SUSTAINABLE DEVELOPMENT GOALS

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Education for Sustainable Development Kit: Consuming Sustainably

Sustainable Development Goal 12: Responsible Consumption and Production

Learner Guide

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Learner Guide

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ESD KIT: CONSUMING SUSTAINABLY

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INVESTIGATION 1: MATERIAL GOODS AROUND US

Learning Outcome: Identify and consider the useful lifespan of products to begin considering sustainable consumption and disposal practices.

Materials

Per learner:

- "Items in Your Homes" handout

What to Do

1. As a whole group, make a list of ten items you see around the room.
2. Looking at the class list:
   - **a.** How long do you expect to use each item? Do you consider each item temporary or permanent?
   - **b.** How long do you think each item could be used? This is called the item's lifetime. It is an estimate of how long an item and the parts that make it up can last under normal working conditions.
   - **c.** What are the items made of? How do you think this relates to the item's lifetime?
   - **d.** Where was the item made? How far did the item have to travel to get to us? If it didn't have to travel far, the item can be considered to have been sourced locally. If the item does have to travel far, it is considered imported.
   - **e.** What will you do with each item when it breaks or when you are done with it?

3. With a partner, make a list of twenty items you do (or might) have in your own homes on the "Items in Your Homes" handout. These items can be from your bedroom, kitchen, bathroom, garage, and so on.

4. With your partner, analyze the list of items from your homes:

   a. How long do you expect to have each item? Do you consider each item temporary or permanent?

   b. What are the items made of? Are there any similar materials that make up the temporary items? What about the permanent items?

   c. Were the items mostly sourced locally or imported? What about the materials in them — where do the different materials come from? Are those materials local or did they come from far away?

   d. How could you dispose of each item when you are done with it?

   e. Which items do you consider a necessity, and which are a luxury? Circle the item(s) on your list that you consider a necessity. What did you consider while making your decisions? Discuss your considerations.

5. With the whole group, share a couple items and your analyses. Which items did others also list? Did they agree about what were the necessities? The luxuries?

6. Sustainable Development Goal (SDG) 12 is all about responsible consumption and production.

   a. What do you think about when you hear "responsible consumption"?

   b. What about when you hear "responsible production"?

   c. Why do you think responsible consumption and production are important for people around the world?

ITEMS IN YOUR HOMES

Item	Temporary or Permanent?	Material(s)	Method of disposal

Consider

1. Review your list and the items you have circled as being necessities. Compare the number of luxury versus necessity items on your list. Which category did you list more of? Why do you think that is?

2. What was the most common disposal method in your list? Is this a sustainable disposal method? Why do you think so?

3. What are some ways material goods could be consumed more sustainably?

Extensions

1. **Applying Concepts:** Think about the life cycle of one product (a computer, a cell phone, a clothing item, or so on). What do you think the environmental impacts of the product or the process to make the product may be? Complete a life cycle analysis of the product to help determine the environmental impacts of the product. What are the raw materials that make up that product? What goes into the manufacturing or assembly of the product? How is it transported and distributed? How is the item used, and for how long? How is the item disposed of?

2. **Applying Concepts:** Examine a map of your community and identify stores where material goods are sold by outlining them in black ink. Also identify the building you are in by outlining it or coloring it in yellow. Create a Map Key for your community map with a lot of room to add other items, as you may continue to add to your map in other Investigations.

3. Using *Scratch*®: Choose a product from your list and create an animation showing its life cycle:

    a. Raw materials

    b. Transportation of raw material to point(s) of manufacture

    c. Manufacturing process

    d. Distribution of finished product

    e. Use

    f. Possibly re-use

    g. Disposable and recycling

4. Using *Scratch*®: Create a second animation that incorporates ways in which the processes could be changed to make them more sustainable. For example, using different raw materials, local sourcing of raw materials, more energy efficient manufacturing, less packaging, using materials that can be more easily recycled.

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INVESTIGATION 2: MODELING AND ASSESSING TYPES OF TRASH STORAGE

Learning Outcome: Build waste storage models and analyze leachate to compare different methods of waste storage.

Materials

Per group:

- small clear plastic bin (approximately 20 cm x 10 cm x 10 m [8″ x 4″ x 4″])
- small gravel
- hand pump from soap dispenser
- plastic tubing (that fits on the end of the syringe)
- plastic syringe (20–40 ml)
- nylon hose or cheese cloth, about 10 cm x 10 cm (4″ x 4″)
- 2 small rubber bands
- food coloring
- clay (optional)
- 2 small plastic cups
- small mesh strainer (<3″) similar a tea strainer (https://amzn.to/3FIBooO)
- simulated trash, 3 scoops
- gloves for each learner
- pH paper

- waste cup or bucket, labeled waste
- scissors
- water
- tape (optional)
- clear plastic wrap (optional)
- aluminum foil (optional)
- soil (optional)

What to Do

1. Construct the model landscape using the Awesome Aquifer Kit or DIY materials.
   a. Pour the gravel in the clear plastic kit container and spread it out evenly.
   b. Slowly pour about 75 mL (1/3 cup) of water into the container. This simulates the naturally occurring groundwater.
2. Build a model monitoring well:
   a. Cut a small piece of nylon (about 2.5 cm x 5 cm (1" x 2")) and fold into a smaller square.
   b. The hand pump will serve as the well pipe and pump. Cover the end of the hand pump with the nylon square and secure it with a rubber band. This creates a well screen to keep gravel out of the well pipe.

Credit: L. Brase

   c. Place the covered side of the handpump down so it reaches the bottom of the gravel at the middle of one of the shorter walls of the plastic container. Rearrange the gravel around the well so it remains vertical. If tape is available, you may also use tape to keep the handpump vertical. Now you can use this as your model monitoring well.

Credit: L. Brase

3. Collect and analyze a groundwater sample:
   a. Hold the top of the model monitoring well with one hand and use the other hand to pump the simulated groundwater into the small plastic cup. Fill the small plastic cup almost to the top.
   b. Write down observations of color and test the pH of the water. Record your data and observations in the data table under the column titled "Well Prior to Landfill Installation."
   c. Pour the water into the "Waste" bucket and rinse out the small plastic cup.
4. Build a model landfill:

a. On the opposite side of the clear plastic kit container from the monitoring well, move some gravel around to create a small depression.

b. Place the mesh strainer inside the depression and rearrange the gravel to surround it. This is your model landfill.

Credit: L. Brase

c. Build another well to place inside the mesh strainer:

- Cut a small piece of nylon (about 2.5 x 5 cm (1" x 2")) and fold into a smaller square.
- Cover the end of the plastic tube with the nylon square and secure it with a rubber band.

Credit: L. Brase

d. Hold the plastic tube vertically with the covered side down and touching the bottom of the mesh strainer. Place and compact the trash around the hose.

Credit: L. Brase

e. Optionally, put a couple scoops of soil over the top of the landfill and compact it down further.

5. Collect the water that has percolated through the gravel, also known as the leachate:

a. Simulate rainfall at the landfill by sprinkling about 75 mL (1/3 cup) of clean water over the half of the model landscape where the landfill is located.

b. Wait 1 minute and then take samples at both wells.

- Monitoring well: Use the handpump to collect a small cup of water from the monitoring well into a small plastic cup.
- Well inside the landfill: Place the tip of a syringe into the exterior end of tube of the well inside the landfill. Pull the syringe plunger to pump water from the well in the landfill. Transfer it to a second small plastic cup.

c. Analyze the samples by observing the color and taking the pH of the water. Record your data and observations in the data table under "Model 1: Landfill" columns.

d. Repeat 2 more times and record your data.

e. Once complete, clean out the model landscape:

- Remove the wells and rinse them off.
- Empty the contents of the mesh strainer into the garbage and rinse the mesh strainer.
- Carefully drain the model landscape and rinse out the gravel.

6. Assessing the model landfill:

a. Did the wells work? How could they have been improved?

b. How did the water from the monitoring well before the landfill was installed compare to the water from that well after the landfill was installed?

c. How did the water from the well inside the landfill compare to the water from the monitoring outside the landfill?

d. Was the landfill successful at containing the trash? Was the landfill successful at containing the pollutants within the trash? Use evidence in your explanation.

7. Improving the landfill:

a. How could the water quality at the monitoring well be improved? What modifications could you make to the landfill?

b. Using materials that are available to you, make modifications to the landfill so the monitoring well is less polluted. Rebuild the model landscape with both wells and using your modified landfill.

c. Test your design by repeating step 5.

d. Use the data table, or one like it, to record your observations in the "Model 2: Modified Landfill" columns.

	Monitoring Well Prior to Landfill Installation	Model 1: Landfill		Model 2: Modified Landfill	
		Monitoring Well	Well inside	Monitoring Well	Well Inside
Trial 1					
Trial 2					
Trial 3					

8. Discuss your findings with the whole group.

Consider

1. Were your modifications to the landfill successful at reducing the well water pollution? Back up your claim with evidence.

2. What other modifications would you make to the landfill if you had unlimited materials?

3. The landfill you modeled was open to the environment and rain was able to enter. When a landfill is full, it could be officially closed. At that time a cap made of clay or other impermeable material may be put over the top to keep water out. What do you think would happen if a landfill is capped, and therefore little air and rain can enter from the top? What do you think would happen to the surroundings?

4. Many communities have specific regulations for disposing hazardous chemicals or hazardous waste. Why do you think that is? What would happen if hazardous waste was thrown away like normal waste?

Extensions

1. **Testing Variables:** Items that end up in waste storage are usually left to decompose on their own. Do all items decompose? How fast do different items decompose? Test this out by conducting your own soda bottle decomposition experiment. Collect 3–5 different natural items that you can tear or cut apart (eggshells, apple cores, banana peels, leaves, flowers, etc.) and 3–5 synthetic items (plastic bottles, Styrofoam, glass, etc.). Cut off the top of a 2L bottle, then add alternating layers of soil with an item, then more soil and a different item — repeating the layers until the 2L bottle is full. Make a diagram with labels for the layers in your 2L bottle. Monitor the experiment over the next couple weeks or months. Add small amounts of water each week to keep the soil moist.

2. **Applying Concepts:** Knowing if items are classified as hazardous waste will help you dispose of them properly. There may be some items in your building or at your home that are considered hazardous waste like drain cleaner, glass cleaner, furniture polish, rug deodorizer, silver polish, and mothballs.

   a. With an adult, place a sticker on items that are considered hazardous waste to help identify them.

   b. Research more environmentally friendly alternatives to these products.

   c. Research how to dispose of the hazardous waste materials in your community.

3. **Applying Concepts:** A lot of food is thrown away, which decomposes and gives off methane, a greenhouse gas that contributes to global warming.

   a. Instead of throwing away excess food, what could you do with it?

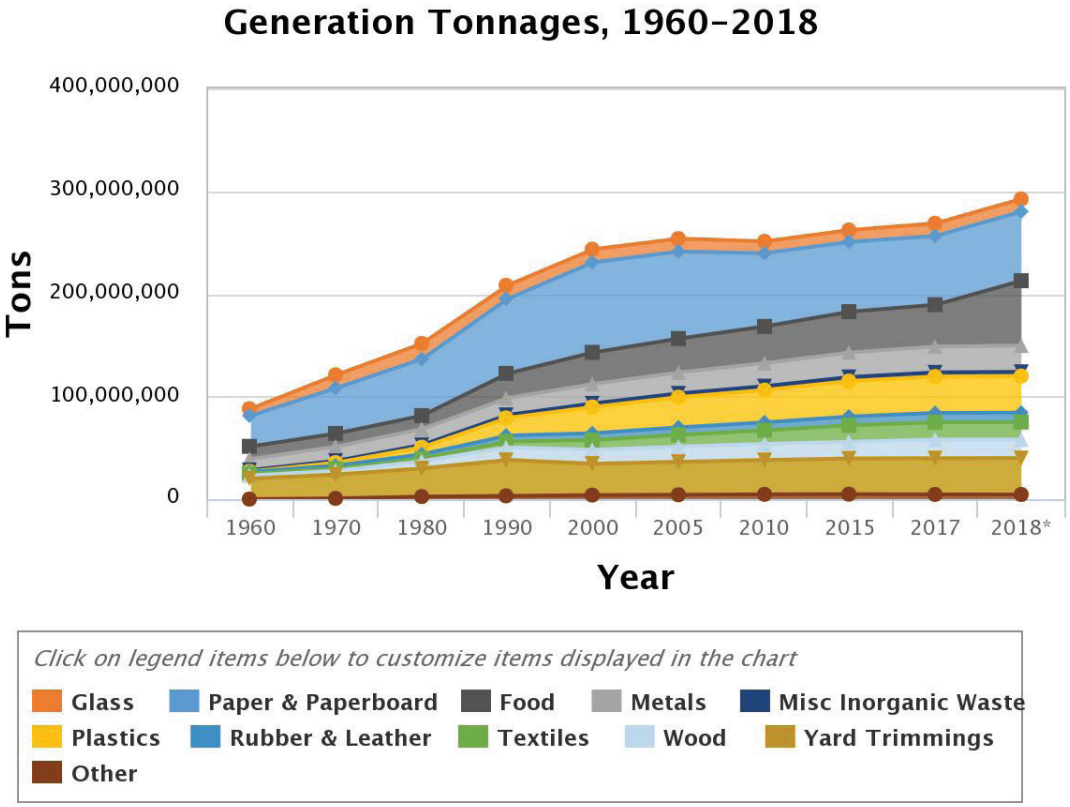
   b. Conduct a food audit in your home for one week. How much food is your family eating? How much food is your family throwing away? What does your family do with parts of food that cannot be eaten, such as some fruit peels, leaves, or cores?

   c. After conducting a food audit, analyze your findings. In what ways could your family reduce food waste? What could your family do with leftover food instead of throwing it away? What could they do with the parts of food that cannot be eaten?

4. **Applying Concepts:** Research where trash goes in your community. Is waste storage regulated? Is it lined? Is it capped? Is any effort made to collect gas, such as methane, from the waste storage facility? If so, does it repurpose the gas for anything?

5. **Applying Concepts:** Examine a map of your community and identify the waste storage locations. Label them as "CL" for controlled landfill, "D" for an uncontrolled landfill/trash heap, and so on. Add these symbols to the Map Key.

6. **Analyzing Data:** Examine the graph, Generation Tonnages, which displays data about the amount and types of waste generated in the United States from 1960–2018. This i s a compound line graph. To read it, you examine the differences in thickness of the different colors. This allows you to see what percent (or fraction) of the total each section (color) represents.



Credit: United States Environmental Protection Agency, https://bit.ly/3sHO8XQ

a. How has the total amount of waste in the United States changed throughout 1960–2018?

b. Which categories typically generate the most waste throughout 1960–2018?

c. Which categories have similar amounts of waste generated throughout 1960–2018?

d. Which categories have increased in the amount of waste generated between 1960 and 2018?

e. Instead of throwing away items in these categories, what could be done with them when they become waste?

f. If these changes were implemented across the United States, what might the graph look like in the future?

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INVESTIGATION 3A: PLASTICS AROUND US

Learning Outcome: Sort and analyze everyday plastics to become familiar with international numbering system and different types of plastics.

Materials

Per learner:

- "Properties of Plastics" handout

Per group:

- 10–15 everyday plastics (can use again in Investigation 3B). Some examples could include plastic water bottles, plastic wrap, plastic bags, plastic juice or milk containers, plastic packaging, etc.
- "Recycling rules for your community" handout

What to Do

1. Observe the plastic items with your team. Discuss similarities and differences between the items.
2. Group the plastics based on your observations. On what did you base your groupings?
3. Walk around to other groups and see how they organized their plastic items and think about how the groupings compared to yours.
4. Find the international recycling symbol. Re-sort the plastics based on the number inside. If items don't have a number, sort them into an unlabeled group.

   a. Make comparisons within the groupings based on appearance, color, flexibility, size, and other characteristics.

   b. On the "Properties of Plastics" handout, fill in the columns "Types of Items" and "Properties" with your group.

5. Discuss your findings with the whole group. Make additions and revise your handout as necessary.

6. Regroup your items into Single Use and Reusable categories.

   a. Are there any similarities between items in the Single Use category? What are they?

   b. Are there any similarities between items in the Reusable category? What are they?

   c. Which types of plastic tend to fall into the Single use category? What about the reusable category?

Consider

1. Examine the properties of #4 recyclable plastics. Why do you think these aren't commonly recycled?

2. Choose one single-use plastic item from your group. Are there alternative materials from which the object could have been made? Can those materials be recycled, or reused? Are there ways to eliminate the need for the item altogether?

3. Recycling in your community:

   a. What are the plastic recycling rules for your community? Are you allowed to mix different plastics together to be recycled? Do you have to sort them? Do you need to remove labels or wash them? How might such requirements affect the amount of plastic that is recycled?

   b. Why do you think it is important to follow the recycling rules in your community?

4. According to The United National Environmental Programme (www.UNEP.org), "Researchers estimate that more than 8.3 billion tonnes of plastic has been produced since the early 1950s. About 60% of that plastic has ended up in either a landfill or the natural environment." Why do you think that is? How could that statistic be improved?

5. What are ways you and those in your community can use plastic more wisely?

Extensions

1. **Applying Concepts:** If not completing Investigation 3B, reuse the plastics from this Investigation to make a toy or artwork.

2. **Applying Concepts:** Inventory and analyze the plastics in the building you are in or your home. Which type of plastics are most common? Do they exhibit similar properties as you observed in the investigation? Are they single use or reusable?

3. **Applying Concepts:** Examine a map of your community and identify recycling locations. Research locations as needed. Color code or label the locations and add these colors/ symbols to the Map Key.

PROPERTIES OF PLASTICS

International Recycling Number	Types of Items	Properties	Polymer	Can it be recycled?
1				
2				
3				
4				
5				
6				
7				
Unlabeled				

INVESTIGATION 3B: PLASTICS IN AQUATIC ENVIRONMENTS*

Learning Outcome: Explore the densities of plastic items to determine if items will sink or float in water and the possible impacts on ocean animals.

Materials

Per group:

- tall transparent container, about 0.5 m deep (1.5–2 foot deep), such as a clear bucket (**https://bit.ly/3wjJhNa**) or a clear container (**https://thd.co/37HqGCy**)
- 10–15 plastic items (can reuse the ones from Investigation 3A)
- set of "Ocean Feeder" cards
- "Water Column Cross Section" handout

Per learner:

- "Plastics in the Water Column" handout

What to Do

1. Make a list of some plastic items you have used or seen before. If these items end up in a river or lake, what would they affect?
2. Experiment with plastic items — determining if they can sink or float.
   - **a.** Analyze each plastic item and record the Resin ID Code (RIC) in the chart on the "Plastics in the Water Column" handout. Make a prediction if the plastic will float or sink in water.
   - **b.** Fully submerge each item and rotate it around to remove all the air from inside. Then observe if it floats or sinks. Record the results.
   - **c.** Why do you think some objects floated and others sank?
3. Analyze the plastic items using density.
   - **a.** The density of fresh water is around 1.00 g/ml and the density of salt water near the oceans' surface is around 1.03 g/ml.
     - Why do you think salt water is more dense than fresh water?

- How can density be used to predict if an item will sink or float?

b. Examine the density table and analyze the types of plastics.

- Which types of plastic will float in both fresh and sea water? Explain your reasoning.
- Does that match your findings? Explain.

Resin ID Code	Name	Density (g/mL)	Uses
	Plastics		
1	**PETE** Polyethylene terephthalate	1.38-1.39	Soft drink and water bottles, peanut butter containers, salad dressing and vegetable oil containers
2	**HDPE** High-density polyethylene	0.95-0.96	Milk jugs, detergents, household cleaners, motor oil containers, some garbage bags, butter and yogurt tubs
3	**PVC** Polyvinyl chloride	1.16-1.45	Clear food packaging, medical equipment, siding, piping, windows, shampoo bottles
4	**LDPE** Low-density polyethylene	0.92-0.94	Squeezable bottles, various bags (for bread, frozen food, shopping and dry cleaning), clothing, furniture
5	**PP** Polypropylene	0.90-0.91	Syrup bottles, ketchup bottles, caps, straws, medicine bottles
6	**PS** Polystyrene (two kinds)	0.020-1.07	CD cases, meat trays, egg cartons, disposable plates and cups
7	**Other** Many kinds	Varies	DVD cases, iPod packaging, signs and displays, nylons

Credit: Monterey Bay Aquarium, https://bit.ly/39zvZV5

4. Let's think about plastic in the ocean.

a. How do you think plastic can get into bodies of water (lakes, rivers, oceans)?

b. How do you think plastic can impact animals in the ocean?

5. Marine animals feed in different oceanic zones. There is the surface zone which is where the water meets air. There is the pelagic zone which is the entire depth of the open water column where fish swim and plankton drifts (which can be further divided into zones by how much light there is an overall depth). Finally, there is the benthic zone which is on or near the ocean floor.

a. Divide up the Ocean Feeder cards between your group members.

b. On your own, answer the following questions for each animal you are in charge of: What animal are you analyzing? Where does the animal feed? What plastics could affect this animal and how?

- On the Water Column Cross Section activity sheet, draw or write the name of the animals where they would feed on the water cross section. Next to the name of the zone, write the plastic RIC's that could pollute the feeding zone.
- How might the shape and size of a plastic object impact if an animal is affected?

c. Discuss each animal with your group members and answer the following questions:

- What animals feed at the surface? What plastics could affect these animals? Why?
- What animals feed in the open water? What plastics could affect these animals? Why?
- What animals feed on the sea floor? What plastics could affect these animals? Why?
- How might the shape and size of a plastic object impact if an animal is affected?

d. On the Water Column Cross Section activity sheet, draw or write the name of the other animals from your group, and where they would feed on the water cross section. Next to the name of the zone, write the plastic RIC's that could pollute the feeding zone.

Consider

1. What would happen if the plastics you tested made it to the ocean? Which plastics that you tested would impact the western gull? What about the sea otter?

2. A large portion of plastic pollution in the ocean is discarded fishing nets, called ghost nets. Other fishing debris can include abandoned lines, ropes, crates, baskets, and fish-aggravating devices. What issues might these cause to marine life?

Extensions

1. **Applying Concepts:** Reuse the plastics from this Investigation to make a toy or piece of artwork.

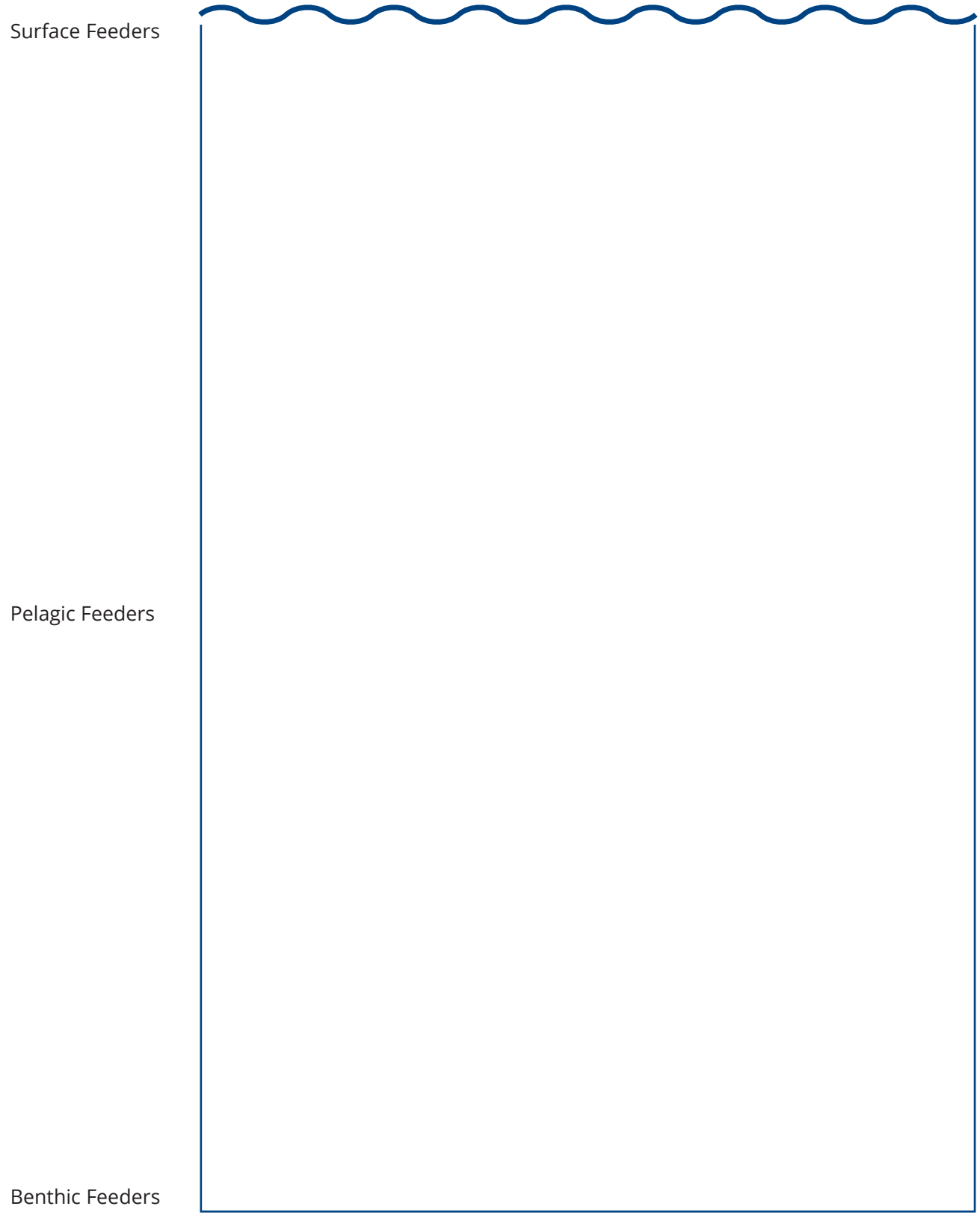
2. **Applying Concepts:** Examine a map of your community and identify rivers, streams, bays, and/or oceans that could provide a way for waste and pollution to move within your community. Research locations as needed. Color code or label the waterways and add these colors/symbols to the Map Key.

3. Using *Scratch*®: Create a *Scratch*® game or animation that explores the effect of plastic pollution on marine life. Here are some *Scratch*® projects you can look at, learn from or remix: **https://scratch.mit.edu/search/projects?q=plastic%20in%20the%20ocean**

PLASTICS IN THE WATER COLUMN

Plastic item	RIC	Prediction: sink or float?	Results: sink or float?

