cellular Nutrition and Waste

Science Background:

Increased Heart Rate During Exercise & Maintaining Homeostasis

During exercise, your heart rate increases to maintain a state of balance, known as homeostasis."Homeostasis" means balance or equilibrium. How your body works to maintain equilibrium is reflected in how your vital signs vary with activity. Heart rate, blood pressure and respiration are lowest during periods of rest and sleep. During exercise, blood pressure, pulse and respiration increase to meet the increased demand for oxygen and

nutrients by your musculoskeletal system. The adjustment of vital signs to match your body's level of physical activity is an example of homeostasis in action.

Metabolism

Metabolism is the rate at which cells of your body consume oxygen and nutrition. The increased demand of muscle cells for oxygen and nutrients during exercise is a state of increased metabolism. Homeostasis is maintained when your heart can provide the rate of blood flow necessary to meet your body's increased metabolic demand for oxygen and nutrients.

Homeostasis, Cellular Nutrition and Waste

Exercise increases the production of cellular wastes such as carbon dioxide and lactic acid. Your cardiovascular system maintains homeostasis between the delivery of oxygen and nutrients and the removal of cellular wastes by increasing your heart rate. Your increased heart rate speeds up delivery of oxygen and nutrient rich blood to your musculoskeletal system while increasing the rate at which blood is taken away from tissues and delivered to the lungs to receive oxygen.

Homeostasis and Blood Flow

The total amount of blood in a human body remains the same during exercise. To maintain homeostasis, your body redistributes blood flow. During exercise, blood flow to the nervous system, gastrointestinal tract, kidneys, brain and spleen decreases, while blood flow to the musculoskeletal system increases.

Temperature Homeostasis

Metabolic processes generate heat. The cardiovascular system helps to maintain homeostasis with respect to body temperature. An increased heart rate increases the delivery of blood to your skin. Increased blood flow to your skin and sweating causes dissipation of heat, and body temperature remains within normal limits.

Evaluate

Consider the following questions:

1. According to your experimental data, which exercise can maximize your metabolism?
2. Can you explain why different hearts and body systems respond to the same stimulus differently?