WATER COLUMN CROSS SECTION



OCEAN FEEDER CARDS

Black-footed Albatross

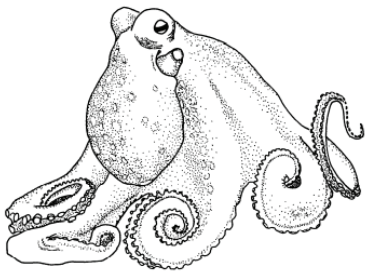
Black-footed albatross — **Surface and Pelagic Feeder**
Phoebastria nigripes — size: wingspan up to 7 ft. (215 cm) and 7.7 lbs. (3.5 kg)

This seabird spends three years at sea when it first leaves the nest. It lands on the water to sleep and eat. It locates prey with a keen sense of smell. Parents regurgitate their prey to feed their chicks.
Diet: squid, fish, fish eggs, crustaceans
Feeding Strategy: forages on the surface while swimming or dives underwater to catch food with beak
Habitat: open ocean (sandy shore during breeding)

Giant Sea Bass

Giant sea bass — **Pelagic and Benthic Feeder**
Stereolepus gigas — size: to 8.2 ft. (2.5 m), 562 lbs. (255 kg)

These fish are able to quickly and dramatically change colors. Often known as black sea bass, these large fish aren't known for speed. Thus they often feed on the ocean floor.
Diet: sting rays, skates, lobster, crabs, flatfish
Feeding Strategy: catch prey by rapidly opening large mouth; hide in shadows of kelp to ambush some prey
Habitat: open water

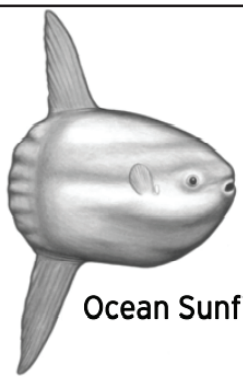


Giant Pacific Octopus

Giant Pacific octopus — **Benthic Feeder**
Enteroctopus dofleini — size: to 50 lbs. (23 kg) and 15-ft. (4.5 m) wide

This octopus has over 2,000 suckers through which it grips, smells and tastes. It is able to change its color to camouflage into its surroundings.

Diet: clams, abalone, rockfish, crabs, other octopuses
Feeding Strategy: catches food with suckers and crushes with beak
Habitat: reefs and pilings

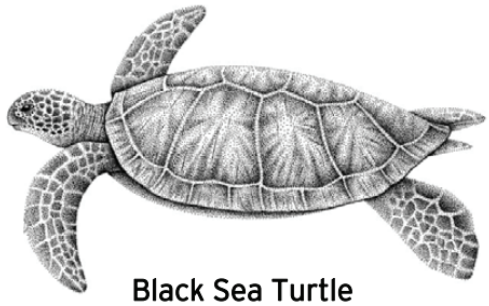


Ocean Sunfish

Ocean sunfish — **Pelagic Feeder**
Mola mola — size: to 14 ft. (4.3 m), 5,000 lbs.(2,268 kg) (up to 1,000 lbs. in Monterey Bay)

This fish hatches from a tiny egg and grows up to be the size of a small pickup truck. Ocean sunfish live in almost all of the world's oceans and often swim at the surface sometimes appearing to sunbathe!
Diet: jellies, plankton, small fishes like anchovies
Feeding Strategy: slurps food through fused teeth, shredding prey until its small enough to swallow
Habitat: open water

Credit: All: Monterey Bay Aquarium, https://bit.ly/39zvZV5

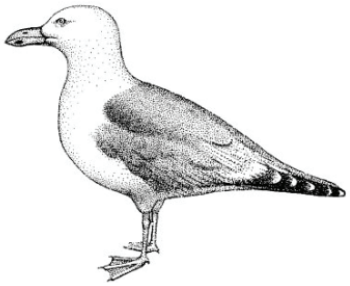


Black Sea Turtle

Black sea turtle **Pelagic Feeder**
Chelonia agassizii size: to 4 ft. (1.2 m)

This sea turtle is actually a type of green sea turtle. As a juvenile, it feeds in the open ocean on invertebrates, algae and jellies. As an adult, it becomes primarily an herbivore and moves closer to shore, eating sea plants.

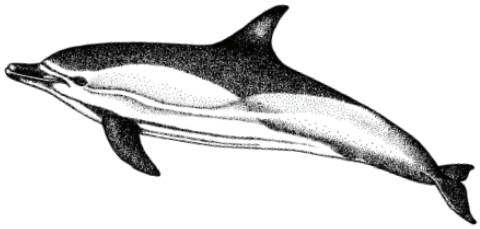
Diet: jellies, invertebrates, sea plants, algae
Feeding Strategy: uses sharp beak to cut and tear its food.
Habitat: open water



Western Gull

Western gull **Surface Feeder**
Larus occidentalis size: 24-27 inches (61-70 cm)

To break open prey like clams and sea urchin, this sea-bird drops its food from high in the air to hard surfaces below. Often fed by humans, contaminants in people food can harm its health.
Diet: fishes, carrion (dead animals), marine invertebrates, birds, birds' eggs, garbage
Feeding Strategy: uses beak to catch small fish at the surface
Habitat: coastal water



Common Dolphin

Common dolphin **Pelagic Feeder**
Delphinus delphus size: to 8 feet (2.5 m), 250 pounds (113 kg)

These dolphins travel in pods of up to 2,000 animals. They are extremely active and ride the waves of large ships and whales. They work together to herd schools of fish into a tight ball and then eat them.

Diet: fishes and squid
Feeding Strategy: catches prey with beaklike mouth
Habitat: open water

Southern Sea Otter

Southern sea otter **Benthic Feeder**
Enhydra lutris size: to 5.5 ft. (1.7 m)

An otter hunts on the seafloor but returns to the surface to eat. It uses its chest as a table. An otter has pockets of skin under each forearm where it can keep prey or tools to crack open its food.

Diet: crabs, snails, urchins, clams and other benthic invertebrates
Feeding Strategy: uses paws to catch and open food
Habitat: kelp forest

Credit: All: Monterey Bay Aquarium, https://bit.ly/39zvZV5

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Sustainable Development Goal 12: Responsible Consumption and Production

INVESTIGATION 4A: ASSESSING HOW ITEMS ARE PACKAGED

Learning Outcome: Analyze how goods are packaged to assess the type and amount of materials used.

Materials

Per group:

- "Recycling Rules for Your Community" handout
- "Packaging Assessment" handout
- 5 pieces of different types of packaging (food wrappers, bottles, boxes, plastic bags, boxes with Styrofoam, etc.)

What to Do

1. What are some ways items are packaged? Brainstorm with your group and write your ideas on the Packaging Assessment handout. Four categories are listed to get you started. What other two categories can your group think of?

2. Analyze each item your group received. Discuss the questions below and rate your packages on the Packaging Assessment handout.

   a. What types of material(s) is the packaging made of?

b. What do you consider the purpose of the packaging (to hold liquid, to keep food fresh, to mail the item, to protect fragile items, to serve a food item to a customer, etc.)?

c. What do you think was the useful lifetime of the packaging (i.e., how long is the item in the packaging)?

d. When it is time to dispose of the packaging, how should each component be disposed? Is it clear on the packaging whether or not it can be recycled?

3. Compare your items to each other:

a. Which packaging do you consider to be the most eco-friendly? Why do you think so?

b. Which packaging do you consider to be the least eco-friendly? Why do you think so?

c. Are there any similarities between packages that scored higher? What about between packages that scored lower?

Consider

1. How could the packaging that you analyzed be changed to make it more eco-friendly?

2. Why do you think some items have more packaging than others?

3. How do you think the packaging for natural items compares to those for processed items (e.g., potatoes compared to potato chips)?

4. Think about why consumers may purchase natural or processed items, and why consumers may purchase items as single serve or in bulk.

a. What role could sustainability play in why items are purchased?

b. What role could advertisers play in why items are purchased?

Extensions

1. **Applying Concepts:** Think about the different packaging you use at home. What changes could your family make to dispose of less packaging? What packaging items could you reuse that you would normally throw away?

2. **Applying Concepts:** Conduct a packaging audit at home. For each type of packaging, answer the questions listed in step 2 of the Investigation and rate the packaging on the "Packaging Assessment" handout.

3. **Applying Concepts:** Think about all the different roles in a retail trade system — producer, advertiser, consumer, waste manager, and so on. How do these roles relate to one another? How could these roles individually improve sustainability in their role in the system?

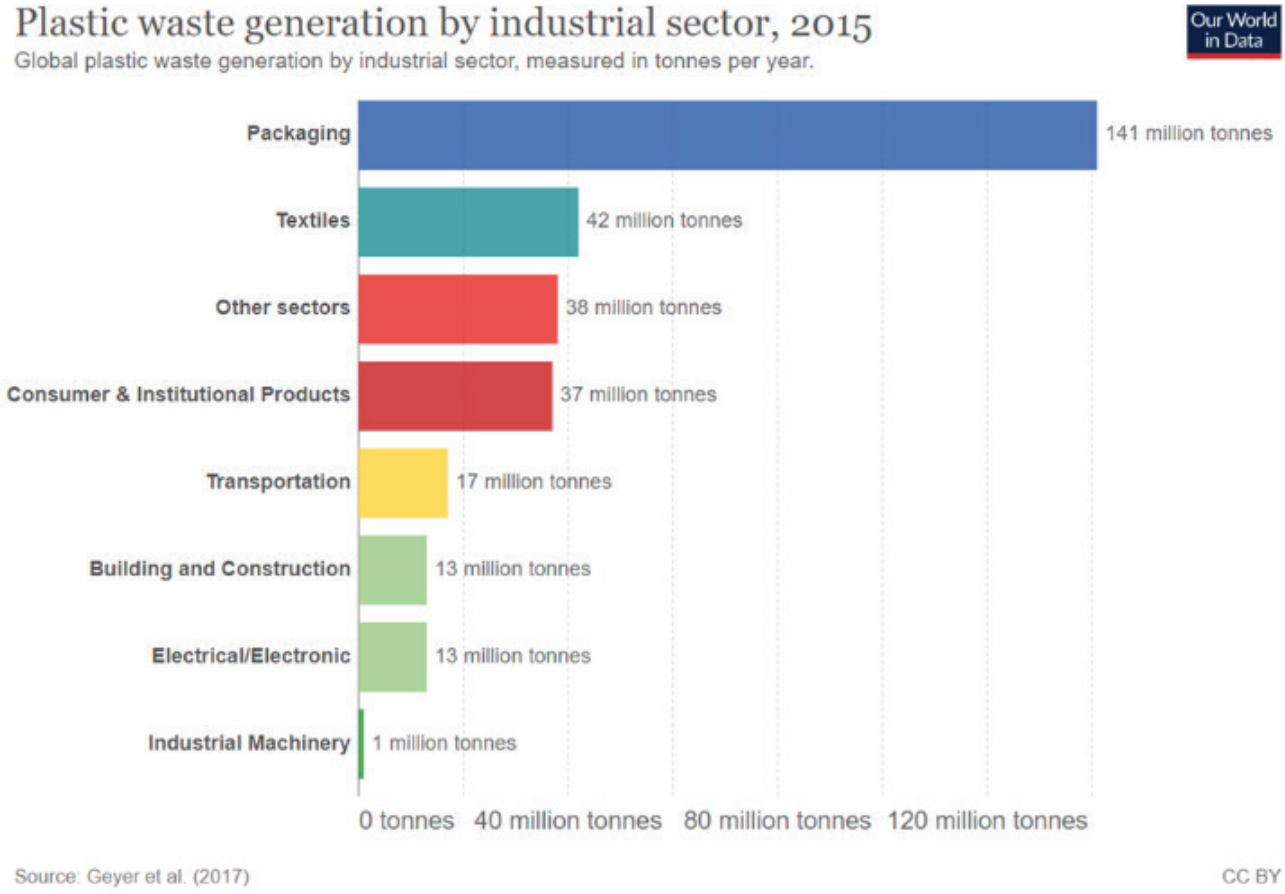
4. **Applying Concepts:** Imagine you are an advertiser for a product that you have designed to be sustainable in some specific way. What is the product? What makes it sustainable? How would you communicate the sustainable features to convince consumers to purchase this product? How would you make the advertisement effective, while also being catchy? Draw up your design ideas for the packaging or store display, write a script for a commercial, or design a *Scratch*® project to share your ideas.

5. **Analyzing Data:** Examine the graphic, "Plastic waste generation by industrial sector," which displays global data collected in 2015.

a. What percentage of plastic waste was generated by the packaging sector?

b. Why do you think packaging generated the most plastic waste in the industrial sector in 2015?

c. How do you think the amount of packaging waste when the data were collected would compare to current data? Why do you think this?

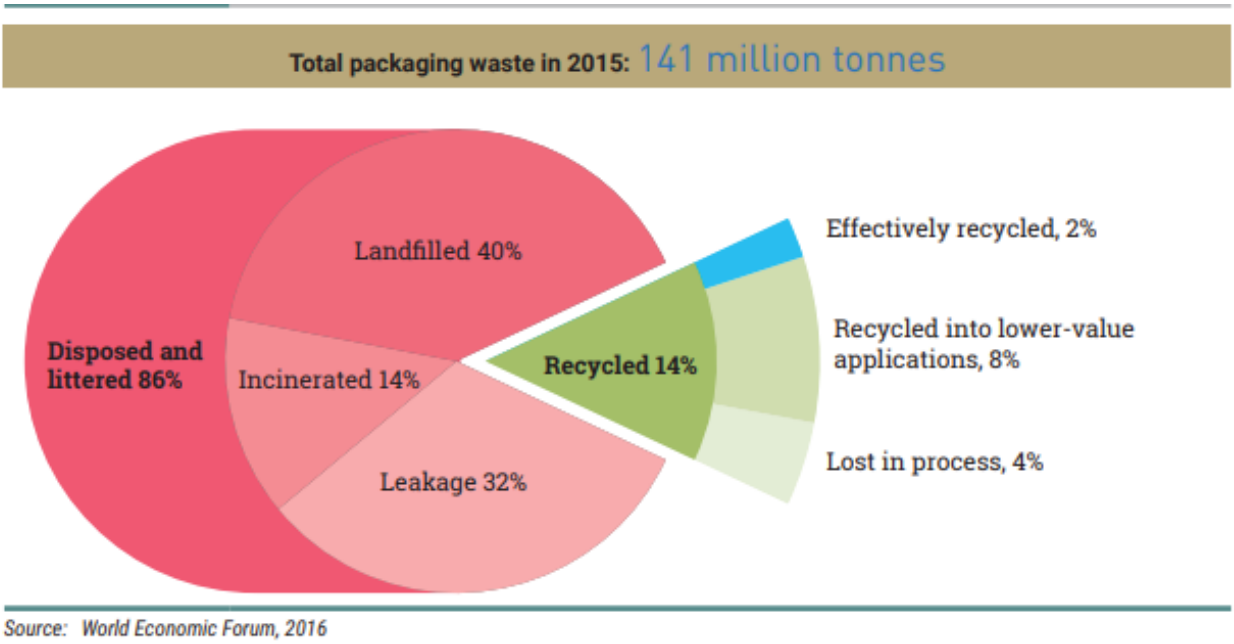


Credit: Our World in Data, https://ourworldindata.org/faq-on-plastics

6. **Analyzing Data:** Examine the graphic, "Total packaging waste in 2015."

a. What stands out to you about the graphic?

b. Why do you think only 14% of packaging waste was recycled in 2015?



Credit: World Economic Forum, 2016, https://www.unep.org/resources/report/single-use-plastics-roadmap-sustainability

Packaging Assessment

1. Brainstorming: What are some ways items are packaged?

Food/Drinks	Toys	Electronics	Personal hygiene items		

2. Rate the packaging: Fill out the chart for each item.

Types of packaging					
Is the packaging...					
returnable?					
reusable?					
recyclable?					
made from recycled material?					
compactable?					
using minimal materials?					
able to be separated if it includes more than one type of material?					
Total number of 'yes'					

INVESTIGATION 4B: COMPARING FOOD PACKAGED AS SINGLE SERVE VERSUS IN BULK

Learning Outcome: Measure single serve and bulk items and their packaging to calculate and compare product, waste, and cost ratios.

Materials

Per group:

- scale (can be shared, if necessary)
- large bowl to hold items on the scale
- food items (chips or crackers packaged as single serve and as bulk, with prices)
- reusable containers (optional)

What to Do

1. Make some observations of the item packaged in bulk and as single serve:
   - **a.** How is the bulk item packaged?
   - **b.** How is the single serve item packaged?
   - **c.** When the bulk package is empty, how should it be disposed of?
   - **d.** When the single serve package is empty, how should it be disposed of?
2. Analyze the bulk item:
   - **a.** Place the empty bowl on the scale and record its mass.
   - **b.** Open the package and empty the contents into the bowl.
   - **c.** Using the scale, record the mass of the bowl with the food in it.
   - **d.** Subtract the mass of the empty bowl from the full bowl to determine the mass of the food that was inside the bulk package.
   - **e.** Record the mass of the empty packaging used for the bulk item.
3. Analyze the single serve portion item:
   - **a.** Place the empty bowl on the scale and record its mass.
   - **b.** Open the package and empty the contents into the bowl.
   - **c.** Using the scale, record the mass of the bowl with the food in it.
   - **d.** Subtract the mass of the empty bowl from the full bowl to determine the mass that was inside the smaller package.

e. Using the scale, record the mass of the empty packaging from the single serve item.

4. Compare the amount of packaging to the amount of the item when packaged in bulk versus single serve:

a. Calculate the ratio of the item to the bulk packaging by dividing the mass of the bulk packaging (2e) by the mass of the item inside the bulk packaging (2d).

b. Calculate the ratio of the item to the single serve packaging by dividing the mass of the single serve packaging (3e) by the mass of the item inside the single serve packaging (3d)

c. What do you notice about the amount of packaging compared to chips for the bulk item and for the single serve item?

5. Compare the cost for the same mass of item when packaged in bulk vs. single serve:

a. Cost of the item when purchased in bulk: _____ single serve: _____

b. Calculate the cost per 1 g of the bulk item by dividing the cost (5a) by the mass from the bulk packaging (2d).

c. Calculate the cost per 1 g of the single serve item by dividing the cost (5a) by the mass from the single serve packaging (2d).

d. What do you notice about the cost when the item is purchased in bulk vs. as single serve?

6. Make some calculations:

a. How many packages of the single serve item would it take to get the same amount as inside the bulk package?

b. How much would that cost?

Facilitator Demonstration Preparation:

1. Create three holes evenly around the top edge of both identical bowls using the hole punch or screwdriver.

2. Cut six identical lengths of wire or string that are about the diameter of the bowl.

3. Tie a piece of wire or string to each hole.

4. For each bowl, gather the three pieces of wire or string in the middle and tie them in a knot.

5. Tape a hanging bowl to each end of the wooden dowel rod.

6. Locate the center of mass on the dowel rod:

a. Tie a small string (about 10 cm [4 in]) around the center of the dowel rod.

b. While holding the string, move the dowel rod back and forth until it is perfectly balanced.

7. Create a tag at the center by wrapping duct tape around the dowel rod.

a. You can either use the balance by loosely holding the tag, or

b. punch a hole through the duct tape tag and attach some string. Hang the balance from a ring stand or similar support.

8. For this demonstration, use an item that can be bought in both bulk and single serve quantities that is different from what students used in the Learner Investigation.

Facilitator Demonstration:

1. Before the demonstration begins, make some predictions:

   a. Do you think your earlier results will be consistent if you were to test other items sold in bulk versus single serve? Why or why not?

   b. Examine the item that will be tested. How many single serve packages do you predict it will take to get the same mass as inside the bulk item?

2. Results:

   a. How many single serve packages did it take to get the same mass inside the package as the bulk item?

   b. How much packaging was generated from the single serve items, and how does that compare to the bulk packaging?

3. Compare the costs for the same amount of the item:

   a. What was the cost of the bulk item?

   b. Calculate the cost of the single serve items for the same weight of the item.

Consider

1. Compare the difference in cost between bulk and single-serve items. What would be the justification for the difference in cost?

2. What items do you think are better to buy in bulk instead of in smaller servings?

3. When would it make more sense to buy smaller servings of items instead of in bulk?

4. How could the packaging for the bulk or single serve item be more sustainably produced?

Extensions

1. **Testing Variables:** Investigate how variables impact packaging by comparing other single serve and bulk items like shampoo, spices, rubber bands, etc. How many single serve packages does it take for the same mass of interior contents as the bulk item? How does the amount and mass of packaging compare for all the single serve items and the bulk item?

2. **Applying Concepts:** List items you have at home in bulk and as single serve portions. Recognize that other factors like cost and storage space might come into play rather than sustainability when your family is purchasing items. Asses your list and determine which items may be possible and more beneficial for your family to buy in bulk.

3. **Applying Concepts:** Examine a map of your community and identify stores that sell items primarily in bulk and stores that require or ask that you bring in your reusable containers. Label them and add the symbols to the Map Key.

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Sustainable Development Goal 12: Responsible Consumption and Production

INVESTIGATION 5A: ELECTRONICS IN A HOME

Learning Outcome: Analyze electronics in a home to consider the prevalence of electronics, the lifetime of electronics, and how electronics should be disposed.

Materials

Per learner:

- drawing or graph paper; or printed floorplan

What to Do

1. Imagine you own your dream apartment. Consider the following questions and then design it!
   - **a.** Who lives with you?
   - **b.** How many bedrooms would the apartment have?
   - **c.** What other rooms would there be?
   - **d.** What furniture would you own?
   - **e.** What appliances?
   - **f.** What other electronics?
   - **g.** What else would be inside the apartment?
   - **h.** What kind of lighting would you use?
2. Complete an electronics inventory of your dream apartment. For each room, write down any electronics that would be inside, even if they are not included in the floor plan.
3. Assess each electronic:
   - **a.** How long do you plan to keep it? Will you update to a new model in the next five years?

b. If this electronic stops working, are you able to fix it yourself? Are you able to pay to have it fixed, or would you need to replace it altogether?

c. When you want to get rid of this electronic device, how will you dispose of it?

Consider

1. E-waste has become the world's fastest growing waste stream. Why do you think that is? Why is there so much e-waste?

2. Why do you think there are strict rules and regulations for discarding electronics?

3. How could you and others in your community reduce your e-waste?

Extensions

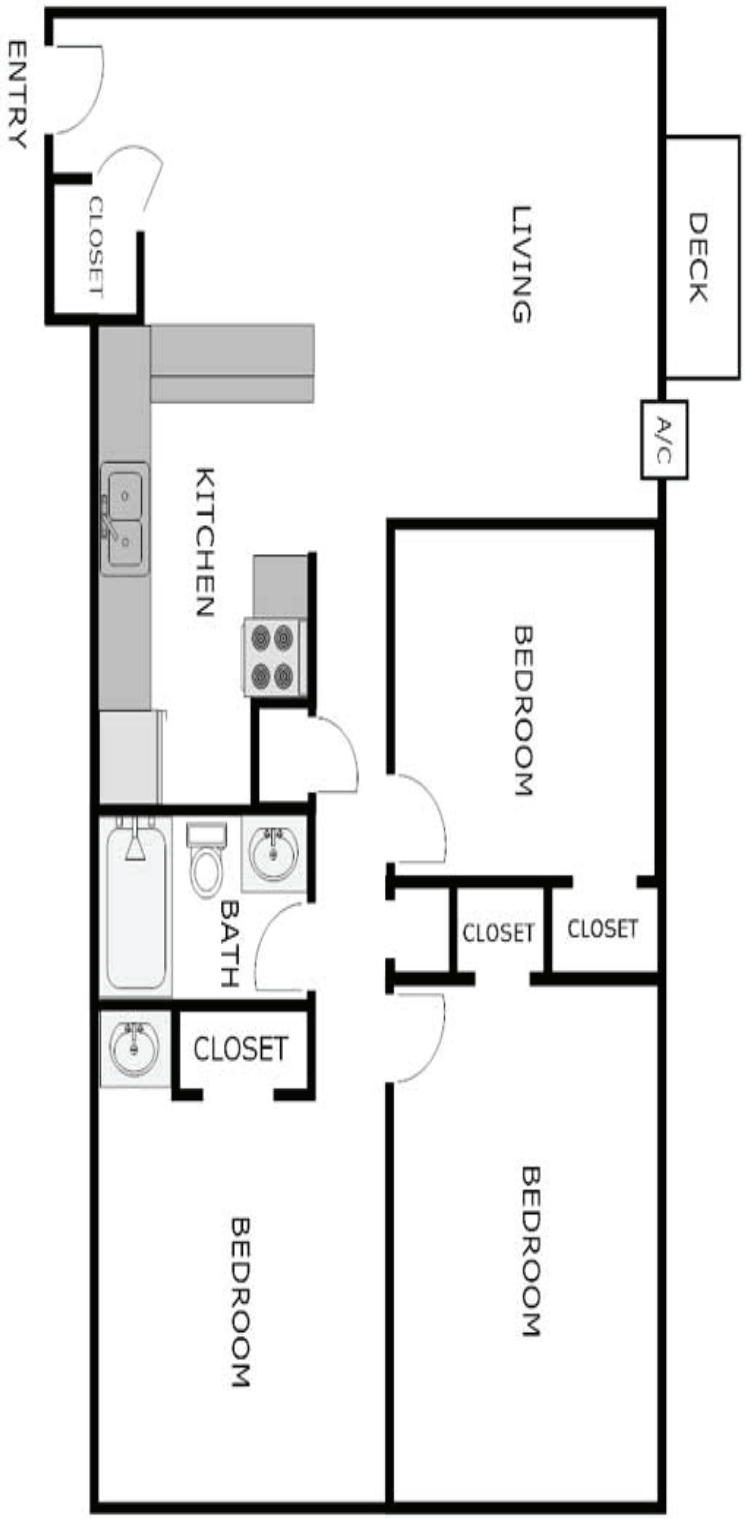
1. **Applying Concepts:** Electronics inventory: Inventory the electronics in the building or room you are in. Would the items be able to be fixed or would they need to be replaced if they stop working? Make a plan for how each item should be discarded following local procedures.

2. **Applying Concepts:** Explore the IFIXIT website (**https://www.ifixit.com**). Look up repair guides for electronics that you are familiar with from home or school. Do you find this website helpful? Would you repair an electronic device using this site next time one breaks? Why or why not?

3. **Applying Concepts:** Examine a map of your community and identify electronic repair stores or e-waste disposal sites. Research locations as needed. Color code or label the locations and add these colors or symbols to the Map Key.

4. **Applying Concepts:** Think about the life cycle of one electronic product (a computer, a cell phone, or so on). What do you think the environmental impacts of the product or the process to make the product may be? Complete a life cycle analysis of the product to help determine the environmental impacts of the product. What are the raw materials that make up that product? What goes into the manufacturing or assembly of the product? How is it transported and distributed? How is the item used, and for how long? How is the item disposed of?

5. Using *Scratch*®: Design your dream apartment using *Scratch*®. One scene can be the floor plan. Then create a scene for each room. Consider adding animations as well.



Credit: pending final design. 3-bed-1-bath-1008 wedgewoodcommonsapartments.com

INVESTIGATION 5B1: ANALYZING E-WASTE INTERNATIONALLY

Learning Outcome: Analyze data to understand and compare international e-waste statistics and the importance of recycling e-waste.

Materials

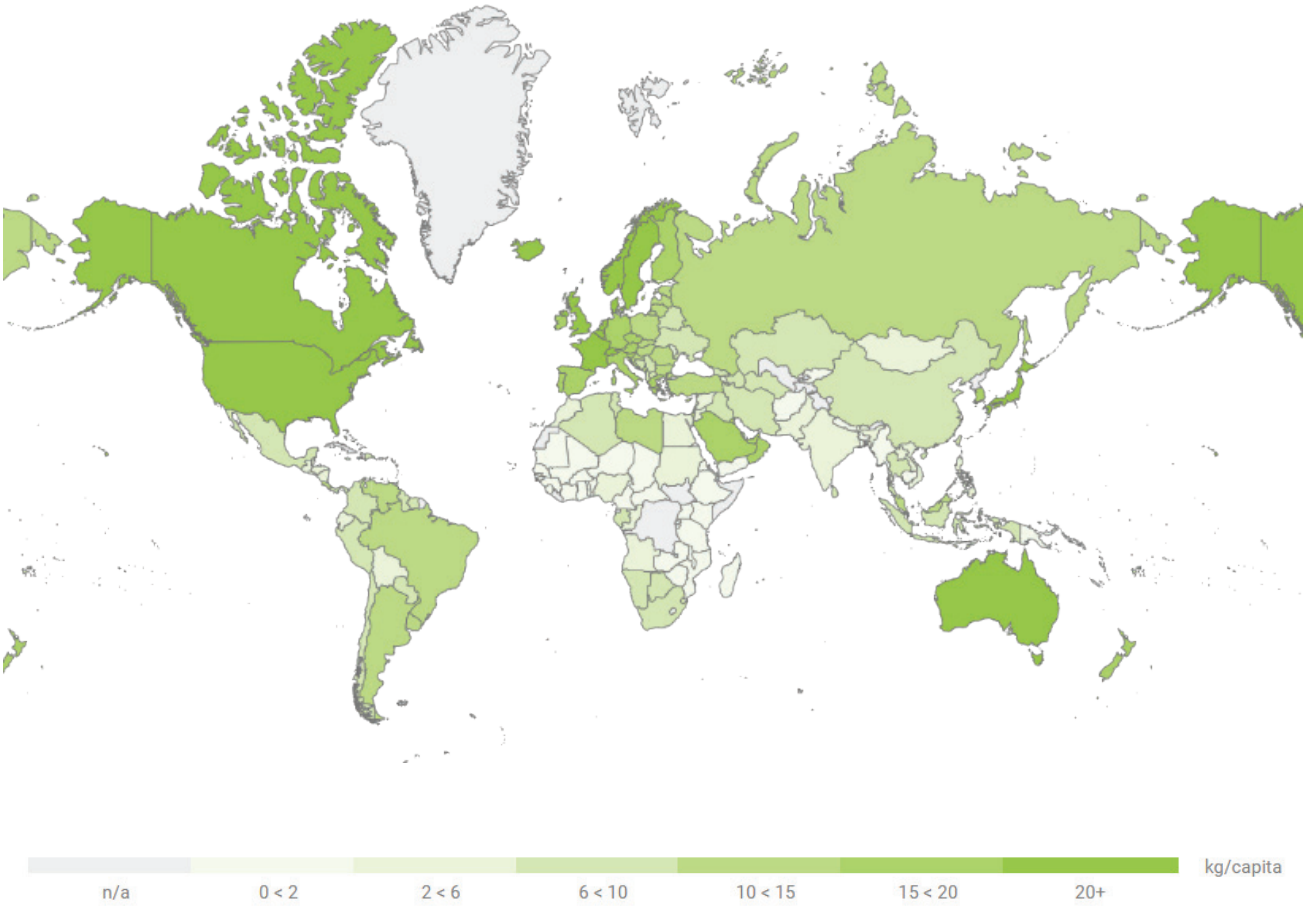
Per group:

- data sheet for your country

What to Do

1. Think about all the different types of Electronics and Electrical Equipment (EEE) there are.
   - **a.** In what ways do you use EEE?
   - **b.** Write down 3–5 EEE that you can think of in each of the following categories: Temperature exchange equipment (such heaters and air conditioners), computer screens and monitors, lighting, large equipment, small equipment, and small information technology (IT) and telecommunication equipment.
   - **c.** What is inside of EEE? What are some parts or materials used to make EEE?
2. When EEE is discarded, is it considered e-waste?
   - **a.** Which of the above categories of EEE do you think contributes the most to e-waste? Why do you think so?
   - **b.** Which categories of EEE do you think contribute the least to e-waste? Why do you think so?
   - **c.** When you are done with EEE, what are some ways it could be discarded? How can EEE be discarded so that it does not create a hazard?
   - **d.** Why are there special methods to discard EEE? How is e-waste different than regular waste?
3. Examine the 2019 map of e-waste generated per capita. Per capita is a measurement that compares statistics on a 'per person' basis. To read the map, look at the shade of green that corresponds to the key. The darker the green, the higher the amount of generated e-waste.

E-WASTE GENERATED PER CAPITA



Credit: Baldé, C.P., Forti V., Gray, V., Kuehr, R., Stegmann,P. : The Global E-waste Monitor – 2017, United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Vienna. **https://globalewaste.org/**

a. What countries generated the most e-waste per capita in 2019? Identify the areas on the map.

b. Which continent(s) shown on the map generated the most amount of e-waste per capita in 2019? Identify the areas on the map.

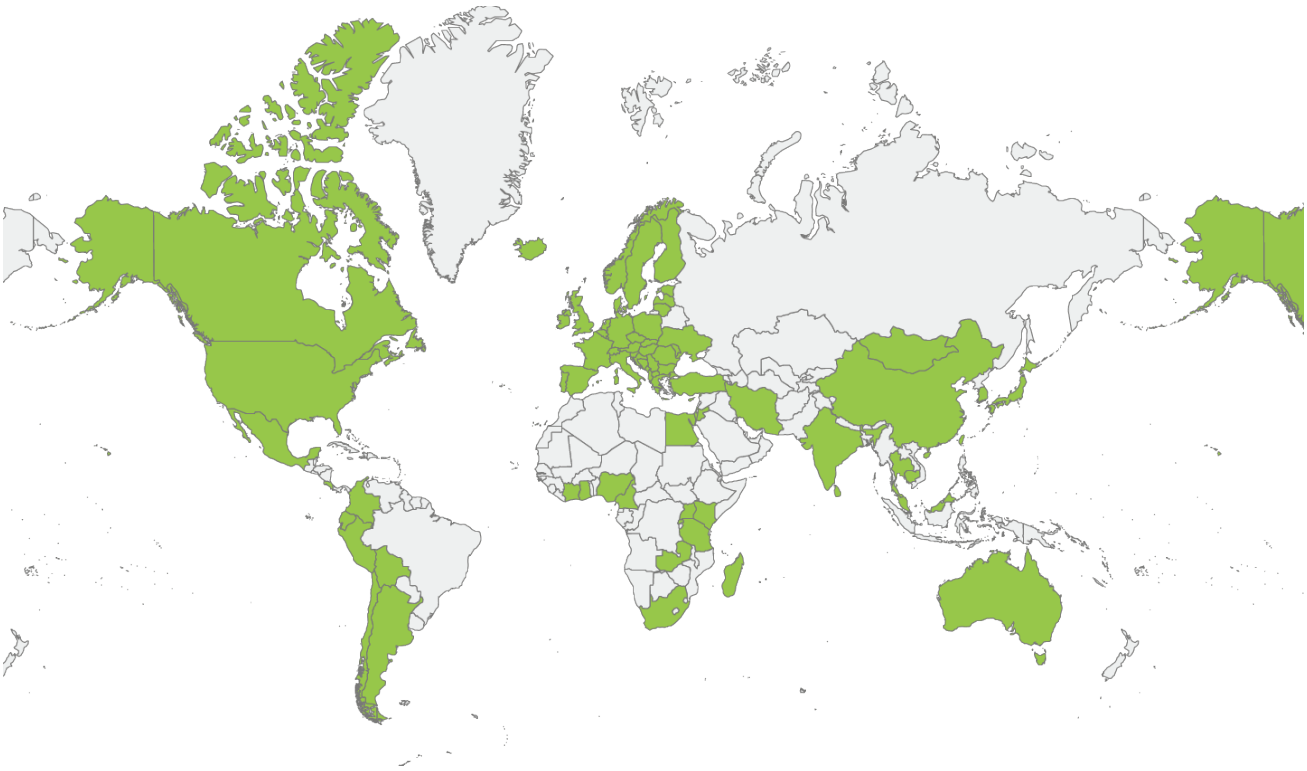
c. Which continent(s) shown on the map generated the least amount of e-waste per capita in 2019? Identify the areas on the map.

d. What do you notice about the amount of e-waste, in general, that was generated per capita in 2019?

e. In which areas was there the biggest variation in the per capita e-waste generated?

4. Examine the 2019 map of National Legislation Regarding E-Waste. Countries that have national legislation regarding e-waste are green, and countries without e-waste legislation are uncolored.

NATIONAL LEGISLATION REGARDING E-WASTE



Credit: Baldé, C.P., Forti V., Gray, V., Kuehr, R., Stegmann,P. : The Global E-waste Monitor – 2017, United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Vienna, **https://globalewaste.org/**

a. What do you notice about the amount of legislation regarding e-waste?

b. Compare the 2019 map of e-waste generated (in step 3) with this map. What do you notice? What surprises you? Are there any similarities between the two maps?

c. If you were a policy maker, what would you do with the information from both maps?

5. Examine the 2019 data from The Global E-Waste Statistics Partnership about EEE and e-waste about Poland, Ukraine, and the Russian Federation (**https://globalewaste.org/**). The amount of EEE and e-waste is given in kiloton (kt), which is a unit of mass.

GLOBAL E-WASTE STATISTICS FOR THREE COUNTRIES

	Poland	Ukraine	Russia
Population	37,959,000	41,878,000	143,896,000
EEE put on the market	635 kt	366 kt	1977 kt
E-waste generated	443 kt	324 kt	1631 kt
E-waste formally collected*	246 kt	40 kt	90 kt
E-waste collection rate	60%	13%	6%

*** data unavailable for 2019; refers to most recently available data**

a. What do you think "e-waste formally collected" means?

b. What do you notice about EEE and e-waste generated in Poland compared to Ukraine and Russia?

c. What are some similarities in the data across countries?

d. How do the e-waste collection rates compare between the countries? Why do you think that is?

6. To compare the data between the countries, let's look at the data per capita (per person).

PER CAPITA GLOBAL E-WASTE STATISTICS FOR THREE COUNTRIES

	Poland	Ukraine	Russia
EEE put on the market (kg per capita)	16.7	8.7	13.7
E-waste generated (kg per capita)	11.7	7.7	11.3

a. What do you now notice about the per capita data?

b. Is anything surprising or confusing about the data?

Consider

1. The amount of small IT equipment that contributes to global e-waste has been decreasing since 2015. Why do you think that is?

2. What do you think the future is like with respect to EEE and e-waste? Why do you think so?

INVESTIGATION 5B2: ANALYZING E-WASTE FROM YOUR COUNTRY

Learning Outcome: Analyze data to understand and compare international e-waste statistics and the importance of recycling e-waste.

Materials

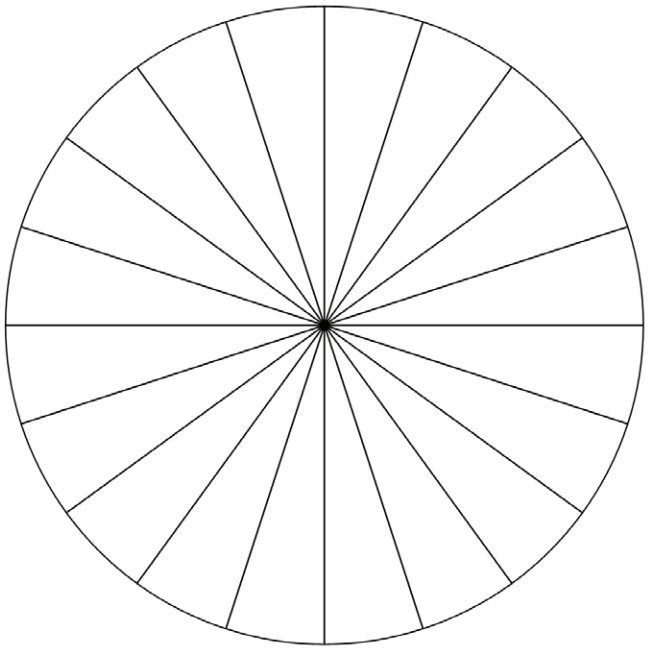
Per group:

- data sheet for your country

What to Do

1. Analyze data from your own country.
   - **a.** From what year is the data you are analyzing?
   - **b.** In the most recent data, what is your country's EEE put on the market per capita? How does it compare to the three countries you looked at in Investigation 5B1 (Poland, Ukraine, and the Russian Federation)?
   - **c.** In the most recent data, what is the e-waste generated per capita in your country? How does it compare to the three countries you looked at in Investigation 5B1?
   - **d.** In the most recent data, what is your country's e-waste collection rate? How does it compare to the three countries you looked at in Investigation 5B1?
   - **e.** How does the most recent data from your country compare to data from a previous year? What has increased? What has decreased? Why do you think these statistics have changed?
   - **f.** Does your country have national legislation about e-waste? What year was the earliest legislation put in place? How do you think these statistics may have been different before that legislation?
   - **g.** Some countries report on e-waste generated per category (small IT, large appliances, etc.). If your country reports those data, determine what percentage each category contributes to the total e-waste generated by dividing each category by the total of all six categories. Then create a pie chart reflecting the data. If your country doesn't report e-waste generated per category, make a prediction of what the data may look like in your country. Each slice on the graph is 5%, which may assist you with creating your graph. Be sure to fill in the key and title.

E-waste generated in _____



- ☐ Temperature Exchange Equipment
- ☐ Large Equipment
- ☐ Small Equipment
- ☐ Screens
- ☐ Small IT
- ☐ Lighting

Credit: L.Brase

Consider

1. From your Electronics Inventory from 5A, categorize the electronics into the six main categories (temperature exchange equipment, large equipment, small equipment, screens, small IT, and lighting) and create a pie chart to display the data.

2. What are some ways your community and country can promote a reduction in e-waste?

Extensions

1. **Applying Concepts:** Imagine you are a policy maker. What would be some of your priorities regarding EEE and e-waste? Look at the legislation in your country and other countries nearby. How would you improve the legislation?

2. **Applying Concepts:** From your Electronics Inventory from 5A, categorize the electronics into the six main categories (temperature exchange equipment, large equipment, small equipment, screens, small IT, and lamps) and create a pie chart to display the data.

INVESTIGATION 5B3: INSIDE E-WASTE

Learning Outcome: Analyze data to understand and compare international e-waste statistics and the importance of recycling e-waste.

Materials

Per group:

- copies of enlarged images from Investigation (optional)

What to Do

1. E-waste contains hazardous materials like lead, mercury, and many more. The hazardous materials found in EEE can cause a variety of adverse effects on human health, like skin problems, nervous system damage, liver damage, and more. How do you think these hazardous chemicals could enter the body and cause these adverse effects?

2. What jobs or what people do you think are most exposed to the hazardous materials inside EEE?

3. EEE can be made up of valuable materials, some of which we can examine on the periodic table. The periodic table is an organization of all discovered chemical elements. Examine a periodic table that identifies elements found in EEE and if they are also precious metals, critical raw materials, or non-critical metals.

   a. What do you notice about the number of elements that could be found in EEE?

   b. How many elements found in EEE are considered precious? What are they?

   c. Name some products that contain at least one precious element?

   d. Only about 17% of e-waste is formally collected and recycled, on average. What happens to the precious and critical elements when EEE is recycled?

   e. What happens if EEE isn't recycled?

4. Let's look at four of the precious elements in more detail. Examine the table: Metal Concentration in Electronics and Ore. The units are parts per million (ppm), which is a unit for concentration. The higher the number, the more metal is in the electronic device. For example, there at 20 ppm gold in a television board which means that for every one million parts of everything in a television board, 20 of the parts are gold.

METAL CONCENTRATION IN ELECTRONICS AND ORE

Product	Copper (ppm)	Silver (ppm)	Gold (ppm)	Palladium (ppm)
Television board	100,000	280	20	10
PC board	200,000	1,000	250	110
Mobile phone	130,000	3,500	340	130
Portable audio scrap	210,000	150	10	4
DVD player scrap	50,000	115	15	4
Average electronics	138,000	1,009	127	52
Ore/mine	6,000	216	1	3

Modified from Kumar et al. 2017 (which pulled data from Desjardins, 2014; Investing News Network, 2016; McLeod, 2014; Namias, 2013; Vicic, 2015)

a. Where do you think these precious metals come from? Where can you find copper, silver, gold, and palladium? From where and how are they extracted?

b. When looking at the table, what do you notice? Does any of the data surprise you?

c. When elements are in the same family (column on the periodic table), they share properties and behave similarly. Look back at the periodic table and determine which three of these precious metals are in the same family.

d. Compare the amount of gold between the electronics listed. Which uses the most gold?

e. How does the amount of gold in electronics compare to the amount of gold in the mined ore?

f. Compare the amount of the other three precious metals in electronics to the amount in the mined ore. What do you notice?

g. Out of these four precious metals, which is the most abundant in the listed electronics? Why do you think that is?

h. These four elements are all excellent conductors of electricity and are relatively soft. Why do you think these elements are considered precious?

i. Notes for the Facilitator: These metals are relatively rare in nature but are important in making products.

j. Why is it important to recycle electronics from an economic point of view?

k. Notes for the Facilitator: Recycling electronics reduces the amount of new resources that need to be located and mined, which can be expensive and disruptive/destructive to the environment.

l. The recyclability of a product is assessed by the ability to recycle it and if it is cost effective to recycle it. Consider the palladium in DVD and audio scrap. Do you think palladium is being extracted from those products? Why or why not?

m. Notes for the Facilitator: It is unlikely because there is already infrastructure to mine palladium ore in place, which is likely more cost effective than trying to extract a similar concentration out of e-waste.

5. Examine the figure: Resource savings from recycling of desktops and laptops. This is called a stacked bar graph. The length of each bar shows the total, and the different colors show what components or categories make up the total. In this graph, the cumulative exergy extraction from the natural environment (CEENE) score is considered for laptops and desktops that are recycled and sent to the landfill. CEENE quantifies the amount of each resource drawn from the natural environment in a life cycle assessment. The higher the CEENE score, the more resources used.

RESOURCE SAVINGS FROM RECYCLING OF DESKTOPS AND LAPTOPS

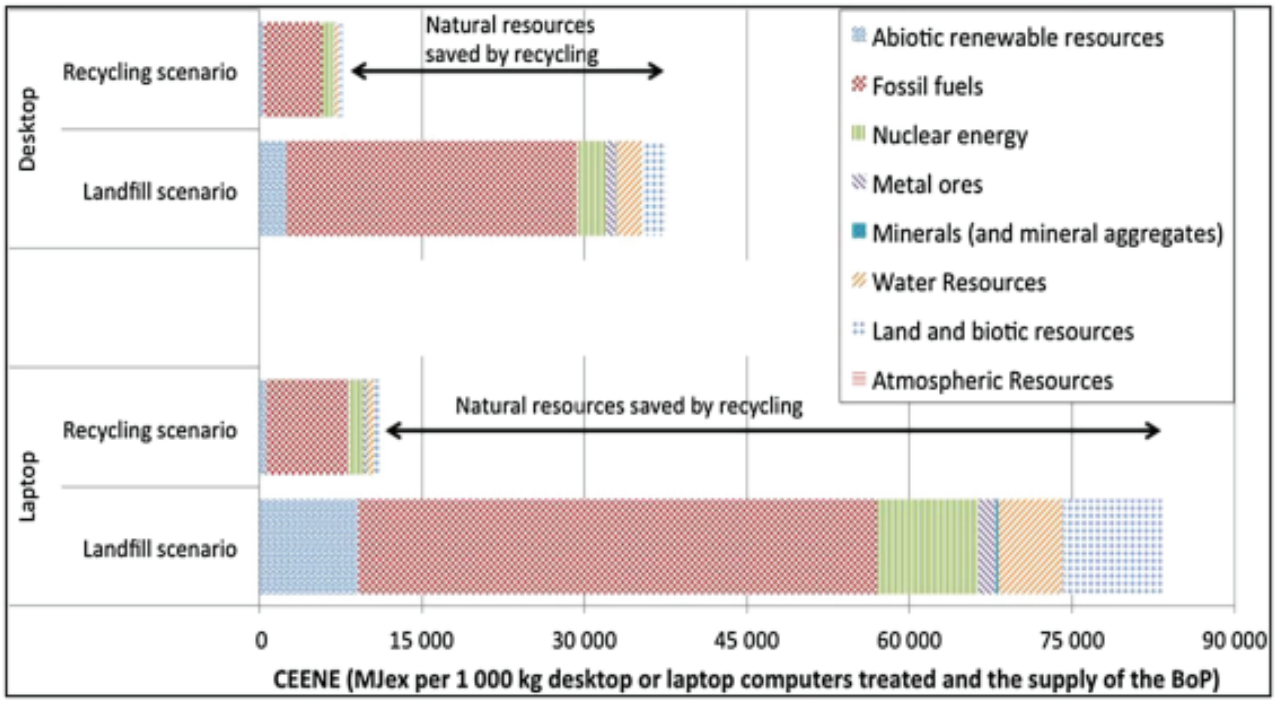


Fig. 6. Resource savings from recycling of desktops and laptops.

Credit: Kumar et al. 2017

a. Look at the total amount of resources used between a laptop that is recycled and a laptop that goes to the landfill. What were the CEENE scores for the recycling scenario and the landfill scenario?

b. What types of natural resources would be saved by recycling a laptop instead of putting it into a landfill?

c. How do you think natural resources are preserved by recycling the laptop instead of throwing it away?

d. Examine the fossil fuel component of the Desktop scenarios. About how many times more fossil fuel resources are in the landfill scenario compared to the recycling scenario?

e. Choose another resource to examine. How does it compare in the recycling scenario and the landfill scenario?

f. Compare the CEENE score for a recycled laptop and a recycled desktop. What do you notice? Why do you think this is?

g. Compare the CEENE score for a laptop and a desktop sent to the landfill. What do you notice? Why do you think this is?

Consider

1. EEE contain hazardous substances that are dangerous to our health. What precautions do you think need to be taken for people transporting and handling EEE and other hazardous materials?

2. Recycling EEE saves energy and resources. Why is this important? What do you think would happen if all EEE was sent to landfills?

Extensions

1. **Analyzing Data:** In 2019, 53.6 million metric tonnes of e-waste were generated and only about 17% of e-waste was collected and recycled. Using the information below, calculate how much money was sent to landfills inside e-waste.

Amount of materials in e-waste	Material	Market Price (USD) per tonne
10 tonnes	Gold	$58,552,855
136,000 tonnes	Aluminum	$2,974
85,000 tonnes	Copper	$10,062
1.1 tonnes	Cadmium	$325,440
1,000,000 tonnes	Iron	$127
8,100 tonnes	Lead	$2,349
700 tonnes	Cobalt	$70,500

2. **Applying Concepts:** Think about an electronic device you own. Research what hazardous substances are inside of it. How can it be discarded when you are done with it so that it does not become e-waste? Explain why it is important to discard this electronic thoughtfully.

3. **Applying Concepts:** The World Health Organization researched and reported on how e-waste affects children in "Soaring e-waste affects the health of millions of children, WHO warns" (**https://bit.ly/WHO_ewastechildrenreport**). Read the article and write a short summary of what you learned and how it makes you feel.

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

INVESTIGATION 6A: ASSESSING YOUR CARBON FOOTPRINT

Learning Outcome: Consider various aspects of their life (including their house, food, and transportation) to assess their carbon footprint and discuss ways to reduce it.

Materials

Per learner:

- "Assessing Your Carbon Footprint" handout

What to Do

1. Think about the three main categories that contribute to carbon emissions — household, food, and transportation.
   - **a.** What do you think contributes to carbon emissions in the household category?
   - **b.** What do you think contributes to carbon emissions in the food category?
   - **c.** What do you think contributes to carbon emissions in the transportation category?
   - **d.** What are some ways these categories overlap?
2. Consider your daily or weekly activities in each of these categories and assess how they can impact the environment. Answer the questions on the "Assessing Your Carbon Footprint" handout about your household.
3. Add up your score in each category. Column A is worth one point, column B is worth two points, column C is worth three points, and column D is worth four points.

   a. How many points did you calculate for the household category? What is the contribution of the household category to your carbon footprint: low (15–29 points), medium (30–44 points), or high (45–60 points)?

   b. How many points did you calculate for the food category? What is the contribution of the food category to your carbon footprint: low (9–17), medium (18–26), or high (27–36)?

   c. How many points did you calculate for the transportation category? What is the contribution of the transportation category to your carbon footprint: low (6–11), medium (12–18), or high (19–24)?

4. Discuss some ideas about how to reduce your carbon footprint with a partner. Remember, little changes can make a big difference in lowering your carbon footprint (and little changes made by many people can have a significant overall impact).

   a. What actions could you and your household take to reduce your carbon footprint in the household category?

   b. What actions could you and your household take to reduce your carbon footprint in the food category?

   c. What actions could you and your household take to reduce your carbon footprint in the transportation category?

Consider

1. Think about the building you are in. What features of the building do you think contribute most to its carbon footprint? Does the building have any features that have been installed to help it to have a lower carbon footprint? If yes, what are they? If no, how could the building lower its carbon footprint?

2. In the food category, the types of food your household usually consumes impacts your carbon footprint. Why do you think that matters? Why does consuming beef cause a larger carbon footprint than eating other protein like beans or tofu?

Extensions

1. **Analyzing Data:** With an adult from your household, calculate your carbon footprint by answering similar questions on a Carbon Footprint Calculator by the Global Footprint Network (**https://www.footprintcalculator.org/home/en**) or by The Nature Conservancy (**https://bit.ly/3wuKmlA**). You will receive an actual value for your carbon footprint, and how your footprint compares to others. What was your total footprint? Where do you rank compared to others? Were there any questions that surprised you or new carbon impacts that you learned? Were there some questions that were difficult to answer? Discuss the quiz and your results.

2. **Analyzing Data:** Examine the data on ecological footprint and biocapacity for your country on **https://data.footprintnetwork.org/#/**. Ecological footprint measures how much demand human consumption places on the biosphere. Biocapacity is the area of productive land available to produce resources or absorb carbon dioxide waste, given current management practices. For the most recent year, what is the ecological footprint per person? How does it compare to the biocapacity per person with the most recent data? How have the trends changed over time?

3. **Applying Concepts:** Examine a map of your community and identify areas that give community members an option to lower their carbon footprint, such as bus stations, shared bike rentals, hybrid or electric car dealerships, or community vegetable gardens. Research locations as needed. Color code or label the locations and add these colors/symbols to the Map Key.

4. Using *Scratch*®: Create a carbon footprint calculator in *Scratch*®. Your project should ask the user questions about their energy consumption and use that information to calculate how much CO_2 they are producing. Here are four carbon footprint calculators made by *Scratch*® users:

   - **https://scratch.mit.edu/projects/735051359/**
   - **https://scratch.mit.edu/projects/735051633/**
   - **https://scratch.mit.edu/projects/735051782/**
   - **https://scratch.mit.edu/projects/735051880/**

5. Look at these projects for ideas and programming techniques. Remix one of these or build your own carbon footprint calculator. Pay careful attention to how the program uses the answers to each question to calculate the amount of CO_2 generated.

ASSESSING YOUR CARBON FOOTPRINT

Assessing Your Carbon Footprint: Household				
	A	**B**	**C**	**D**
How many people live in your home?	1–2	3–4	5–6	6+
What type of home do you live in?	Apartment or Condo	Duplex	Townhouse or row house	House
Do you take mostly showers or baths?	Only showers	Mostly showers	Mix of both	Mostly baths
How often is the shower or bath in your house used each day?	1–2	3–4		7+
How often do you turn off the water when you brush your teeth?	Always	Usually	Sometimes	Never
Do you have energy efficient appliances in your home?	Yes, all of them	Yes, most of them	Yes, one or two of them	No, none of them
Do you use energy efficient light bulbs?	Yes, all of them	Yes, most of them	Yes, one or two of them	No, none of them
How many loads of laundry do you estimate your household does each week?	1–2	3–4	5–6	7+
How many hours a day does your household watch TV, play video games, or use a computer?	0	1–3	4–9	10+
Does your household turn off the lights when they leave a room?	Always	Most of the time	Sometimes	Rarely
Does your household turn off the TV when they are not watching it?	Always	Most of the time	Sometimes	Rarely
How many of your household's chargers are plugged in when not in use?	0	1–2	3–4	5+
Does your household have heat or air conditioning?	No	Yes, and it is a smart thermostat	Yes, we manually adjust the temperature	Yes, and we set it at one temperature
How many bags of garbage does your household dispose of each week?	0–2	3–4	5–6	7+
Does your household recycle paper products, plastic, cans, and glass?	Yes, all of the time	Yes, most of the time	Some of the time	No, usually not

Assessing Your Carbon Footprint: Food and Drinks				
	A	**B**	**C**	**D**
What kind of food does your household eat?	Just vegetables	Vegetables, eggs, dairy	Everything but red meat	Everything
From where does your family purchase food?	Locally, from farms and farmers markets	A mix of large and small stores	At large stores	Online
Most often, how is your dinner prepared?	We always eat home cooked meals	We usually eat home cooked meals which may include prepackaged items	We eat a mix of homecooked meals and picking up prepared food.	We always purchase prepared food.
How many individual servings of wrapped food does your household eat each day? (such as chips, crackers, cookies, etc.)	None	1–5 times	6–10 times	11+ times
How many times a week does your household eat out at restaurants?	Never	Once a week	2–3 times a week	4+ times a week
Think about your usual lunch at school. How much of the packaging do you throw away or bring home?	I take it all home to use again.	I throw away or recycle some items and bring some home including a reusable lunch box	I usually recycle or throw away most items.	I throw it all away.
When you pick up groceries at the store or market, how do you get them bagged?	We use reusable bags	We use boxes	We use paper bags	We use plastic bags
How many bottled or packaged drinks (water, juice, soda, etc.) do you have a week?	None; I use a reusable water bottle	1–2	3–6	Every day or multiple times a day (7+)
Does your family have a compost pile or use a composting service?	Yes			No

Assessing Your Carbon Footprint: Transportation				
	A	**B**	**C**	**D**
How do you get to school each day?	Walk, bike, or similar	Ride the bus	Carpool	Car with my own family only
How many times a week does your household use a car?	Never	1–9 times	10–14 times	15+ times
How often do you use public transportation?	Daily	Often	Rarely	Never
How many times have you flown in an airplane in the past year?	Zero	Once	Twice	3+ times
What kind of car(s) does your household drive?	None	Small car or hybrid	Mid-sized	Large SUV or truck
If you are going on a trip, how do you usually travel?	Bus	Train	Car	Plane

INVESTIGATION 6B: TESTING LIGHT BULB EFFICIENCY USING A MICRO:BIT (TECHNOLOGY-DRIVEN INVESTIGATION)

Learning Outcome: Compare the amount of light and heat emitted by different types of light bulbs to consider and compare the relative efficiencies of the bulbs.

Materials

Per group:

- light bulbs: incandescent, WLED, compact fluorescent (each preferably with the packaging)
- calculator
- computer
- micro:bit or other microprocessor
- 3V battery pack to power the micro:bit (recommended)
- lamp

What to Do

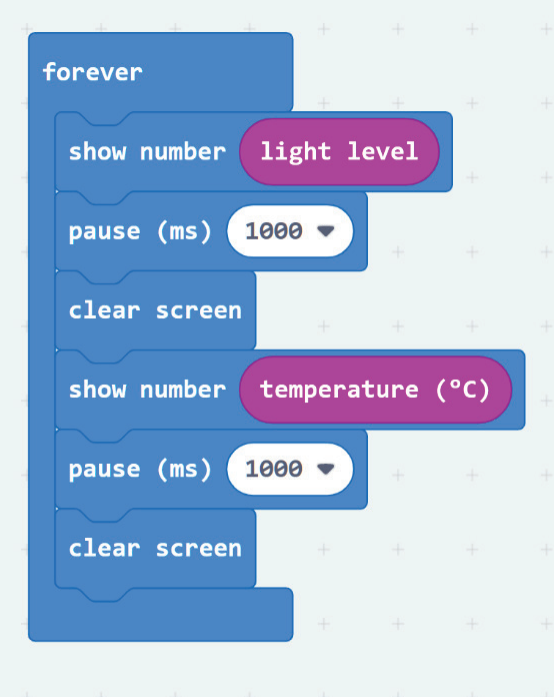
1. Think about light used in buildings.
   - **a.** What types of lights are there in the room?
   - **b.** How many light bulbs are in the room?
   - **c.** Estimate how many light bulbs there are in your home. What about outside, near your home?
   - **d.** What affects the number of light bulbs in a location?
   - **e.** How is the light at your home different than the light in the room you're currently in?
   - **f.** What times of the day do you think the most electricity to power lights is used at home? What about in the building you are in now? Why do you think so?
2. There are different types of light bulbs available for consumers. Carefully examine the light bulbs that your group has. How are they alike? How are they different? Draw diagrams of each light bulb and identify the similarities and differences.
3. Make a chart with 4 columns titled "Type of Bulb", "Lumens", "Watts", and "Lumens per Watt." The chart should have enough rows for the title row and one row for each bulb.
4. Enter in as much information as you can into the first three columns.

5. Calculate the number of lumens per watt by dividing the lumens by the number of watts for each bulb. This is a measure of the bulb's efficiency. A greater number of lumens per watt means the bulb is converting more of the electricity it consumes into light compared to a bulb that generates fewer lumens per watt.

6. Examine your chart. How do the relative efficiencies of the bulbs compare? Discuss your thoughts with your group.

7. Program the micro:bit to display temperature and light.

   a. Enter the following MakeCode program, shared at https://makecode.microbit.org/_196MKkHwdbKP.



Credit: Logo Foundation

   b. Download the program to the micro:bit.

   c. If you have a 3V battery pack, you may disconnect the micro:bit from your computer and power it from the 3V battery pack.

8. Examine the micr:bit screen. It only displays a single digit, so two and three digit numbers scroll by.

   a. The light level should be displayed on the screen. The number displayed for light level is just a number between 0 (dark) and 255 (bright light — the maximum that can be recorded), which is useful for comparing relative brightness. It is not a measure of lumens or any other standard unit.

   b. After one second, the screen is cleared and the temperature in degrees Celsius is displayed.

SAFETY NOTE: *This activity should be done only with adult supervision. There are two safety issues:*

1 **The lamp should be unplugged** *and turned off when changing bulbs to reduce the chance of electric shock.*

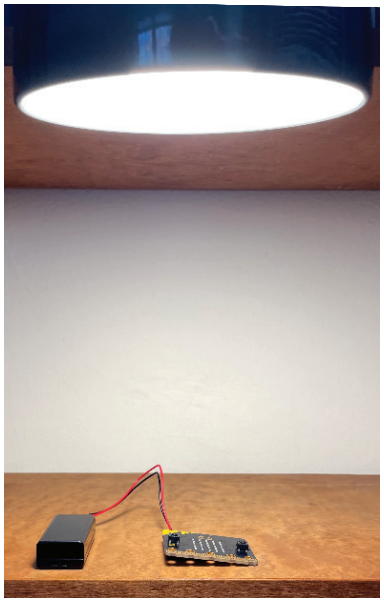
2 **Bulbs get hot.** *This is especially true of incandescent bulbs. Do not touch a bulb when it is lit. After turning unplugging the lamp and turning it off, allow sufficient time for the bulb to cool down before touching it.*

9. While a lamp is unplugged, put the LED bulb in the lamp.

10. Position the micro:bit so it is 20–30 cm away from the bulb, by placing the micro:bit on a table, floor or other surface with the lamp above it. The micro:bit screen needs to be facing the bulb. It also needs to be in a position where you can read the temperature and light values as they appear on the screen.

11. While the lamp is still off, note the temperature displayed on the micro:bit. This is the "off temperature." Remember, the temperature and light level will be displayed alternatively on the micro:bit display screen with only one digit shown. Two- and three-digit numbers will scroll.

12. Plug the lamp in and turn it on. Keep track of temperature and light emitted every minute for 15 minutes maximum. If the temperature rises about 45˚C, turn the lamp off and unplug it.



Credit: Logo Foundation

13. Turn the lamp off and wait until the temperature returns to the off temperature in step 11.

14. Unplug the lamp and replace the LED bulb with another type of bulb.

15. Repeat steps 11–14 using other bulbs.

Consider

1. What differences do you see, if any, between the light emitted from light bulbs?

2. What differences do you see, if any, between the heat emitted from light bulbs?

3. Rank the bulbs that you tested in terms of most efficient to least efficient. Use evidence to explain your reasoning.

4. How might the various materials that make up the light bulbs impact the disposal?

Extensions

1. **Analyzing Data:** Create graphs of the data you collected. How do the graphs compare? What trends in the data can you see by analyzing the graphs that may not have been apparent earlier?

2. **Analyzing Data:** Examine Figure 3, "Quantity of light bulbs sold over time," which displays data collected between 2005–2019 in Japan.

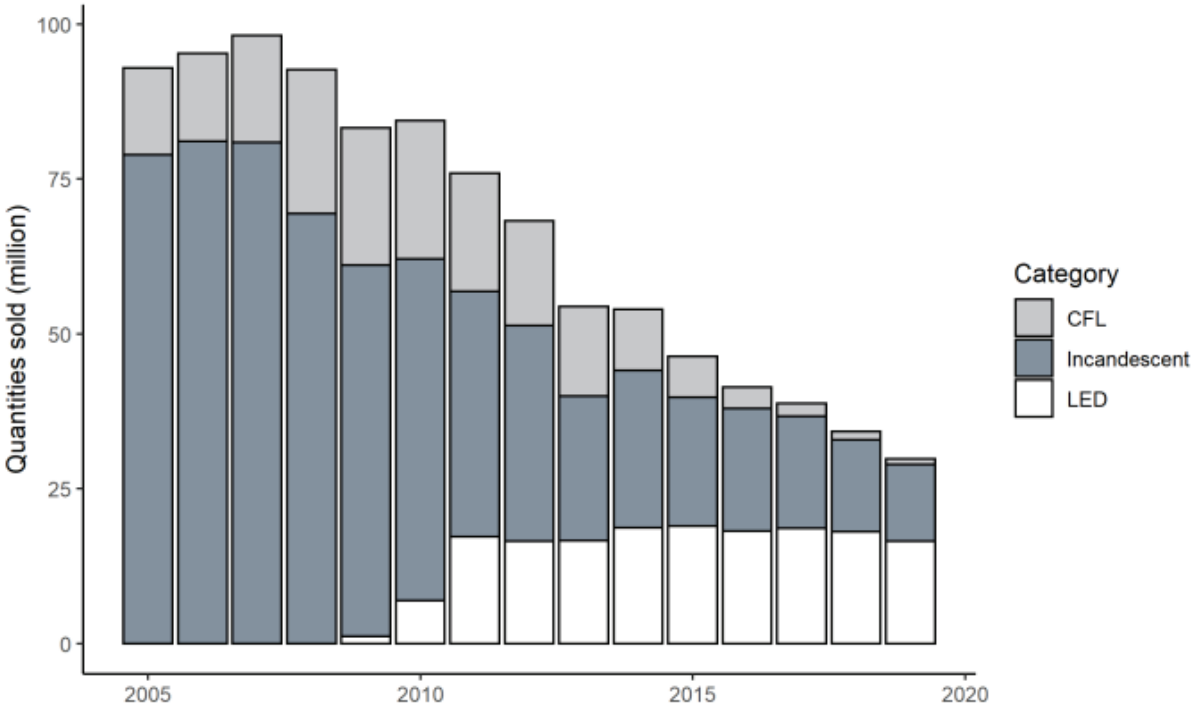


Figure 3: Quantity of light bulbs sold over time

Credit: Reproduced with permission from Fukasawa, T. (2021). Consumer preference for durability and energy efficiency: Welfare analysis of Light Bulb market. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3839998.

a. What do you notice about the overall trend of light bulbs sold? What could be some reasons for this trend?

b. Do you think this trend is unique to Japan? Why or why not?

3. **Analyzing Data:** Examine Figure 4, "Price of light bulb products over time," which displays data collected from 2005 to 2020 in Japan for compact fluorescent (CFL), incandescent, and light-emitting diode (LED) bulbs. The vertical lines show the standard errors in the data, while the three lines indicated in the key are the trends. Study the trendlines.

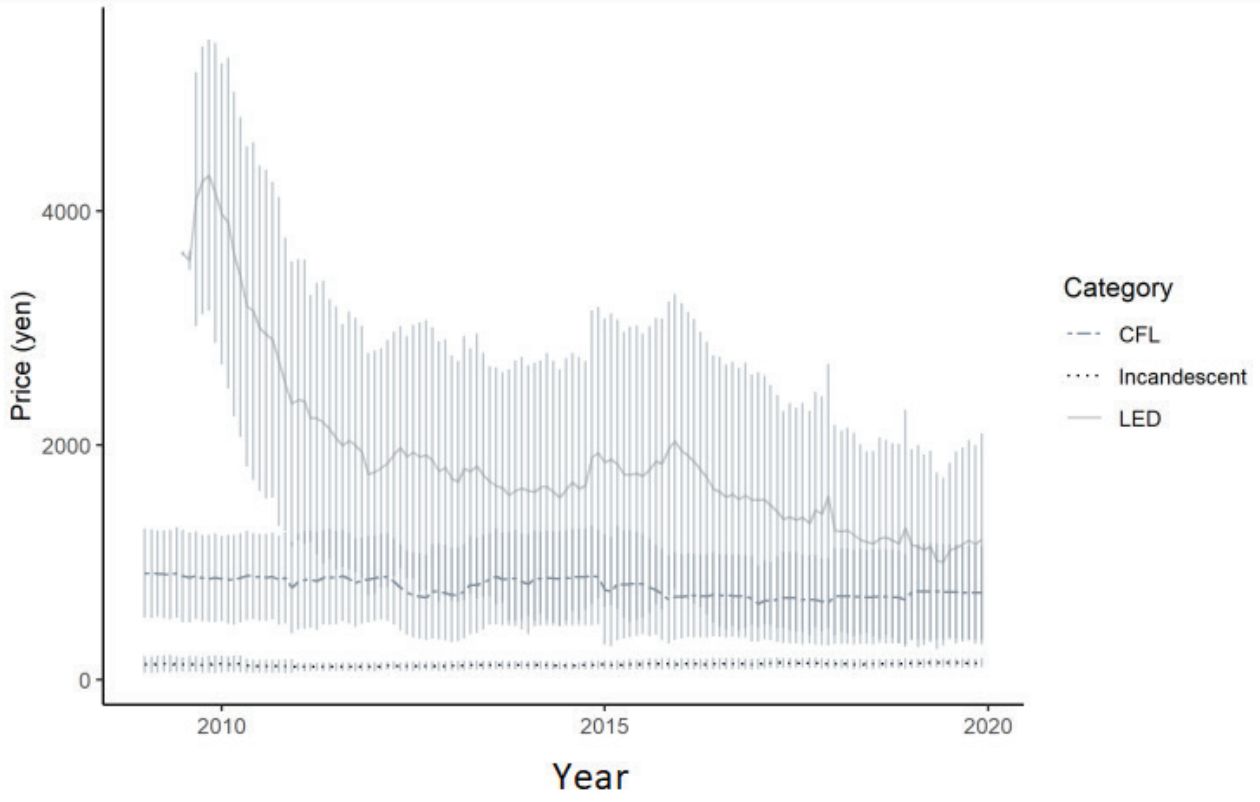


Figure 4: Price of light bulb products over time

Credit: Reproduced with permission from Fukasawa, T. (2021). Consumer preference for durability and energy efficiency: Welfare analysis of Light Bulb market. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3839998.

a. What do you notice about the trends of the CFL, incandescent, and LED light bulbs?

b. Consider the energy efficiencies you explored in the Investigation and the prices displayed in Figure 4. Which bulb(s) do you think are most cost efficient? Why do you think so?

4. **Applying Concepts:** Research how each type of bulb generates light and heat. Why do you think incandescent bulbs produce more heat than CFL, LED, or fluorescent bulbs?

5. **Applying Concepts:** Light is a type of electromagnetic (EM) radiation. Heat can also be transferred by a type of EM radiation — called infra-red radiation. What are other types of EM radiation are there? Find out more about the full spectrum of EM.

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

INVESTIGATION 7A1: ANALYZING FABRICS

Learning Outcome: Test and analyze different fabrics to compare natural and synthetic materials.

Materials

Per group:

- "Analyzing Fabrics" handout
- 10 cm x 10 cm squares of 2 natural fabrics (like cotton, wool, or bamboo)
- 10 cm x 10 cm squares of 3 synthetic fabrics (like spandex, nylon, polyester, or rayon)
- scissors
- magnifying glass, dissection microscope, or compound microscope
- 20–30 cm (8–12 in) PVC pipe to use as a static wand
- ruler or tape measure
- medium or fine sandpaper, small square (5 cm x 5 cm)
- pipettes, one for each staining solution
- staining solutions (ketchup/water mixture, mustard/water mixture, cranberry or grape juice, balsamic vinegar, etc.)
- vinegar solution (15 mL (1 T) of vinegar with 60 mL (4 T) of water)
- towel or cloth
- small cup of water

- clear cup or beaker
- fan (optional)

What to Do

1. Think about the different types of fabrics that make up your clothes and other household items like blankets, towels, drapes, toys, and so on.

   a. List as many different types of fabric as you can.

   b. Fabrics are made up of fibers that can come from animals or plants (natural fibers) or can be made from chemical compounds (synthetic fibers). Go through your list and infer if each fabric you listed is natural or synthetic.

2. Your group has a set of fabric samples. Examine and describe each sample. How does each look, feel, and smell? Are they thick or thin? What type of clothing might you expect to be made out of each? Fill in your results on the handout "Analyzing Fabrics."

3. Conduct some quick tests on each swatch of fabric and fill in your observations on the handout "Analyzing Fabrics." Conduct the tests for each fabric sample.

   a. Cut a small slice off the fabric swatch and pull out a couple threads. Examine the threads and record your observations.

   b. Examine the threads under a magnifying glass or microscope. Record your observations and include a sketch.

   c. Attempt to stretch out the thread to see if it breaks (and how easily). Record your observations.

   d. Examine the fabric swatch under a magnifying glass or microscope. Record your observations and include a sketch.

   e. Wad up the fabric into a ball and hold for 10 seconds then release. Record observations immediately and after 2 minutes.

   f. Rub the fabric aggressively around the PVC pipe, and then touch the pipe on a metal chair, the sink, or something that is grounded to the floor, to discharge the pipe. Hold the fabric up near your hair. Recharge the pipe with the fabric, and then discharge the pipe. Hold the fabric up near your clothes and other objects. Make observations about static electricity.

   g. Hold one side of the fabric on the table. Stretch the fabric along the table until it starts to distort but does not break or rip. Measure how far the fabric was able to stretch. Turn the fabric 90˚ and repeat. Record observations and measurements.

   h. Rub the fabric on the surface of sandpaper 10 times. Take observations. Repeat for another 10 strokes. Take new observations.

   i. Using the opposite side of the fabric from the one used on the sandpaper test, add three drops of each stain solution in separate locations on the fabric. Allow them to sit for one minute, then carefully blot off the extra liquid with a paper towel. Record your observations.

   j. Attempt to clean the stains made in the previous step using the vinegar solution and a towel for 3 minutes. Pat out excess moisture. Make observations of how readily the fabric stained and if the stain was able to be removed.

k. Dip the fabric in water, then squeeze the water out of the fabric into a cup. Make observations about how much and how quickly the fabric absorbed water, and how much was released when it was wrung out.

l. Allow the fabric to dry for 3 minutes by shaking the fabric or blowing on it. Make observations about the ability of the fabric to dry.

INVESTIGATION 7A2: ANALYZING DYES

Learning Outcome: Test and analyze different dyes to compare natural and synthetic materials.

Materials

Per group:

- set of synthetic and natural dyes for at least 2 colors
- chromatography strips, about 15 cm (6 in) long (https://amzn.to/3Mn77OX)
- chromatography solvent (preferably acetone, alternatively isopropanol or water)
- wooden rod, ruler, or similar long rigid object
- pencil
- tape
- container(s) to accommodate chromatography strips side by side
- plastic wrap
- paper towel

SAFETY: *Acetone is an irritant and is highly flammable. If it gets on your skin, wash off with soap and water. If it contacts your eyes, rinse with water for several minutes.*

What to Do

1. Fabrics are often dyed to be a certain color. What do you think makes up these dyes?
2. What natural objects or resources do you think you could use to make the following dye colors?
   - **a.** Red
   - **b.** Orange
   - **c.** Yellow
   - **d.** Green
   - **e.** Blue
   - **f.** Indigo
   - **g.** Brown
   - **h.** Black
3. Count the number of dye samples you have for a specific color and pull out that many pieces of chromatography paper, trying to handle the strips by the edges only.

a. Cut the strips so that when they hang into the container, the bottom of the strip will touch the solution but the dot of dye on the strip does not contact the liquid.

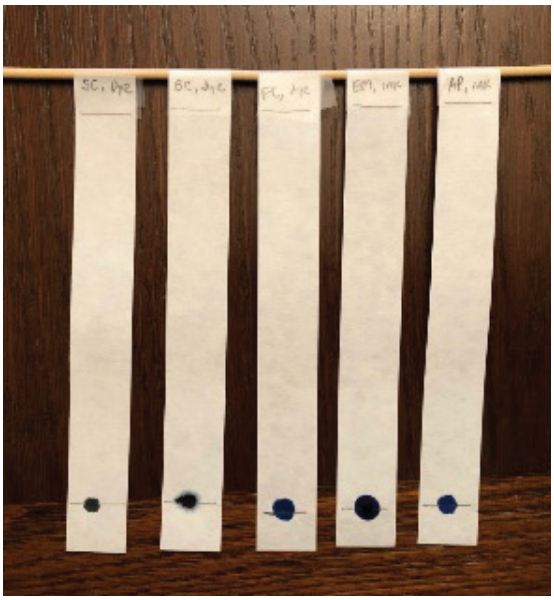
b. On each strip, measure about 1–3 cm (about 1") up from the bottom of the strip and draw a line with a pencil. Repeat at the top of the strip.

Credit: L.Brase

4. Label the strips at the top, above the line, in pencil, to identify the type of dye.

5. Make a small circle (about .5 cm diameter) of the corresponding dye in the center of the pencil line at the bottom of each strip. Let the dye dry.

6. Tape the tops of the strips to a rod, pencil, or ruler so they hang down next to each other. The bottoms of all of the strips should be at about the same level. If the strips are wider than your container, use different rods and containers.



Credit: L.Brase

7. Hang the strips across the empty container(s). Mark the height of the bottom of the chromatography strips on the side of the container.

8. Remove the rod with all of the hanging strips and put enough acetone in the container so the bottoms of the strips will just touch the top of the liquid.

9. Hang the strips over the container with acetone.

a. The acetone should touch each strip below the bottom line and the spot of dye.

b. Cover the container with plastic wrap to prevent acetone evaporate to escape.

c. Carefully add small amounts of acetone as necessary so each strip is at least touching the liquid.

10. The acetone will start to move up the strips. It will make contact with the dye, and then continue up the strip, carrying some of the dye with it.

11. When the acetone reaches the top line (or after 10 minutes), remove the strips. Lay them flat on a dry surface that will not be harmed by the acetone.

12. Observe the results for each strip. Draw and write about the observations for each dye.

13. Repeat steps 3–12 for another color, if available.

INVESTIGATION 7A3: DYEING FABRICS

Learning Outcome: Test and analyze different fabrics and dyes to compare natural and synthetic materials.

Materials

Per learner:

- "Dyeing Multi-Fiber Fabric" handout

Per group:

- set of synthetic and natural dyes of the same color
- 2 containers, one for each dye
- 2 pieces of the same multi-fiber fabric (**https://www.flinnsci.com/multi-fiber-test-fabric-1-yard/ap6135/**, or **https://bit.ly/38utjrP**)
- water
- tongs or tweezers
- magnifying glass or dissection microscope

What to Do

1. Make a prediction using what you know about natural and synthetic fabrics: How do you think the dyeing process will be similar and how might it be different for natural and synthetic fabrics?
2. Make a prediction using what you know about natural and synthetic dyes. What are some similarities and some differences in how a fabric might look if it was dyed with natural or synthetic dyes?
3. Place the multi-fiber fabric in container with the natural dye. After five minutes, remove the fabric with tongs, rinse it with water, and then dry it with a paper towel.
4. Observe and record how each fabric on the multi-fiber fabric looks on the handout "Dyeing Multi-Fiber Fabric."
5. Dip a second multi-fabric strip in the container with the similar color of synthetic dye for 10 seconds. Observe and record how each fabric on the multi-fiber fabric looks on the handout "Dyeing Multi-Fiber Fabric."
6. Observe both strips under a magnifying glass or microscope. Record observations.
7. Compare how the different types of fabric in the multi-fiber fabric that was tested took up the color from natural dye.
8. Compare and contrast how different types of fabric took up the color from the synthetic dye.
9. Discuss your results with the whole group.

Consider

1. Compare and contrast the different fabrics you tested in Investigation 7A1. What fabrics were similar? Which were different? Use evidence from your tests in your explanations.

2. Predict which fabric samples are made of natural fibers and which are made from synthetic fibers in Investigation 7A1. Write your predictions on the handout and separately explain why you made your predictions.

3. What do you think the benefits of using natural fibers are? What about the drawbacks or limitations?

4. What do you think the benefits are of using synthetic fibers? What about the drawbacks or limitations?

5. Think about materials and resources used to produce each type of fabric. Do you think synthetic or natural fabrics are a more sustainable option? Why do you think so?

6. Compare the results of the chromatography experiment.

    a. How do the results from the natural dyes compare to the synthetic dyes?

    b. If you tested inks and dyes, how do they compare?

    c. What other information would you like to know to make sense of the chromatography results?

7. What are some benefits to using natural dyes? What about the drawbacks or limitations?

8. What are some benefits to using synthetic dyes? What about the drawbacks or limitations?

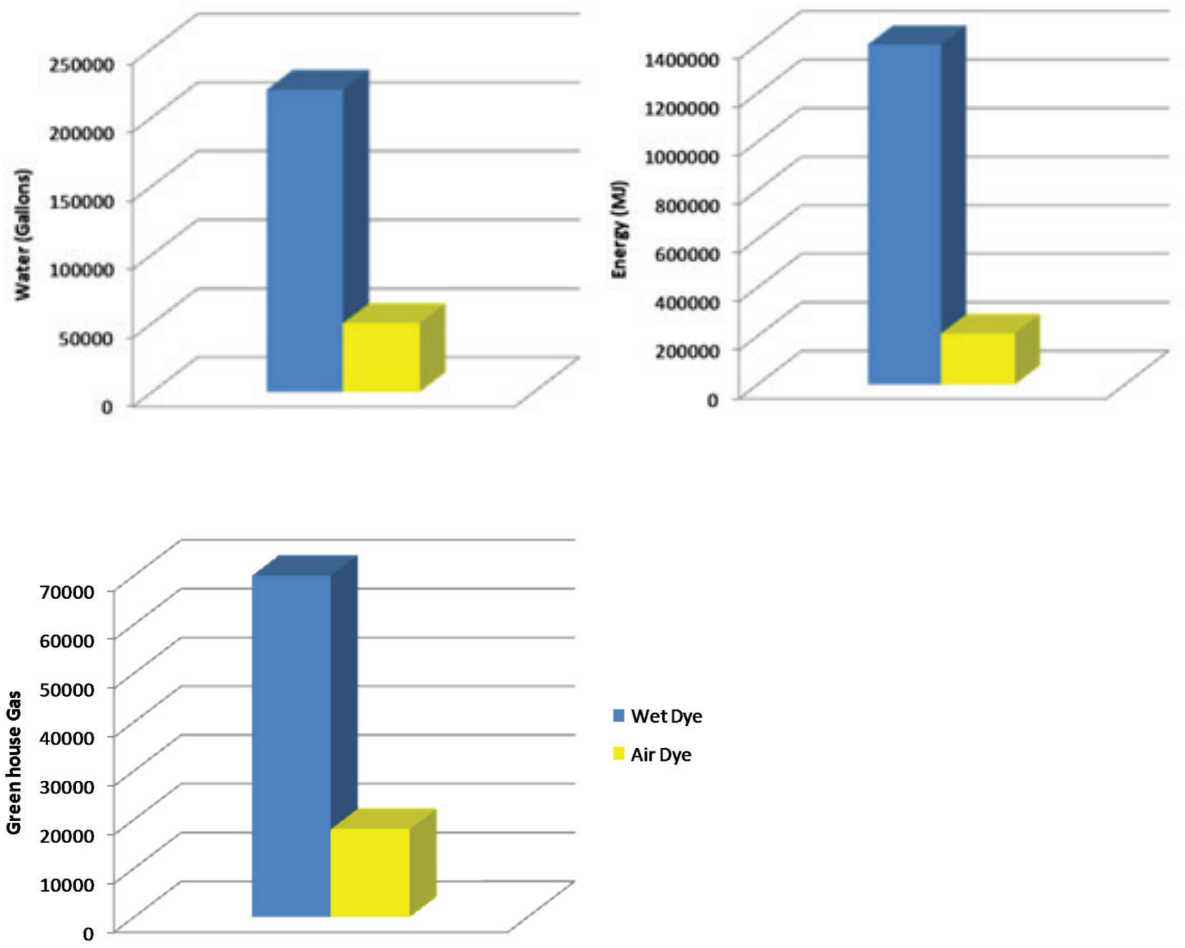
Extensions

1. **Testing Variables:** Obtain a small piece of clothing, like socks or a bandana, made mostly from natural materials like cotton, linen, and so on. Write down all the materials from the tag. These will be your experimental variables. Make a prediction about what would happen if you buried it under dirt for several weeks. With permission, bury the item in a pot of soil outside. Keep the soil moist and in a warm environment, if possible. Every week, dig up the clothing item, rinse it off, then dry it out. Record your observations. Bury the fabric again and repeat for multiple weeks.

2. **Testing Variables:** Variables like sunlight and washing clothing have been known to lighten or fade dyed fabrics. Design and carry out an experiment that tests the effects of sunlight or washing on different fabrics or on different dye colors. Be sure you use clothing you are willing to get rid of and have permission to use. Also be sure you design an experiment that only tests one variable at a time.

3. **Analyzing Data:** Traditional wet dyeing uses water to dye fabrics and fibers. Air dyeing is a process that uses air instead of water. Examine the charts that show the "Comparison of air dyeing and traditional wet dyeing process for 25,000 medium men's t-shirts" in water, energy, and greenhouse gas emissions. Use evidence from the charts to describe which dyeing process is more sustainable.

COMPARISON OF AIR DYEING AND TRADITIONAL WET DYEING PROCESS FOR 25,000 MEDIUM MEN'S T-SHIRTS



Credit: Kant 2012, **https://www.scirp.org/html/4-8301582_17027.htm**

4. **Applying Concepts:** Conduct a clothing audit. Review the tags of your clothes and make a list of the different types and amounts of fabrics. Are your clothes made up mostly from synthetic or natural fabrics? Which types of fabrics are most common? Why do you think so? Would you predict the fabric was dyed with synthetic or natural dyes? Why do you think this?

5. **Applying Concepts:** Examine the figure "Direct and indirect impacts of textile dyes on several substances." A textile is any material made of interlacing fibers. Fabric is a type of textile. Other examples include carpet and medical bandages.

   a. What are some of the direct impacts of textile dyes?

   b. What are some of the indirect impacts of textile dyes?

   c. List and look up some vocabulary words you are unfamiliar with.

d. What questions are you left wondering after examining this figure?

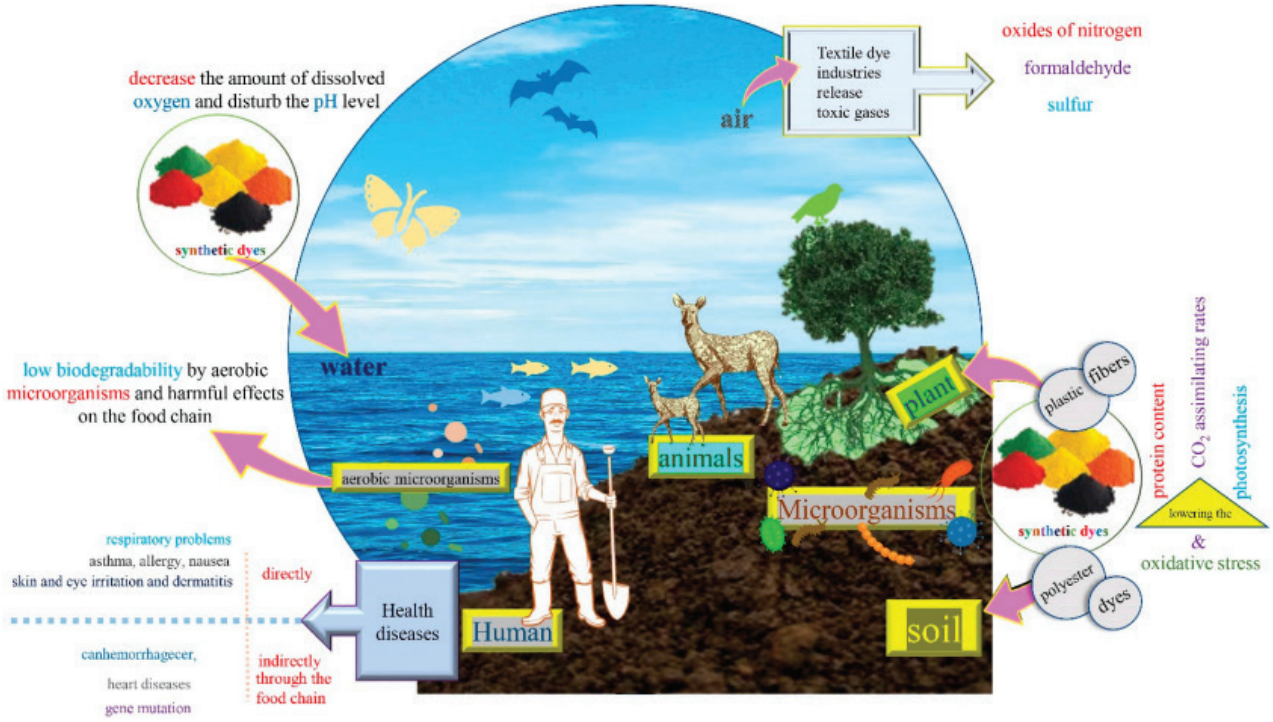


Figure 2. Direct and indirect impacts of textile dyes on several substrates.

Credit: Slama et al. 2021

6. **Applying Concepts:** Examine a map of your community and identify stores that sell clothing, fabric, yarn, or dye that is made from natural materials. Label them and add the symbols to the Map Key.

Analyzing Fabrics

Fabric Sample	A	B	C	D	E
2. Description					
3a. Thread observation by eye					
3b. Thread observation under magnification					
3c. Thread stretching					
3d. Fabric observation under magnification					
3e. Wadded up fabric					
3f. Static electricity					
3g. Fabric Stretching					
3h. Abrasion (sandpaper rub)					

Fabric Sample	A	B	C	D	E
3i. Staining					
3j. Stain removal					
3k. Absorbing water					
3l. Drying					
3m. Facilitator Demonstration #1					
3n. Facilitator Demonstration #3					
Prediction: Natural or Synthetic?					
Type of Fabric					
Natural or Synthetic?					

Dyeing Multi-Fiber Fabric

Dye color: ______________________

NATURAL DYE

Fabric type	Observations	Observations under a microscope

SYNTHETIC DYE

Fabric type	Observations	Observations under a microscope

INVESTIGATION 7B: UNDERSTANDING HOW THE FASHION INDUSTRY IMPACTS THE ENVIRONMENT (DATA-FOCUSED ACTIVITY)

Learning Outcome: Analyze data to learn how the fashion industry contributes to global waste and to make decisions about how the environmental impact could be reduced.

Materials

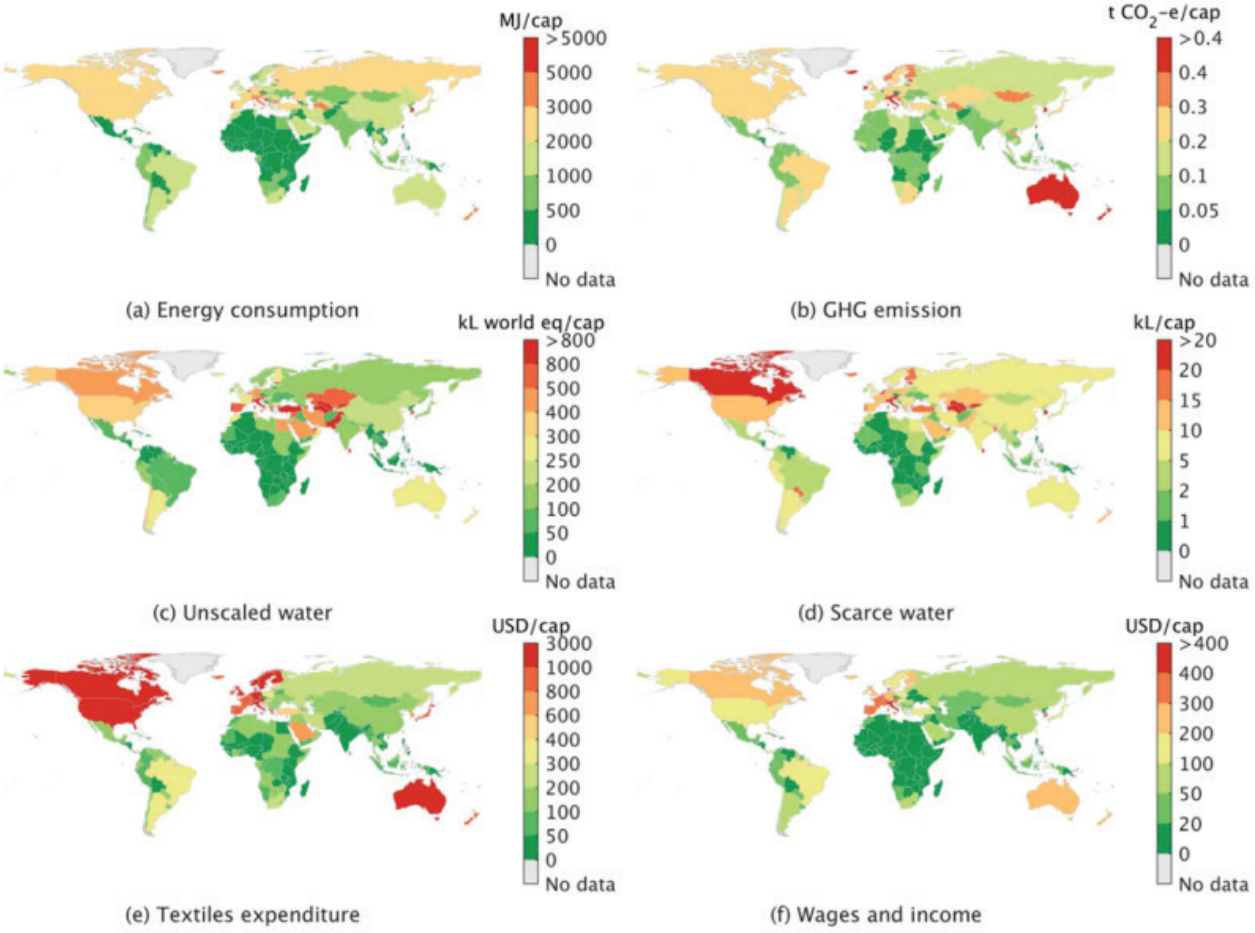
Per learner:

- "SANVT Infographic" handout
- "Potential Sources and Major Possible Transfer Pathways of Microfibers" diagram from **https://bit.ly/3TaVvmc**

What to Do

1. Think about how the fashion industry may contribute to global waste and greenhouse gas emissions. It may be helpful to consider how a t-shirt or a pair of jeans is made.
   - **a.** What resources are used to create this garment?
   - **b.** What resources are used after the garment has been made (i.e., the process of getting garments to customers and discarding garments).
2. Have you heard of the term "fast fashion"? What do you think it means? What may be an example of fast fashion?
3. Examine the maps of per capita footprints for the clothing and footwear sector in 2015. In figure (b) "GHG" stands for greenhouse gas. The data in figure (c), scarce water, has been scaled based on factors related to water scarcity but the data in figure (d), unscaled water, does not take those factors into account.
   - **a.** What do you notice? Are there any trends between the maps? Which maps seem to be similar or possibly correlated?
   - **b.** Examine map e) Textiles Expenditure. Which countries spend the most money on textiles? Why do you think this is?
   - **c.** Examine the continent where you live. Compare your continent to others for each map.
   - **d.** Using evidence from the maps, predict which continents or countries likely have the largest "fast fashion" industry. Explain your answer.

PER CAPITA FOOTPRINTS FOR THE CLOTHING AND FOOTWEAR SECTOR IN 2015



Credit: Peters et al. 2021

4. Examine the Infographic: Environmental Impact by the Fashion Industry, created by SANVT.

   a. List 5 facts or statistics that stood out to you, and your thoughts about each.

   b. What could be done to reduce the environmental impact from the fashion industry?

   c. What are you still left wondering?

Credit: SANVT, https://bit.ly/SANVTDiagram

5. Examine the graph, "World consumption of major textile fibers and variation of cotton's market share." There are two graphs displayed on the axes. The graph using the primary y-axis (to the left of the graph), "World consumption of major textile fibers," is a compound line graph. To read it, you find the differences between the points on adjacent lines. This allows you to see what percent (or fraction) of the total each section (color) represents. The dotted line uses the secondary y-axis (to the right of the graph), "Cotton's share of world textile fiber consumption." Use data from 1960, 1994, and 2014 to answer questions a-c.

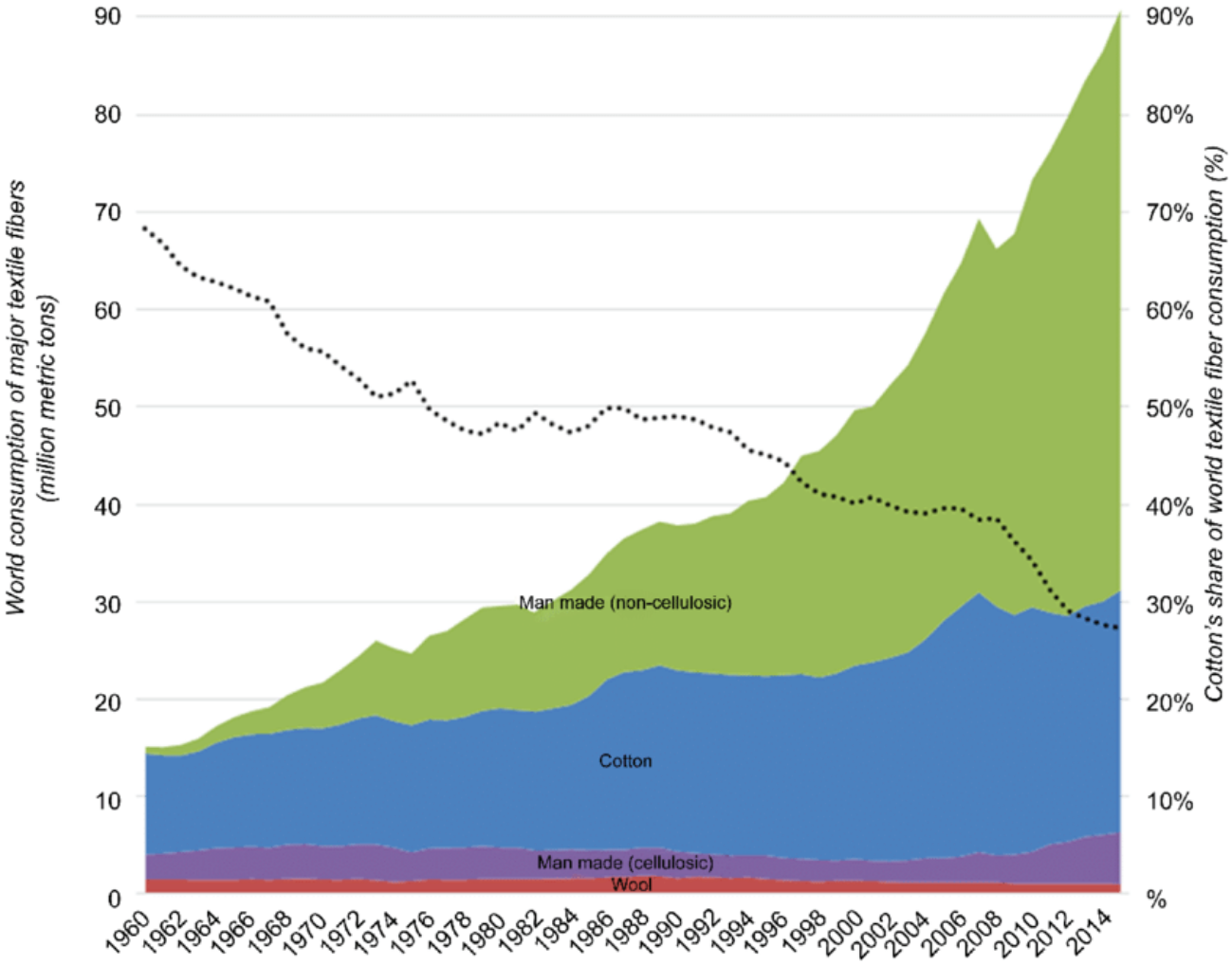
   a. How has the total consumption of textiles changed throughout the years?

   b. Describe the trend of cotton use over time. Give two reasons you think this is occurring.

   c. How has the world consumption of man-made (cellulosic) textiles changed throughout the years?

   d. Man-made (non-cellulosic) fibers include nylon, olefin, acrylic, polyester, and spandex. And are fibers are derived from wood pulp and include rayon and viscose. How does the consumption of non-cellulosic and cellulosic fibers compare? Why do you think this is?

WORLD CONSUMPTION OF MAJOR TEXTILE FIBERS AND VARIATION OF COTTON'S MARKET SHARE



Credit: Krifa and Stevens 2016

6. Polyester is a plastic, human-made fabric created from fossil fuels. Examine the graph, "Growth in global population and textile production by fiber type." There are two graphs displayed on the axes. The primary y-axis (on the left of the graph) displays "Fiber Production" in a compound line graph. The dotted line displays the world population on the secondary y-axis (on the right of the graph).

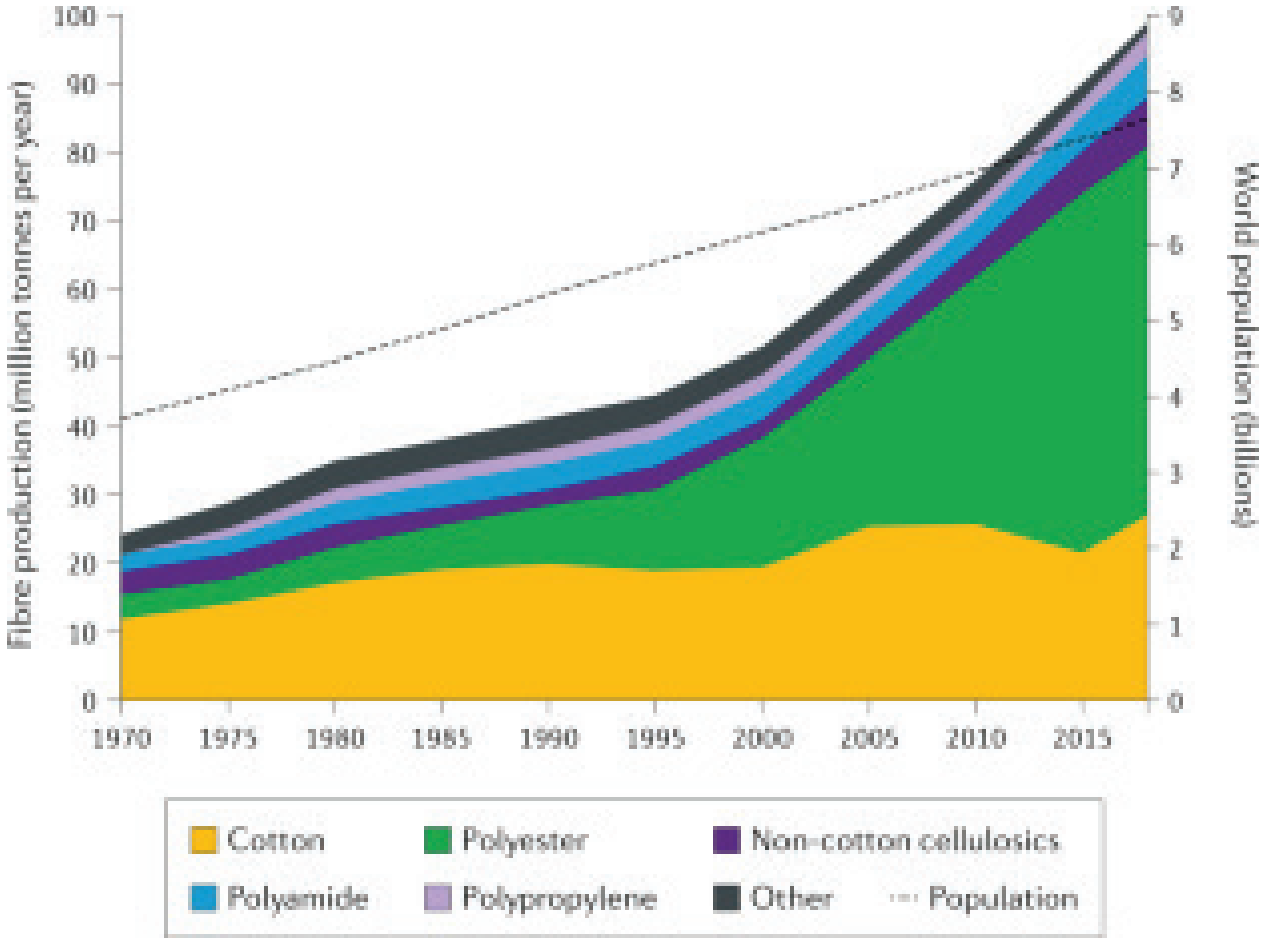
a. How has the production of polyester changed throughout the years?

b. How does the production of polyester compare to other fabrics over time?

c. Examine the total production of fabrics and the global population between 1970 and 1995. What do you notice?

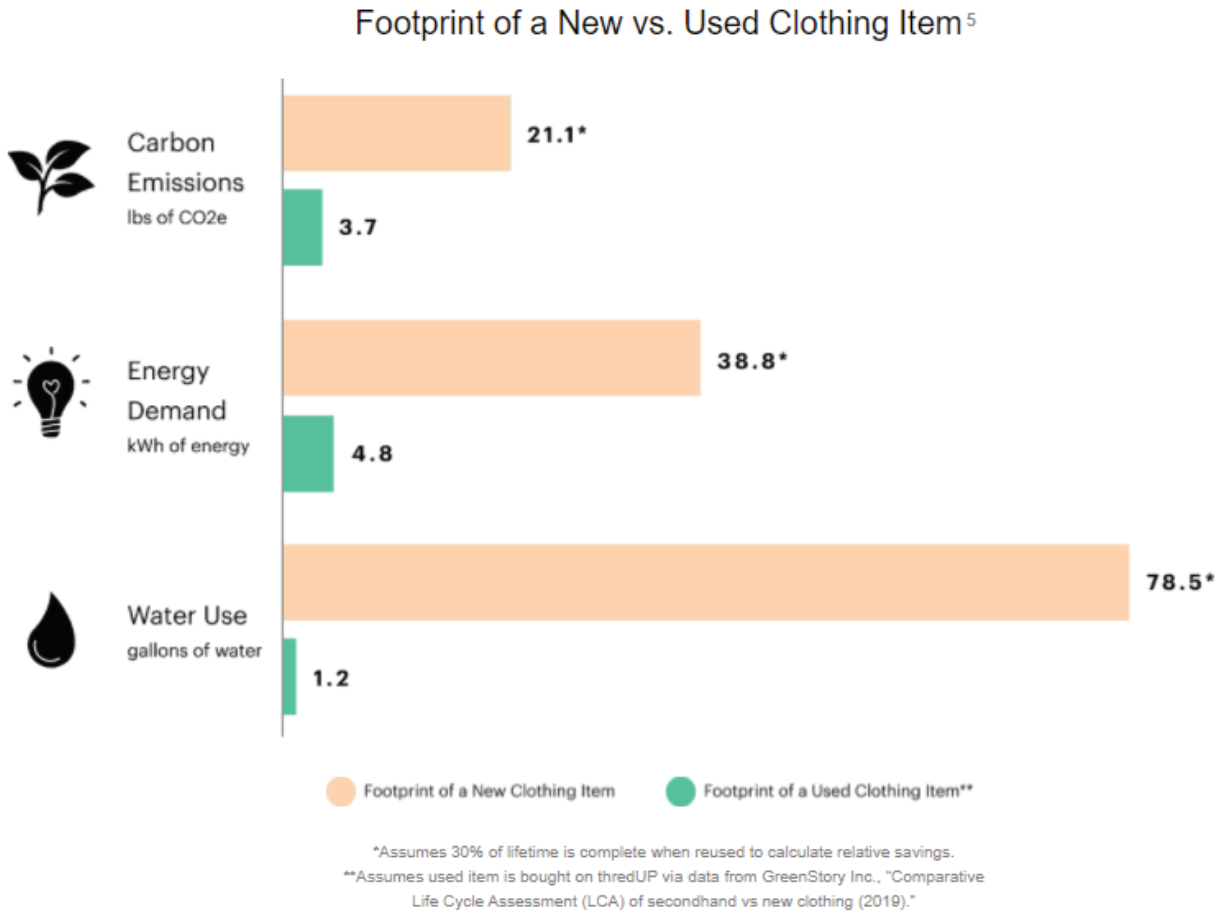
d. Examine the total production of fabrics and the global population between 2000 and 2015. What do you notice?

GROWTH IN GLOBAL POPULATION AND TEXTILE PRODUCTION BY FIBER TYPE



Credit: Niinimaki et al. 2020, https://www.nature.com/articles/s43017-020-0039-9

7. A sustainable practice in the fashion industry is to donate or resell your clothes, and to buy previously used clothes. Explain why this is considered a sustainable practice using evidence from the graph, "Footprint of a New vs. Used Clothing Item."



Credit: ThredUP 2021 Resale Report, https://www.thredup.com/resale/#size-and-impact

8. Microfibers are small bits of plastic released by synthetic textiles that end up in the environment. Examine the figure at: https://bit.ly/MicrofiberPollution.

   a. Look at the bottom of the graphic in the "production," "usage," and "disposal sections." How do microfibers enter the environment?

   b. Look at the top portion of the graphic. Where does microfiber pollution occur?

   c. Why do you think microfibers are bad for the environment?

   d. From the information in the figure, what suggestions could you make to a policy maker or to someone in the fashion industry that would reduce microfiber pollution?

Consider

1. What do you think are some sustainable practices related to responsible fashion consumption?

2. What could policymakers do to encourage sustainability in the fashion industry?

Extensions

1. **Applying Concepts:** Conduct a clothing audit, or use your data from Investigation 7A Extension, and create a graph that shows the amounts of different types of fabrics in your home. How does your data compare to the world data in questions 4 and 5?

2. **Applying Concepts:** Does your country have any policies related to the fashion industry? Are there rules or regulations related to fabrics, dyes, waste, disposal, and so on? Is your country or community involved in any fashion initiatives? What are they?

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

INVESTIGATION 8A: MICRO:BIT-CONTROLLED AUTOMATIC IRRIGATION SYSTEM

Learning Outcome: Use a microprocessor to monitor soil moisture and automate watering of a plant.

Materials

Per learner:

- micro:bit
- computer
- USB cord to connect micro:bit to the computer
- Adafruit STEMMA non-latching relay (**https://www.adafruit.com/product/4409**)
- Adafruit JST to alligator clip adapter (**https://www.adafruit.com/product/4030**)
- 2AA battery holder
- 3–5V water pump with plastic tubing (**https://amzn.to/3Py4oEs**)
- 8 alligator clip wires
- 4 pieces insulated copper wire (10–20 cm long, 18–24 gauge) with 1cm stripped on each end
- potted plant
- 1 quart water container
- 3V battery pack (**https://www.adafruit.com/product/4193**) or power adapter (**https://www.sparkfun.com/products/15101**), optional

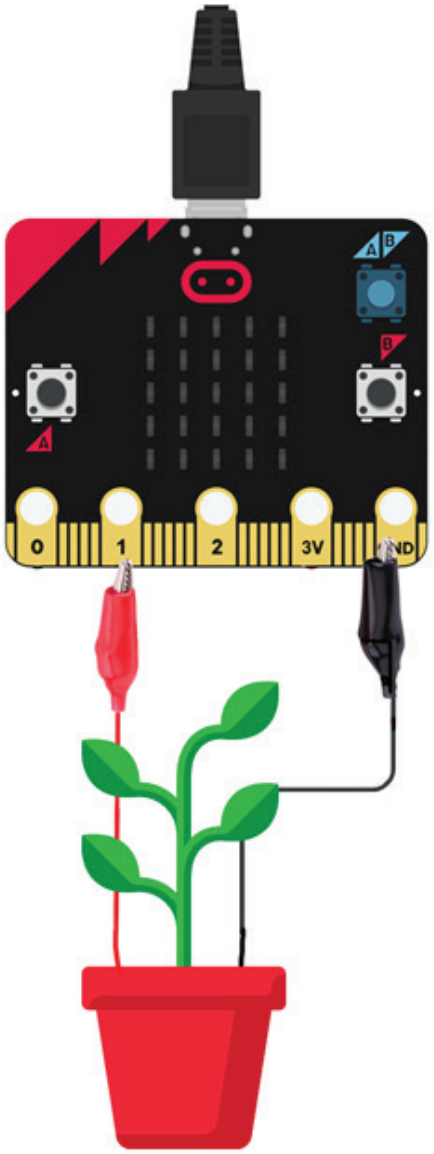
What to Do

1. Set up a system using wires to allow a micro:bit to tell whether plant soil is wet or dry.

   a. Connect a black alligator clip wire to ground (GND) and red alligator clip wire to PIN 1.

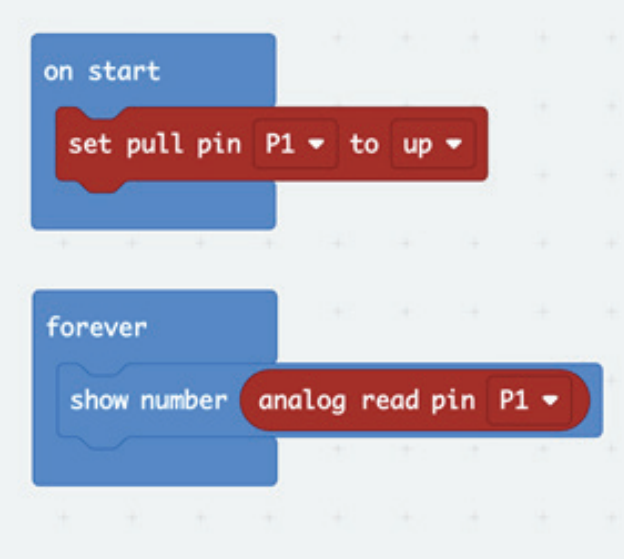
   b. Attach the other end of each alligator clip wire to a stripped end of insulated copper wire.

   c. Insert the other end of the copper wires (which are stripped) into the dry soil of your plant.



Credit: Logo Foundation

2. Program the micro:bit to display the reported sensor values by downloading the MakeCode program in the figure below. You will find the “set pull pin” block is under “Advanced” in the Pins tab. The micro:bit will now report the values from the wires.



Credit: Logo Foundation

3. On the micro:bit, you should see a number around 1000 displayed when the soil is very dry.

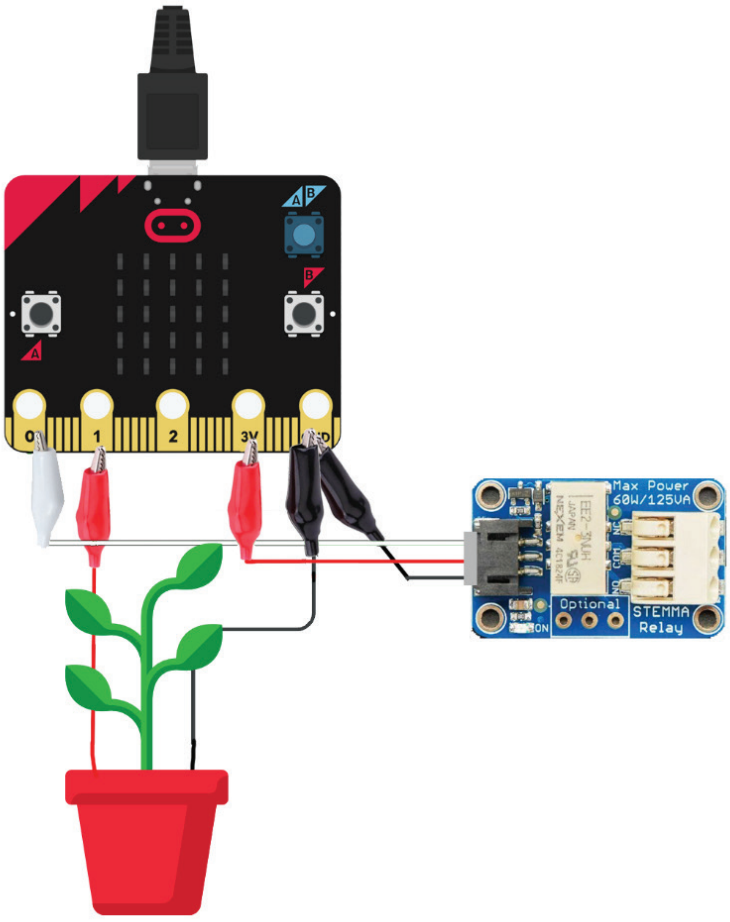
4. Slowly add water to the soil until the number displayed on the micro:bit changes. Wait until the number stabilizes. When the soil is moist, the micro:bit should display a value around 700.

5. Connect the STEMMA relay to the micro:bit using the JST-alligator clip adapters.

   a. Connect the black clip to GND by clipping it onto the other clip already there.

   b. Connect the red clip to 3V.

   c. Connect the white clip to PIN 0.



Credit: Logo Foundation

6. Connect the battery and water pump.

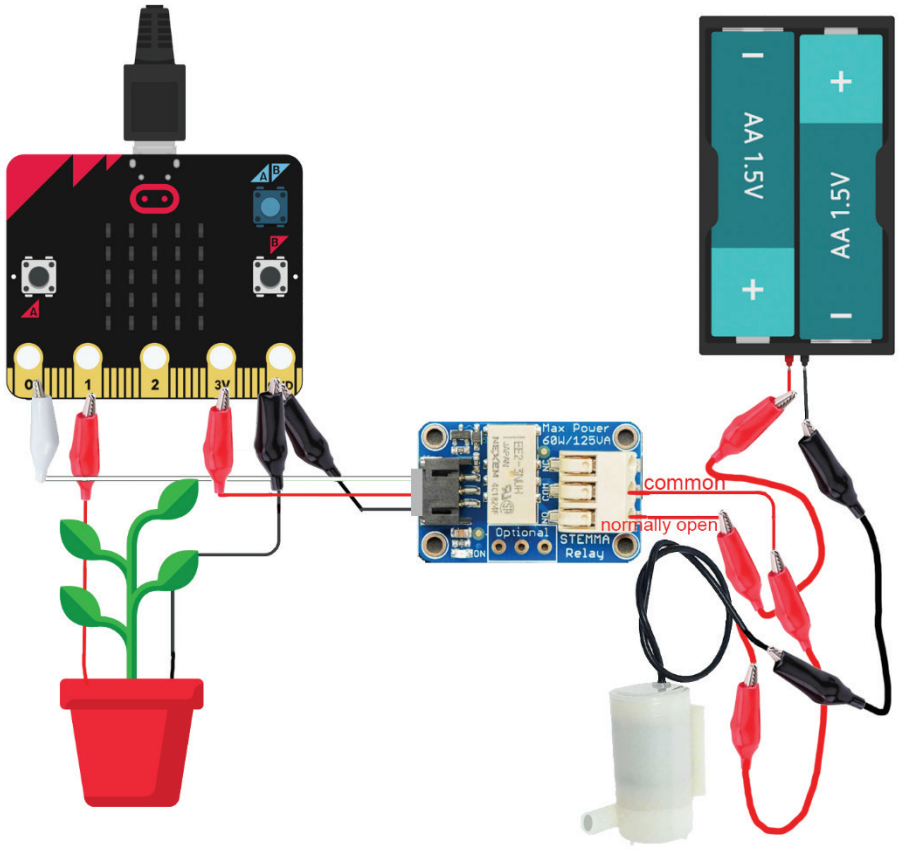
   a. Push one piece of insulated copper wire into the middle terminal on the relay, labeled “Common” underneath the board, or COM on top.

   b. Use an alligator clip to connect this wire to the red wire on the water pump.

   c. Push another piece of insulated copper wire into the bottom terminal on the relay, labeled “Norm. open” underneath the board, or NO on top.

   d. Use an alligator clip to connect this wire to the red positive battery wire.

   e. Use an alligator clip to connect the black negative battery wire to the black wire on the water pump.



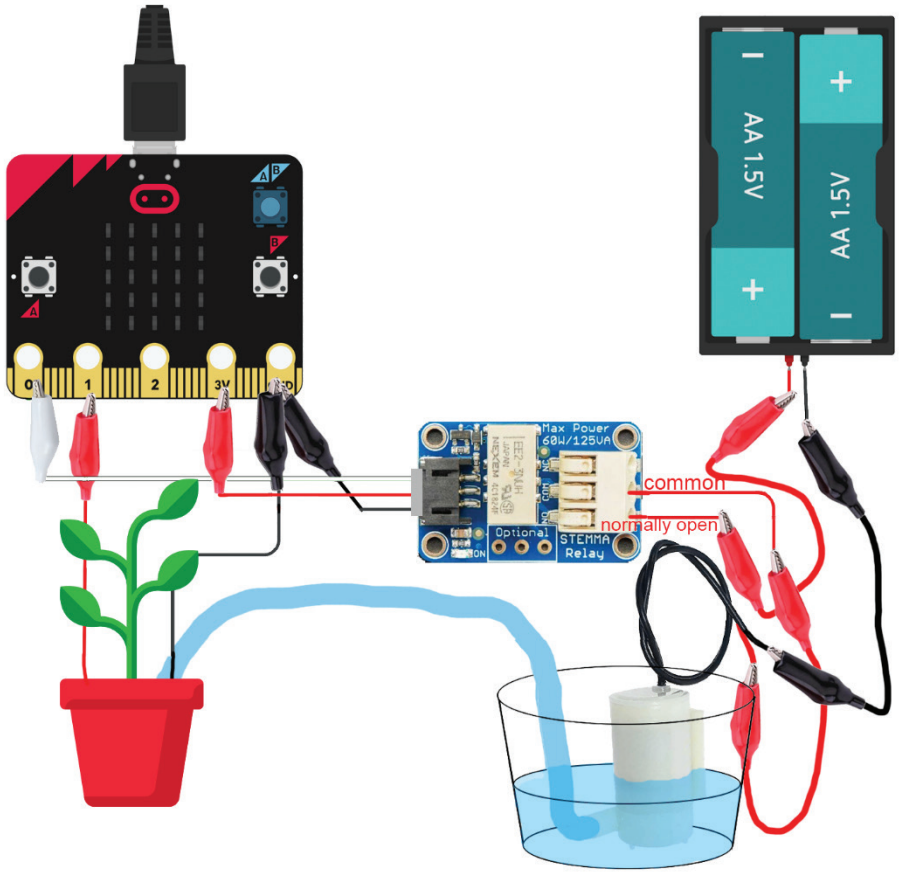
Credit: Logo Foundation

7. Consider the connections you just made: Connecting the battery wires to the relay through the “Normally Open” terminal means when the relay is not activated, the battery circuit will be open and the pump will not be powered. When the relay is activated, the battery circuit closes and the pump will receive power.

Credit: Logo Foundation

8. Fill the container with water until it is about three quarters full.

9. Place the water pump in the container of water while keeping the bare ends of the wires outside the container.



Credit: Logo Foundation

10. Attach the plastic tube to the opening of the water pump and put the other end in the soil near the roots.

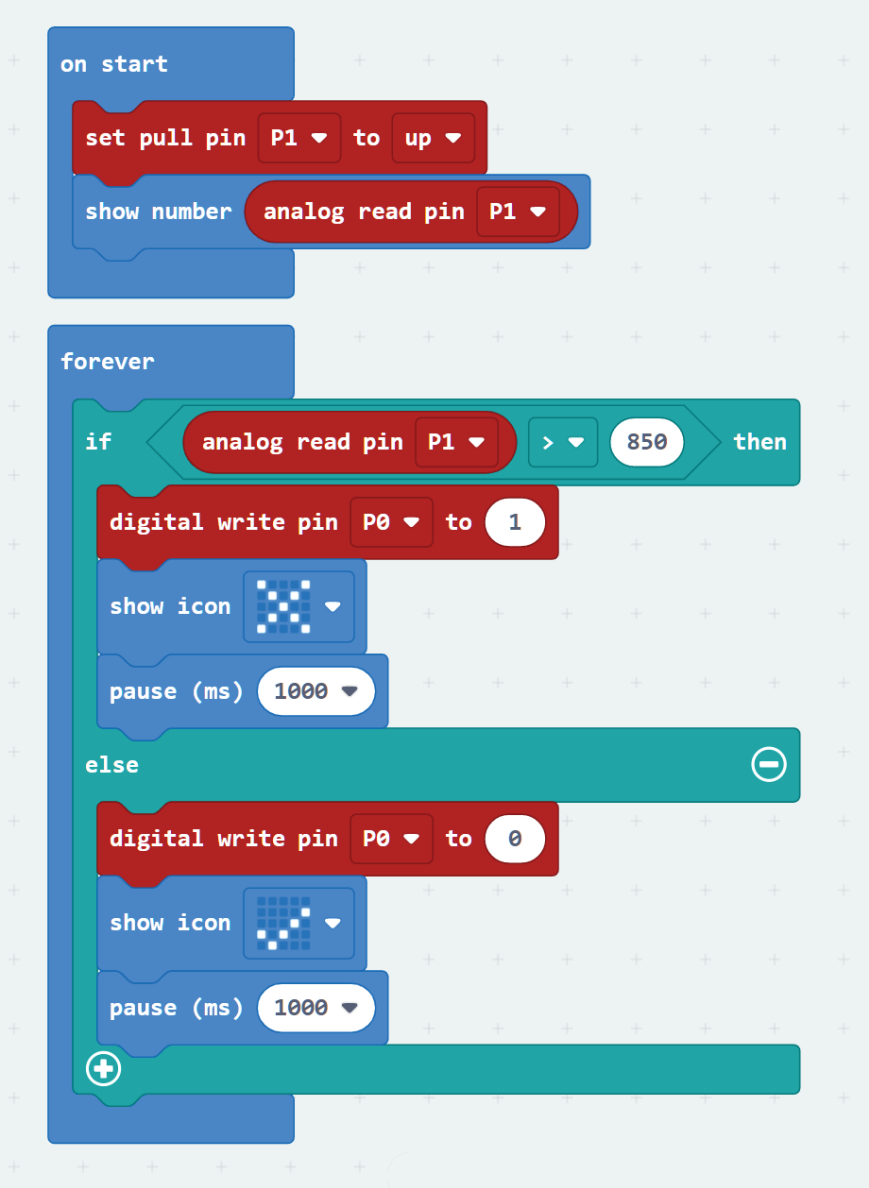
11. Change the MakeCode program to allow the micro:bit to make a decision about when to turn on and off the pump.

a. In the "forever" block, add an if/then/else block for the decision.

b. Create the condition that "if the analog reading on PIN 1 is greater than 850, then" turn on the pump for 5 seconds. 850 was chosen since it is between 700 and 1000 and is considered the "trigger threshold." If your moisture sensor showed a different range in step 4, adjust your trigger threshold accordingly.

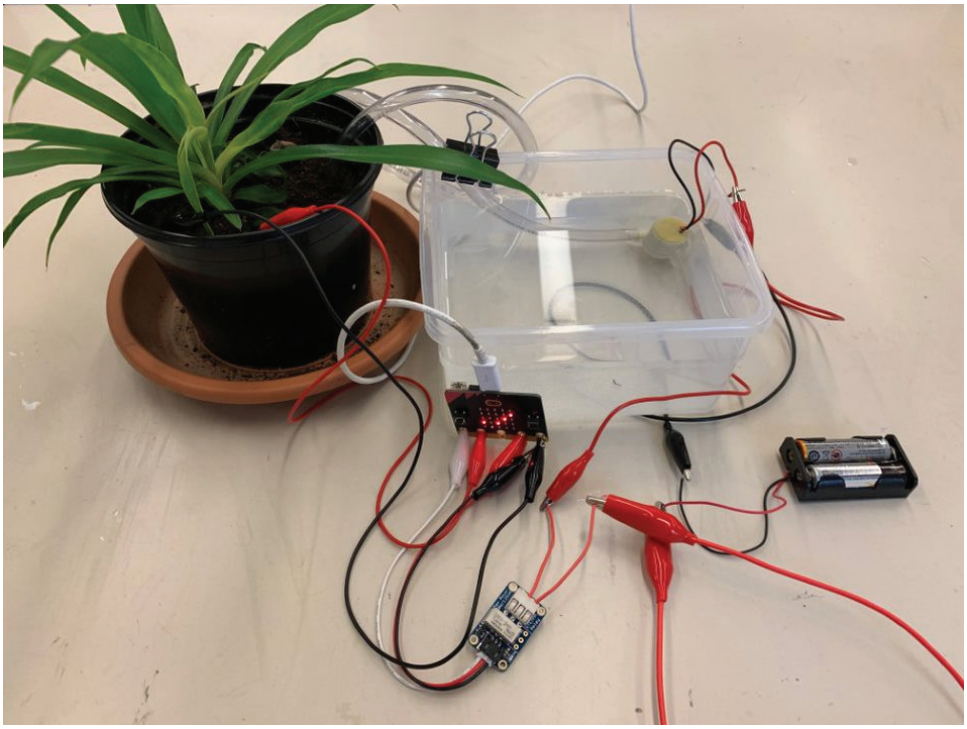
c. In the "else" block, turn off the pump.

12. Download the changed program to the micro:bit.



Credit: Logo Foundation

13. Adjust the watering time as needed for the soil to become moist enough to last a while, which would be about as much water as you would if you were watering the plant by hand.



Credit: Logo Foundation

14. As your system works, water will be used to water the plant and evaporate from the container. Keep an eye on the water level and ensure the water container is more than halfway full and water is above the pump.

Consider

1. Consider where the water is being delivered in this irrigation system compared to traditional watering. How might the delivery location contribute to a more sustainable system?

2. What are pros and cons of using an automated irrigation system like this instead of a traditional system of watering plants?

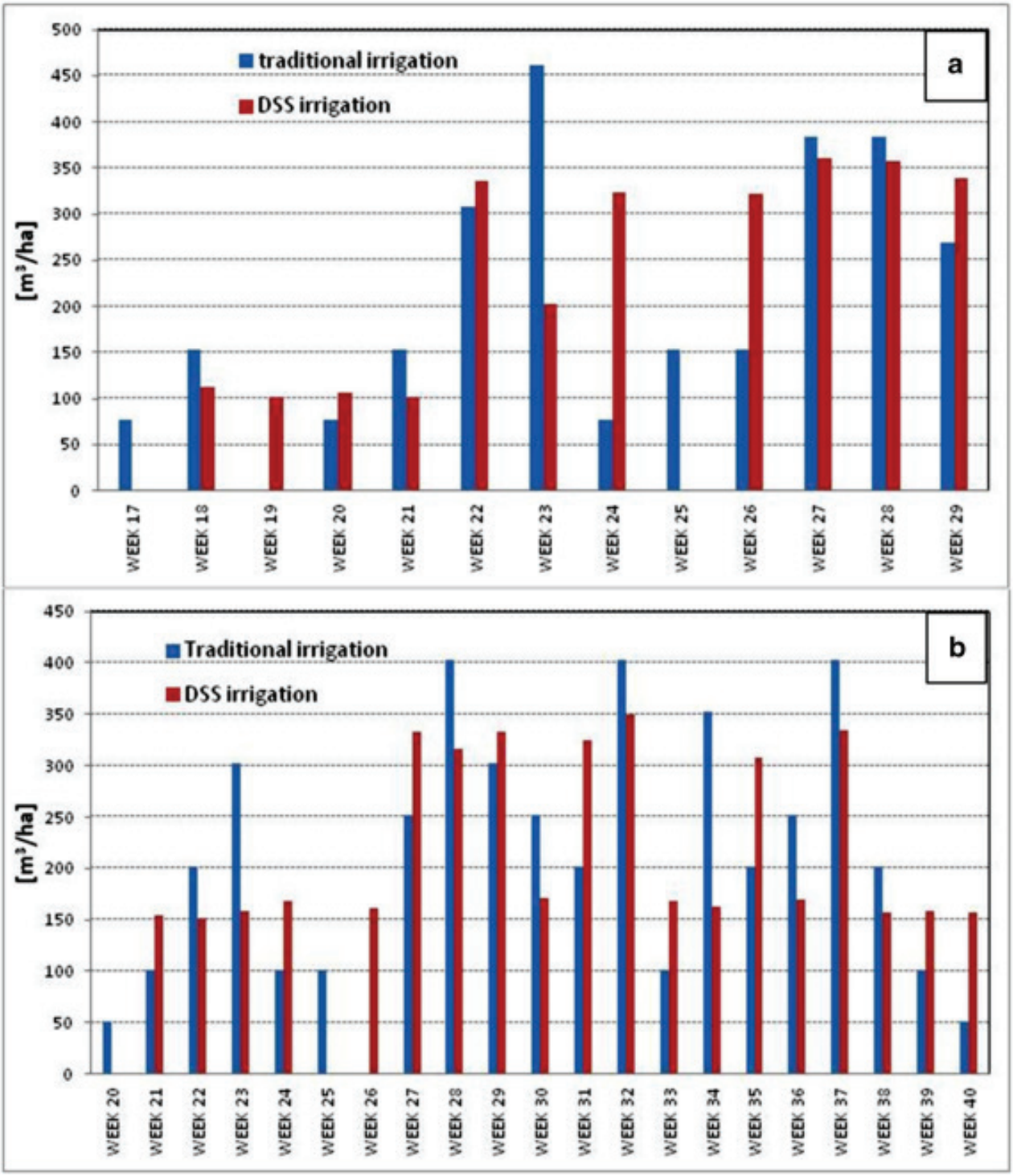
3. How does this technology contribute to sustainability?

4. How could this system be expanded to work at a larger scale? What changes would need to be made? Consider the water source, energy source, and so on.

Extensions

1. **Testing Variables:** Investigate the different methods of watering as a variable. Compare two of the same type of plant, but potted separately, for a couple weeks or months. Water one plant using the automated irrigation system and water the other the traditional way adding water manually when you think it is necessary or on a set schedule. Keep track of water use and plant growth, such as height of the plant and number of leaves. How does the amount of water for each compare? How do the plant growths compare?

2. **Analyzing Data:** Examine the charts that compare traditional irrigation and decision support system (DSS) irrigation for zucchini (a) and eggplant (b). The DSS irrigation system monitors the soil and provides information that can be used to make decisions about when and how much to water the plants. The amount of water used is displayed on the y axis in meters^3 per hectare (m^3/ha).



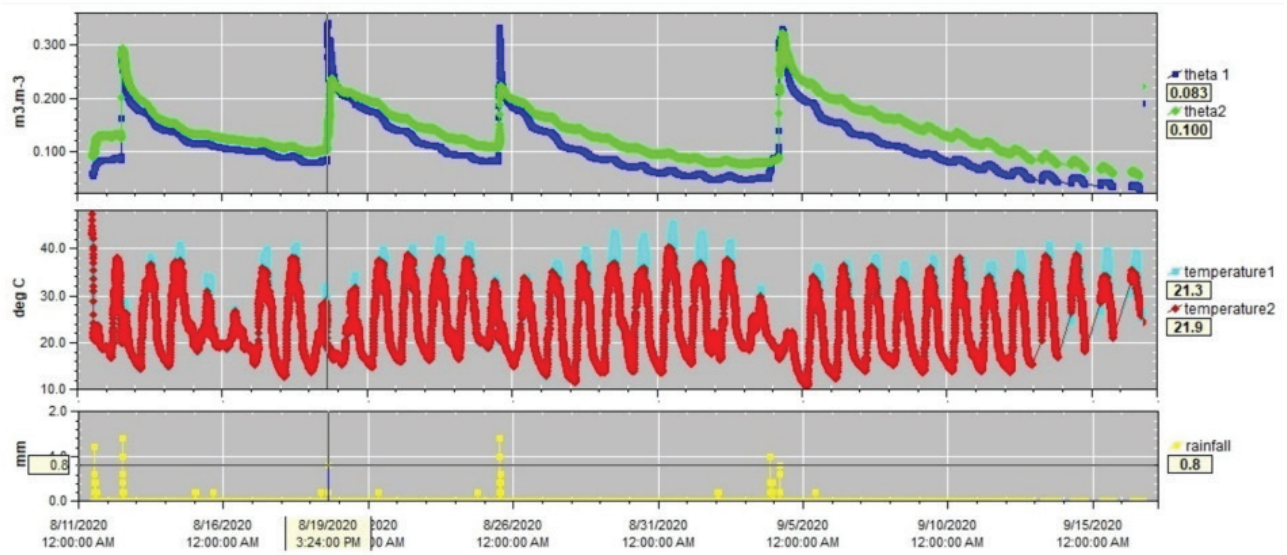
Credit: Casadei et al. 2021, https://link.springer.com/content/pdf/10.1007/s11356-021-12524-6.pdf

a. How are the charts for the zucchini (a) and the eggplant (b) similar? How are they different?

b. Which irrigation system uses less water in general? Why do you think?

3. Analyzing Data: Examine the graphs, "Data Collected from the DSS Irrigation System." The top graph displays data from two soil moisture sensors, the middle graph displays data from two temperature sensors, and the bottom graph displays data from a rain gauge.

DATA COLLECTED FROM THE DSS IRRIGATION SYSTEM



Credit: Casadei et al. 2021, **https://link.springer.com/content/pdf/10.1007/s11356-021-12524-6.pdf**

a. Looking at the graph of the moisture sensors, what do you think is happening in real life between August 11 and September 17?

b. Looking at the graph of the temperature sensors, what do you think is happening in real life?

c. Looking at the graph of the rain data, what do you think is happening in real life?

d. To use the DSS irrigation system, a farmer would receive data like this and then use it to make an informed decision about when to water plants. What date(s) do you think the plants were naturally watered (rain)? What date(s) do you think the farmer watered the plants?

4. **Applying Concepts:** Examine a map of your community and identify any locations that use automatic systems. Color code or label them and add them to the Map Key.

INVESTIGATION 8B: HYDROPONIC GARDENING

Learning Outcome: Build a hydroponic system to understand its components to analyze potential benefits and drawbacks.

Materials

Per group:

- 2 L bottle
- scissors
- measuring cup or graduated cylinder
- beaker or container to test water
- stirring rod or paint stick
- 2 cotton ropes or thin strips of cotton cloth, about 20 cm (8 inches) long
- plant bud of basil, a different type of herb, or similar plant that does not fruit or flower
- growing media like coconut coir, vermiculite, perlite,
- aluminum foil
- water
- hydroponic growing cups (optional) (**https://amzn.to/3OYPIfU**)

What to Do

1. Examine your 2L bottle and identify where it starts to curve near the top, about 10–15 cm below the mouth of the bottle. Draw a line and then carefully cut the bottle with scissors.

Credit: L. Brase

2. Test and treat your water.
    a. Using measuring cups or a beaker, measure the volume (mL) of water determined by the facilitator into the bottom of the 2L bottle.

b. Read the label on the nutrient mix and add the appropriate amount to the water. Stir with a stirring rod.

c. Using pH strips or a digital meter, measure the pH of the water.

d. Adjust the pH of the water using the appropriate pH adjusting solution, if needed. Read the instructions for the solution to determine how much to add.

e. Retest the water. If necessary, make additional adjustments using water or pH solution.

3. Set up the growing tray in the cut off top of the 2L bottle.

a. Put the top of the bottle upside down in the bottom portion of the 2L bottle.

Credit: L. Brase

c. String the wicks through the hole in the overturned top of the 2L bottle. Use tape to temporarily hold the wicks in place.

d. Add growing medium to fill the top of the bottle about 2/3 full. Remove the tape used to hold the wicks and arrange them in the center of the growing medium with the wicks just visible at the top.

Credit: L. Brase

e. Add the plant bud to the growing medium, positioning them so the roots touch the wicks.

f. Surround the plant bud with more growing medium to hold the plant in place.

Credit: L. Brase

4. Wrap the bottom section of the 2L bottle in aluminum foil. This will keep the sun off the water, which can stimulate bacteria or algae growth.

5. Place the 2L hydroponic system in the sun and watch your plant grow! Check the water every couple of days and refresh with water and nutrient mix as necessary. Gently remove the growing tray to replace the water in the system.

Consider

1. Think about what a plant needs to survive. How are those needs met for plants grown in a hydroponic system? How are the needs met for plants grown in soil?

2. How is a hydroponic system designed to eliminate the need for soil?

3. The roots of plants need water and oxygen to survive. How does the hydroponic system you built give the plant roots oxygen? How else could a hydroponic system be designed to add more oxygen to the roots?

4. Why do you think growing a plant in a hydroponic system is considered more sustainable than growing a plant in soil?

5. What are some potential drawbacks of growing plants in hydroponic systems?

6. What are some situations where growing plants hydroponically would be beneficial?

Extensions

1. **Testing Variables:** If you completed Investigation 8A, consider what you learned. How could the micro:bit be used with your 2L hydroponic systems? If you can, try out your idea!

2. **Testing Variables:** Compare the plant grown in a hydroponic system to a plant grown in soil. Plant a similar-sized bud of the same type of plant in a pot with soil. Place the potted plant and the plant in the 2L hydroponic system near each other in the sun and track their growth. Measure the height of the plant, measure the lengths of the leaves, and count the number of leaves. How do the plants compare?

3. **Testing Variables:** Take it a step further! Research and build an aquaponics system, which sets up a mutually supportive relationship of fish and plants. Fish waste provides nutrients for the plants and plants filter the water for the fish.

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

ESD KIT PROJECT: DESIGNING AN ENVIRONMENTALLY CONSCIOUS STORE

People buy many kinds of items including groceries, electronics, clothing, books, and many others. The production of goods and services people consume uses up raw materials from the Earth and releases greenhouse gases into the environment. Consumers and producers need to become more sustainably conscious to reduce the carbon footprint of the products people use. Sustainable producers promote sustainable consumers. A storeowner can help promote sustainability by offering more environmentally friendly options. The more changes made to work toward sustainability, the more this will become part of the general way people think, make decisions, and behave.

Assess a Local Store

Observe a local store or interview its owner to learn about their sustainability practices. Take notes of what they do and don't do, such as if they distribute products or if they are involved in the production of goods. Think about some suggestions of how the store could consume and produce more responsibly.

- Revisit the Investigations in this ESD Kit for help assessing the store.
- Fill out the handout "Assessing a Local Store" with your observations.

Investigation 2: Waste

- How does the store dispose of their waste?
- What sorts of waste does it produce?

- Do they have recycling bins?
- Do they compost?
- Do they dispose of hazardous materials (e.g., cleaning chemicals) properly?
- What do they do with excess food?
- How could they reduce their food waste and waste in general?

Investigation 3 and 4: Plastics and Packaging

- Is the store using recyclable materials? Is it using materials that have been or can be reused?
- How are the goods in the store packaged?
- Does the store ship products to customers or distribute to other stores? How does the store package their goods for shipping?
- How could the store reduce their packaging use?

Investigation 5 and 6: E-waste and Energy

- What electronics are used and/or sold in the store? How energy efficient are they? How often are they powered on and/or plugged in?
- Does the store have an e-waste disposal strategy?
- Does the store get its electronics repaired, or are broken electronics replaced?
- How often are electronics replaced?
- Are their electronics made locally? How far are they transported to the store?
- Does the store use electronic communication methods or hardcopies?
- How could the store reduce its carbon footprint?

Investigation 8: Cloth Items

- Does the store sell any textile merchandise such as clothing, fabric, upholstery, rugs, towels, and so on?
- Are employees required to wear uniforms? Where do they source the textiles from? How are they made?

Investigation 9: Plant Watering Systems

- Does the store display information how food or plants were grown? Are the food or plants sourced or grown locally?
- How do the food or plants stay watered while in the store? Is there an automatic system, or do store employees manually water them?

Design a Store

Using what you learned in the Investigations and your analysis from the local store in Part 1, make some decisions about the store you want to design and how it will improve sustainable production and consumption in your community. Consider the type of store, what items you will sell, what services you will offer, and other details.

Next, decide on your store's location. Examine a map of your community and decide on an ideal location for your store with sustainability in mind. You can choose a new location, or you can use the location of an existing store. Knowing proximity to waste centers, recycling centers, transportation hubs, and established shopping locations may influence your decision of where to set up your business.

Create a Business Plan

Create a business plan for your store that addresses the sustainability topics/questions brought up by each Investigation. Be sure to also include the following information:

- Name of your store or business
- What you will sell, produce, serve, etc.
- Operating hours
- Your intended clientele
- Number of employees
- How you will source your goods
- Whether or not you will include a delivery service
- Considerations for having a low carbon footprint
- Marketing campaign or slogan to promote your sustainable store
- Features that will make your store successful, especially if there are similar nearby stores

Present Your Business Plan

You can describe your business plan in various ways:

- written report
- a slide show
- an animated *Scratch*® presentation
- an oral presentation with visuals or a model, which may also be video recorded.

Assessing a Local Store

Store Name: _____
General Description:

OBSERVATIONS RELATED TO THE ESD KIT INVESTIGATIONS:

Investigation 2: Waste

Notes	Suggestions

Investigation 3 and 4: Plastics and Packaging

Notes	Suggestions

Investigation 5 and 6: E-waste and Energy

Notes	Suggestions

Investigation 8: Cloth Items

Notes	Suggestions

Investigation 9: Plant Watering Systems

Notes	Suggestions

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

APPENDIX 1: USING *SCRATCH*® WITH THE ESD KIT INVESTIGATIONS: TIPS AND TECHNIQUES

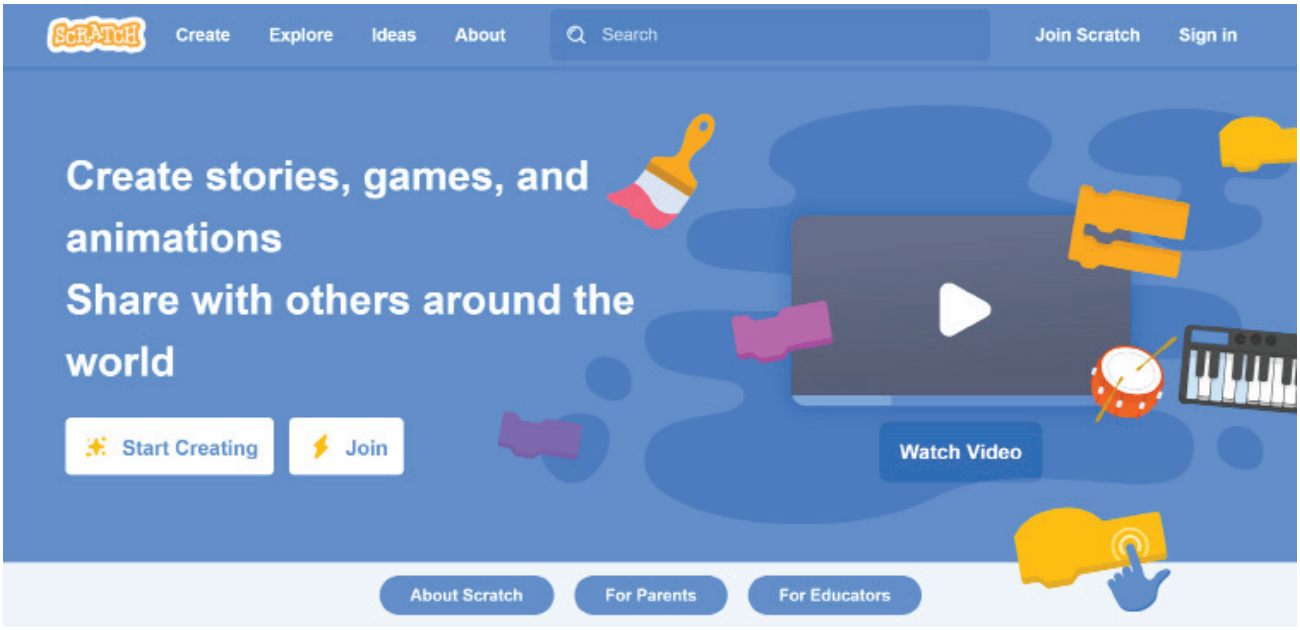
An important aspect of your work with ESD Kits is reporting and presenting the results of the Investigations and ESD Kit Project. This can be done in a variety of ways: written reports, slide shows, videos, and oral presentations. *Scratch*® is a highly recommended platform to report and present findings or designs for projects. *Scratch*® is a programmable learning environment that enables you to design and build your own interactive stories, games, and animations — and to share your creations with others in the online community. *Scratch*® is also a good vehicle for creative and interesting ways to visualize data. In the process, you will also learn how to code.

If you are not already familiar with the basics of *Scratch*®, first look at *Getting Started with Scratch*, which tells you how to set up an account on the *Scratch*® website and where to find introductory tutorials and guides. If you are familiar with *Scratch*®, skip ahead to *Tips and Techniques for Scratch* for how to work with *Scratch*® to share what you learn while working through the ESD Kit Investigations.

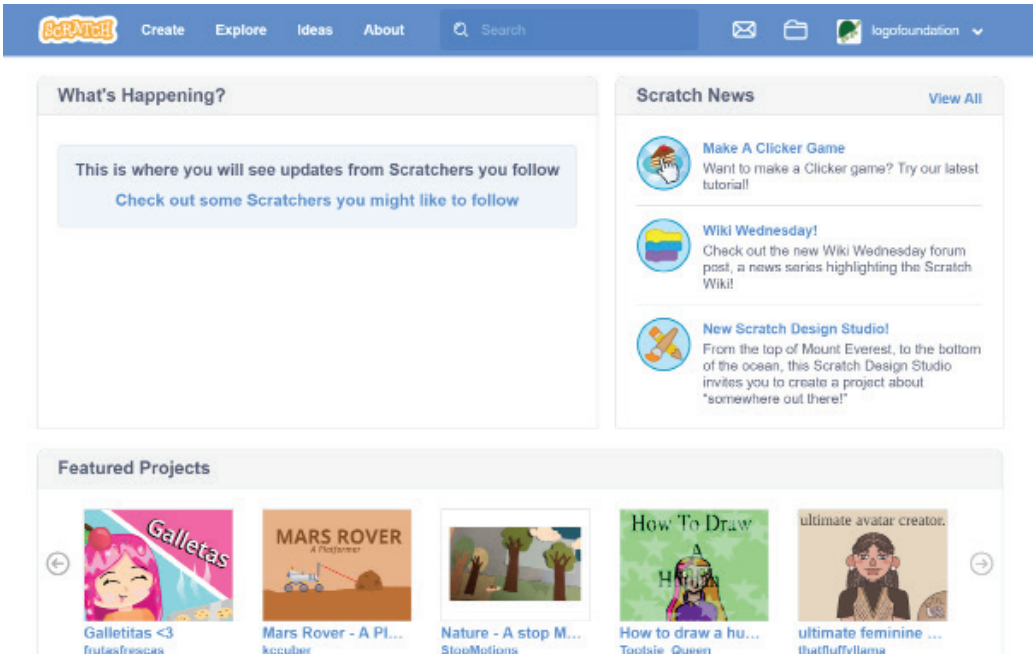
Getting Started with *Scratch*®

Scratch® works in your Web browser. There is no need to download and install an application. Your projects are saved automatically in the cloud. You can sign into your account from any computer and have access to everything you have created.

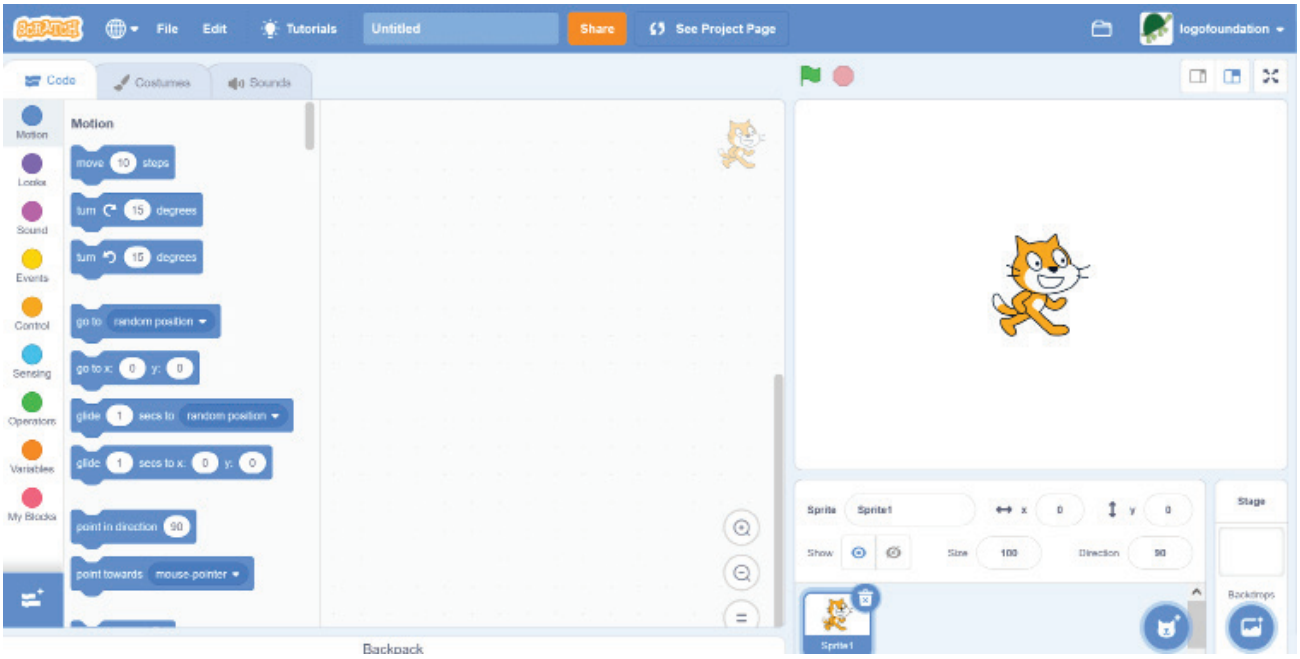
To get started, go to the *Scratch*® website: **https://scratch.mit.edu/** This is what you'll see:



You should first create your own account on *Scratch*® so that you can save your work and share and communicate with other Scratchers. Click the **Join** button at the lower left or **Join Scratch** at the upper right. Follow the steps to set up your account. Once you are signed in, the *Scratch*® homepage will look something like this:

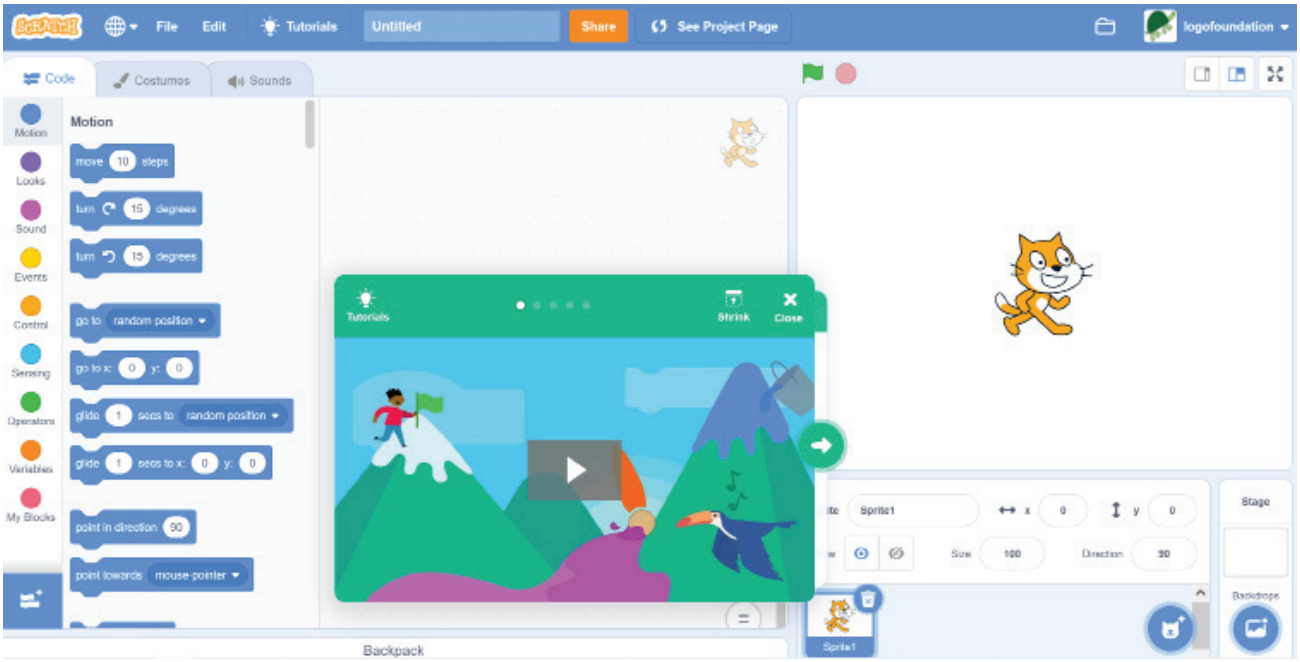


Your username appears at the upper right. You can browse the **Featured Projects** and other projects that appear as you scroll down the page. To get started yourself, click on **Create** at the upper left. This will take you to the *Scratch*® Editor. Your screen will look like this:



You can watch a brief video that shows some of the many things you can do with *Scratch*®. You can also jump right in by clicking on **Create** at the upper left or **Start Creating** at the lower left. This will bring you into the *Scratch*® Editor with an introductory tutorial running.

Click on **Tutorials** at the top of the page to go to a page with links to more than two dozen tutorials that will get you started with *Scratch*®. Each one appears in a window over the Editor.



You can stop and start, and back up as you need to. As you follow the tutorial, you will create your version of the project in the *Scratch*® Editor. Initially it will be called Untitled. You can click on the name and change it. It will automatically be saved in your *Scratch*® account.

More Resources

In addition to the resources on the *Scratch*® website, the *Scratch*® Wiki **https://en.scratch-wiki.info/** has a great deal of information about *Scratch*®.

The *Scratch*®ED website at **https://scratched.gse.harvard.edu** is an archive of documents and projects created by *Scratch*® Educators.

For very young children there is *Scratch*® *Jr*, which you will find at **http://www.scratchjr.org/**. You may download and install it on your iPad or Android tablet. There is also a version for Chromebooks.

Scratch® Tips and Techniques

Putting on a Show

You can think of your *Scratch*® program as a theater. Your screen is the stage, and the backdrops are the scenery. The actors in your show are called sprites. They can wear a variety of costumes, move around, talk, sing, and interact with each other. Your show can have several scenes. To change from one scene to another, you can write the program to change the backdrop, hide characters that won't appear in the next scene, and get new characters to appear.

Working with Images

There are dozens of backdrops for the stage and costumes for the sprites that are built into *Scratch*®. You can choose which ones you want to use. You can also import images into *Scratch*®. These can be your own photos or images produced using other applications or downloaded from the internet. There is also a Paint Editor that you can use to draw backdrops and costumes or to alter existing images.

Visit this page for more information about using images in *Scratch*®: **https://digitalmaestro.org/articles/prepare-images-for-use-in-scratch-code-projects**

Displaying Text

One way to include text in your project is to use the paint program to create or modify a backdrop for the stage, or a costume for a sprite. Click on the letter T and then click where you want to begin your text. This creates a text box where you can type your text. You can also paste text that you have copied from another application. Once you have written some text, you can select the text box with the pointer icon to resize, move, or rotate it. If your text is on a sprite costume, you can make it move around by programming the sprite to move. Text on backgrounds or costumes will remain on the screen until the scene or costume changes.

Another way to use text is to use the **say** or **think** blocks. These can be found in the "Looks" tab to the left of the *Scratch*® program. These will display comic book style balloons with text in them next to your sprite. You can also choose how long these balloons appear, and you can program as many as you want to use in a scene.

Sounds

Using the Text to Speech extension, a sprite can say what you type into the **speak** block.

Scratch® can also play recorded sounds. These can be music, sound effects, and spoken words. You can record music or your own voice in *Scratch*® and then play it as part of your project. To do this, click on the Sounds tab, then on Choose a Sound, then on the microphone icon.

In addition to recorded music, there is a music extension that you can use to create melodies note by note, to be played by a variety of online instruments.

Working with Data

When trying to understand the significance of some data, it is helpful to have a visual representation rather than just a list of numbers. We often see line and bar graphs, pie charts, and other diagrams used for this purpose. For example, look at *Investigation 4: Understanding Our National Energy Mix* and *Investigation 7B: Logging Temperature Automatically Using a micro:bit* where data is used to create graphs. *Scratch*® can be used to draw graphs, but it also adds the ability to create a wider range of visual representations of data that can also be dynamic and interactive.

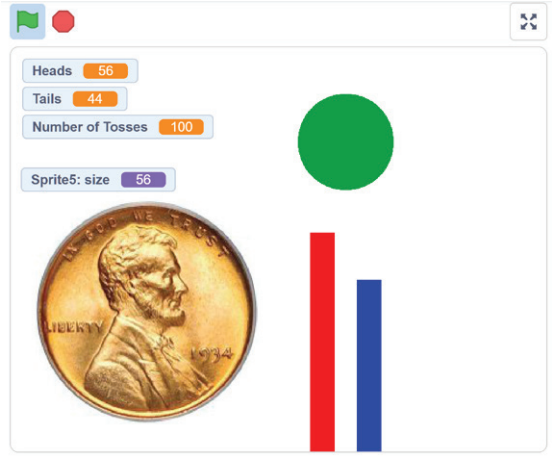
For example, look at the *Scratch*® project Coin Toss: **https://scratch.mit.edu/projects/486312136/**

It uses the **pick random** block to simulate tossing a coin 460 times. It creates a graph showing the percentage of heads as the tossing progresses. The graph looks different each time the program is run, but the following image is typical. In *Scratch*®, you can watch this emerge as the graph is drawn in real time.

Another coin tossing project is Coin Toss Visualization: **https://scratch.mit.edu/projects/2207857/**

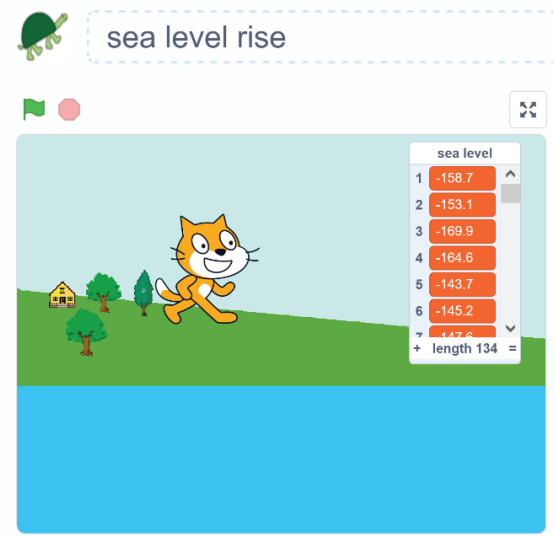
The coin is flipped 100 times and the visual representations of the proportions of heads and tails emerge dynamically. In addition to a bar chart, the size of the green circle increases and decreases based on the percentage of heads up to that point.

In addition to visualization, there is sonification. The pitch of a note played on a virtual piano reflects the percentage of heads.

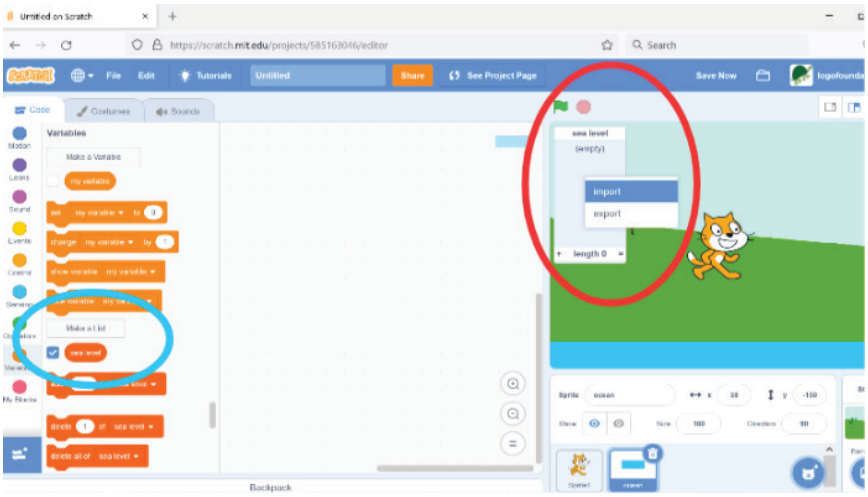


In the coin tossing projects, the program generates the data for the visualizations. You can also bring outside data into a *Scratch*® project.

The sea level rise project at **https://scratch.mit.edu/projects/585163046/** uses global mean sea level data for the years 1880 to 2014 from the **Climate.gov** website. To bring this data into *Scratch*®, we first download it from **Climate.gov** as a .csv file (Microsoft Excel). We then create a list named "sea level" and imported the data into it. Here is how to do that:



Go to the variable section of the code tab and click on Make a List. Give the list a name. The list appears on the stage. (You can make it invisible by unchecking the blue box next to the name.) Now right-click on the list and you will see the option to import or export data. Click input and then select the .csv file you want to import. You can only import one column of a .csv file into the list. If there are more columns in the file, *Scratch*® will ask you which one you want to import. The sea level data file from Climate.gov has three columns. The second column has the data we need on sea level.



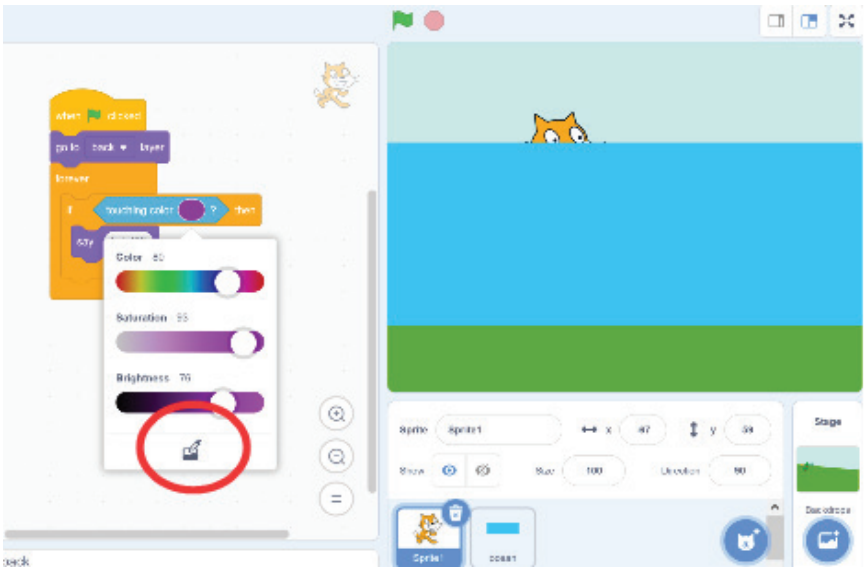
Once the data is imported, you may have to do some touching up. Often a .csv file will have a label in the first row of each column. This label will be imported into the *Scratch*® list along with the data below it. To remove this label and leave only data in the list, click on that first item. An X will appear in it. Click the X to remove the item.

Now the list of sea level data is ready to use. Create a variable named “pointer.” This is used to step through the list of data one item at a time. The Y coordinate of the ocean sprite is set to each value of the sea level data in turn until the end of the list is reached.

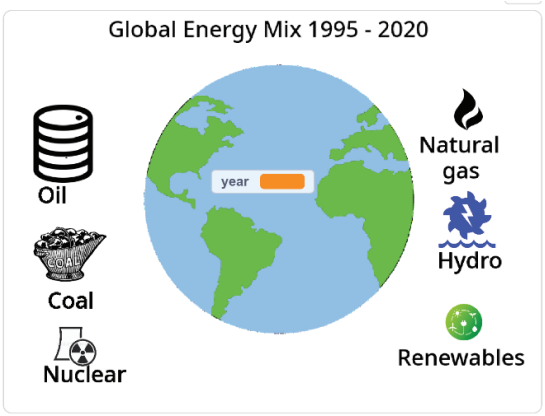
To see more about how the program works, go to the code tab of the ocean sprite, and look at the comments attached to the code for an explanation.

The cat is also programmed to cry out for help as the sea level rises and touches her. The code looks to see if the cat is touching the color blue (the sea) and causes the cat to say “Help!!!” when that happens. Look at the code tab of the cat sprite to see that program.

To get the correct color into the **touching color** block, click on the color oval in the block and then on the color picker icon below the sliders. Then click on the color that you want to pick up. In this case, that’s the blue of the ocean sprite.

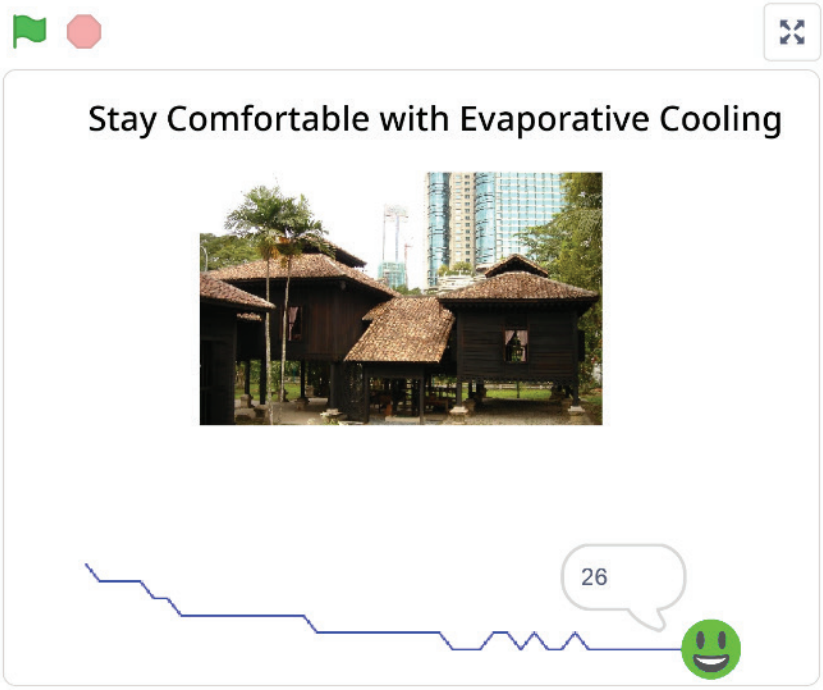


Investigation 4: Understanding Our National Energy Mix looks at the distribution of different energy sources over time. The data are represented by line graphs. The *Scratch*® project *Global Energy Mix* **https://scratch.mit.edu/projects/573662932/** visualized that same data by increasing and decreasing the sizes of icons representing each energy source. You can remix it to use your own icons. You could extend the time frame so as to include projections of the energy mix in the future.



In *Investigation 7B*: ***Logging Temperature Automatically Using a micro:bit***, temperature data will be logged using a micro:bit. The data, when downloaded from the micro:bit as a .csv file can be used to make a graph or *Scratch*® program. Using Excel, we can create a line graph in the .csv file, showing the change in temperature under a damp clay flowerpot over a period of 47 minutes.

The *Scratch*® project *Evaporative Cooling* (**https://scratch.mit.edu/projects/574196032/**) uses that data to draw a line graph in a somewhat different way.

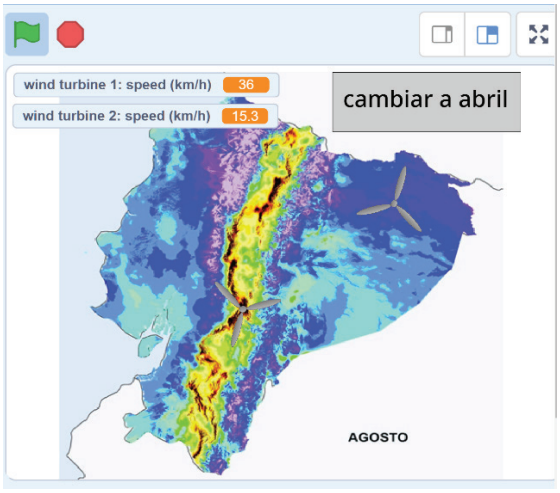


Making Your *Scratch*® Project Interactive

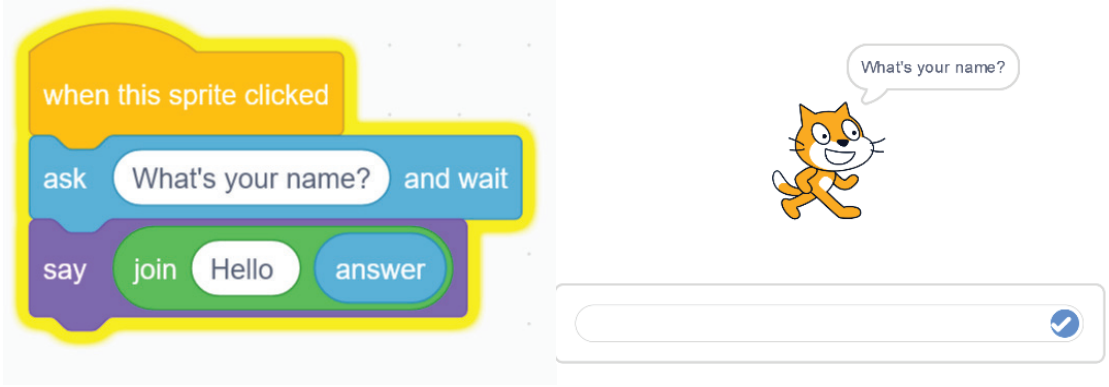
Anyone who uses an interactive *Scratch*® program can affect the course of action, what appears, and the sounds, voices, and music that are heard. Here are some examples:

Exploration 3B1: Locating Wind Energy shows how the potential for wind power in Ecuador varies from one location to another. In the *Scratch*® project Ecuador Wind Power (**https://scratch.mit.edu/projects/579828042**), the colors on the map indicate average monthly wind speeds. There are two sprites in the shape of wind turbines that can be dragged around the map. They are programmed to detect the color they are touching and set the wind speed accordingly. These values appear at the top of the screen. To actively visualize the data, the wind speed variables determine how rapidly each wind turbine spins.

Sprites can be programmed to detect color or other sprites. They can respond to a mouse click. They can be dragged with the mouse or by using specific keyboard keys. Other keypresses could be programmed to trigger other actions.



The **ask** and **answer** blocks allow you to prompt the user for a response and take action based on what they type into the dialog box that appears.



Here, the cat asks, “What’s your name?” When you type in your name and click the check box, the cat replies with “Hello” followed by your name.

You can use this feature to determine the flow of your program. For example, you could create a project where you ask whether the user wants to learn more about Coal or Gas. The response could trigger a switch to an appropriate backdrop and start a flow of information and actions on the chosen topic.

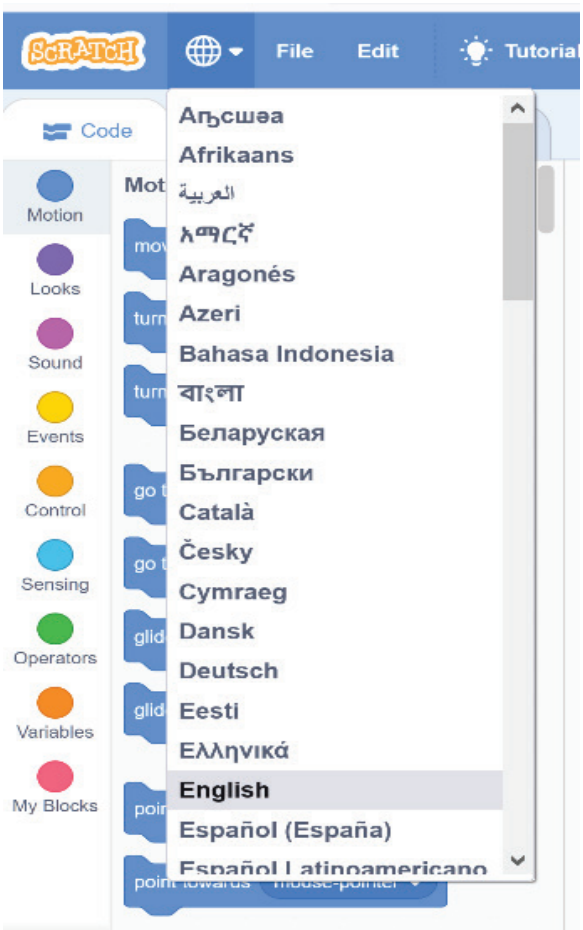
Look at the Sensing section of the Blocks Palette for some additional ways to make your *Scratch*® project interactive.

Changing Language

Scratch® supports many languages. Click on the globe icon in the upper left corner and you will see a list of the available languages. When you select one, the text on the code blocks, the menu items, and other text elements of the *Scratch*® user interface change to that language.

This makes it possible for Scratchers worldwide to work in their own language. It is also useful when looking at a project that someone has created with *Scratch*® set to a language other than your own. You can switch to your language and the code blocks will change so that you can better understand the project.

This feature does not change the text that the user has written on backdrops or sprite costumes, or text written into the **ask**, **say**, or **think** blocks. There is a separate translation extension to change these features.



Scratch® Extensions

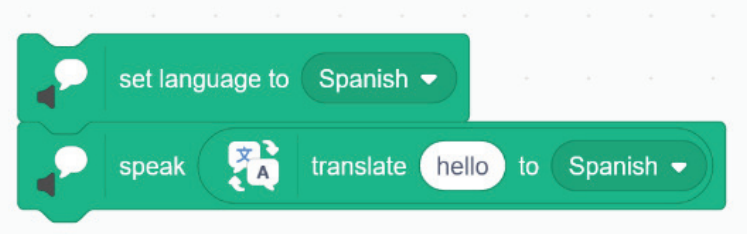
A *Scratch*® Extension is a collection of code blocks for a specific purpose. The Pen extension enables Sprites to draw lines as they move. This is used to draw line graphs in the Evaporative Cooling and Coin Toss projects shown above. The Coin Toss Visualization project uses the Pen extension along with the music extension.

To use an extension, click the icon at the lower left of the *Scratch*® Screen. This brings you to a page where you can select the extension you want to load.

There is an extension for micro:bit which allows *Scratch*® to respond to various movements of the micro:bit as well as the pressing of the buttons on the board.

With Video Sensing, *Scratch*® responds to movements picked up by the computer's camera.

Text to Speech produces audible speech of the written words you type into the speak block. Translate take the text you type into the translate block and reports it translated into the language you specify. It's interesting to use these two extensions together. With the code at the right, you will hear *Scratch*® say "Hola."



Sharing and Remixing *Scratch*® Projects

There are millions of projects shared on the *Scratch*® website. Examining these projects is an effective way to learn more about *Scratch*® programming and project building, as well as about the content conveyed in the projects.

When you first create a *Scratch*® project, it is private so that only you can see it. You can share it so that everyone else who visits the *Scratch*® website can also view it. In either case, only you can make changes to it. But *Scratch*® also allows you to remix someone else's project, making a copy of it for yourself. Here is how that works:

Sign into your *Scratch*® account and go to a project you are interested in. You will see a green "Remix" button at the top of the Projects Page. When you click this, a copy of the project will be saved in your account. It will have the same name as the original project with the word "remix" added at the end. There will be a message at the top of the Projects Page crediting the author of the original.

You are now free to alter it, add to it, use parts of it in another project of yours. You can share your resulting project. For more information about remixing, look at: **https://en.scratch-wiki.info/wiki/Remix**

Additional *Scratch*® Projects Related to the ESD Kits

Here are some examples of Projects created by *Scratch*® users and shared on the *Scratch*® website that relate to the themes of the ESD Kits. You can search on the *Scratch*® website using terms such as "wind power," "water quality," or "renewable energy" and you will find many more.

You can search for Projects or Studios. A *Scratch*® Studio is a collection of Projects that are related to each other in some way. Any *Scratch*® user can set up a Studio. If you search for "renewable energy" you will see Projects related to that theme. If you click the Studios tab, you will see Studios with collections of Projects on that theme. If you click on one of them, you will see the Projects in that Studio.

Wind Power

https://scratch.mit.edu/projects/15858581/
This is an interactive report on wind power and other sources of energy used to produce electricity.

Wind Power Grids

https://scratch.mit.edu/projects/718595
An overview of US Wind Power electric power grids.

The Story of Energy

https://scratch.mit.edu/projects/1021089
This interactive story of energy includes four games focused on using renewable energy sources and reducing energy consumption.

Solar Panel

https://scratch.mit.edu/projects/11732/

This *Scratch*® project presents the case for increased use of solar panels to generate electricity.

Protect our water quality!

https://scratch.mit.edu/projects/437778501/

This animated tutorial on water quality is followed by a brief quiz.

Water Quality

https://scratch.mit.edu/projects/299820109/

This is an interactive presentation about water quality with a quiz at the end.

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

APPENDIX 2: ABOUT MICRO:BIT

The micro:bit is a microcontroller that connects with a wide range of sensors and output devices and is programmed by connecting it to a laptop, tablet, or smartphone. It is designed for use in education and is widely available in many countries. Visit the micro:bit Foundation website at **https://microbit.org/** for all the information you need to get started. Click the Get Started tab on the homepage for tutorials on how to set up and program the micro:bit. To obtain a micro:bit, click the Buy tab on the homepage to locate a distributor in your country.

For activities that include data logging, you will need a micro:bt V2, which is the current version. To become familiar with how data logging works, go to **https://microbit.org/get-started/user-guide/data-logging/.**

The micro: bit is a good choice for ESD Kit Investigations and projects for several reasons. It is

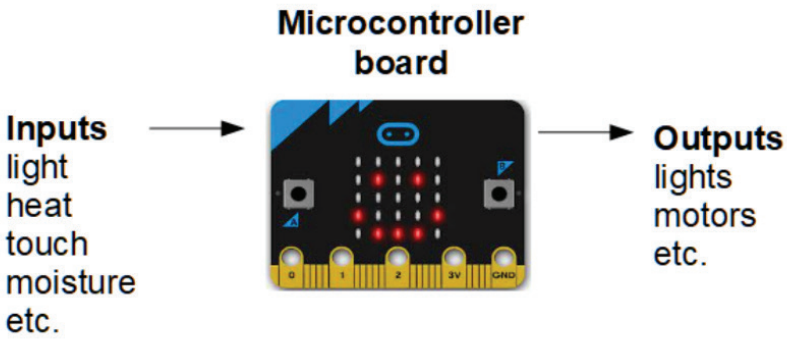
1. designed for education and has extensive support for teachers and students,
2. relatively low cost, and
3. widely available around the world.

Also, micro:bit has sensors built into the board itself, including temperature and light. Additional external sensors may be connected to it. The current version (V2) can be used for data logging.

An alternative to micro:bit is Arduino **https://www.arduino.cc/**, a family of similar microcontrollers. They are also widely available and well-supported.

More About Microcontrollers

A microcontroller is a device that takes inputs from sensors and acts upon them to control various devices. They are found in many appliances including microwave ovens, heating and cooling units, and automobiles.



Credit: Logo Foundation

Here are some examples of how a microcontroller can be used with sensors and output devices:

Light sensor ► turn lights on at night, off during the day

Temperature sensor ► turn a fan on when it's hot, off when it's cool

Moisture sensor ► turn irrigation water on when the ground is dry; off when moist

Microcontrollers can also be used to record sensor data over time. For example, you could record temperature at one-minute intervals over a period of 24 hours and then use the data in a graph or other visual representation.