SUSTAINABLE DEVELOPMENT GOALS

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Education for Sustainable Development Kit: Consuming Sustainably

Sustainable Development Goal 12: Responsible Consumption and Production

Facilitator Guide

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Facilitator Guide

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ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

INTRODUCTION

ESD Kit Strategy

Young learners can be inspired to take an active role in promoting sustainable development in their communities. The Next Generation (NextGen) ESD Kits will help learners build knowledge about important topics that affect all communities and individuals. Unlike past versions of ESD Kits, which were developed as stand-alone activities, ESD Kits are designed to promote sustained attention to a topic and the development of multi-faceted understanding.

Each kit consists of Investigations that are presented in a variety of engaging formats. The focus topics addressed in the ESD Kit Investigations are closely aligned with the United Nations Sustainable Development Goals (SDGs) on which each kit is based. The knowledge that learners develop about the SDGs will bring light to local issues and will prepare them for community awareness and engagement.

UN Sustainable Development Goal (SDG) → **Learning Experiences: Investigations & Project** → **Community Awareness & Engagement**

The first four ESD Kits are currently in development. Each focuses on one SDG:


SDG 6: Clean Water and Sanitation


SDG 7: Affordable and Clean Energy


SDG 12: Responsible Consumption and Production


SDG 13: Climate Action

Learning outcomes for the kits address ideas in the SDG targets, as well as the relevant UNESCO **Education for Sustainable Development Goals: Learning Objectives**.

Learning Progression

Each ESD Kit provides multiple opportunities for learner engagement across a range of learning styles, interests, and skill levels. Each kit starts with an Investigation in which learners reflect on their own relationship with the topic of the SDG — such as their energy use or how they may be affected by climate change. In the remaining Investigations learners will explore different aspects of the topic. The activities in the ESD Kits may make use of one or more active learning approaches, including:

- Hands-on learning
- Data-focused analysis
- Computer coding by designing or repurposing projects in *Scratch*®
- Applications of microprocessors for sensing and control, and for data logging
- Strategies for communicating with others about ideas, problems, and solutions

Across these approaches, learners have opportunities to practice 21st Century Skills such as critical thinking, communication, and information literacy. Each ESD Kit includes a project that allows students to synthesize ideas, relate them to their community, and share them with peers.

Materials

The ESD Kits are designed to be implemented across the world, using materials that are expected to be readily accessible in different international contexts. The material lists in the facilitator guides include specific details about the items to be used. Whenever possible, Investigations use materials and supplies that are familiar and easy to acquire locally. Investigations using more technical items, such as microprocessors, also provide less technical options that address the same concepts.

Uses of *Scratch*® and Microcontrollers

The ESD Kits incorporate the use of *Scratch*®, a widely available, free programming environment that is implemented in dozens of languages and has user support documentation available in many of them. In the ESD Kits, coding is also used with microprocessors (e.g., micro:bit) to support two broad focus areas — technological literacy and creative self-expression.

Computer-based technologies affect every person and society in ways that are direct and other ways that are indirect. Citizens of the future need to understand basic computer processes such as coding to control and automate systems. This understanding is an important aspect of technological literacy and is a foundation for further learning in computer science and other technologically sophisticated fields.

As well, *Scratch*® provides an open-ended but well-supported set of tools for learners to model, explore, and present their ideas about the topics they are learning about in the ESD Kits in creative and technologically advanced ways. Included are many examples of *Scratch*® projects that can inspire learners and/or be the basis of their own work. Presentations provide a way for the learners' ideas to be clarified, validated,

and appreciated by a range of audiences, including their peers, their parents, and other community members.

Extensions

Each Investigation has at least two Extension activities that build on or supplement the concepts covered as learners complete the procedure and analysis questions. There are four categories of Extension activities. *Testing Variables* allows learners to explore additional variables that could be tested within the procedure or a related experiment. *Analyzing Data* has learners describe and explain trends in graphs, maps, and data tables. *Applying Concepts* asks learners to use the main concepts covered in the Investigation to make sense of other phenomena, technologies, or issues. Lastly, *Using Scratch* gives learners ideas for how to make interactive computer-based presentations, stories, and games related to the Investigations. The Extensions are meant to give learners a more complete understanding of the concepts covered. Although they are optional, they are highly recommended.

Facilitator Support

The ESD Kits have been developed by experienced educators and curriculum designers to provide the support needed for facilitators to be successful. At the same time, the guidance in the kit is flexible enough to allow facilitators to respond to their learners and communities by adapting Investigations — such as by accessing locally relevant data, applying ideas to examples that are known to the children, and providing opportunities for learners to creatively express their own ideas in multiple formats, including through *Scratch*® programming.

The facilitator support includes such key elements as:

- An overview that briefly presents key concepts and descriptions of each Investigation.
- A master list of materials, organized by Investigation.
- Detailed step-by-step guidance for facilitating learner participation in each Investigation.
- Photographs of key stages within Investigations.
- Conceptual background needed to guide learners.
- A pacing guide to help facilitators estimate the time each Investigation may take.
- Extension opportunities, guidance connecting each Investigation to the project.
- Questions to consider with learners--and possible responses.
- "Notes for the Facilitator" that point out instructional options and fine points.
- Guidance on the use of microprocessors and *Scratch®.*

With these support features, facilitators will find the ESD Kits useful to inspire the next generation of community problem solvers, whether or not they've worked in education and outreach before.

Partnership Model

ESD Kits will be implemented by Schlumberger employees working in collaboration with partners in their locations. These partners may come from a variety of areas of expertise and may play any of several

roles in the implementation. Examples of partnerships include:

- Educators in the community facilitating specific ESD Kit Investigations, or whole kits.
- Specialists working in areas of the community related to the ESD Kit, such as managers of local water facilities (SDG 6), power plants (SDG 7), retail shops (SDG 12), architectural design firms (SDG 13), to offer learners a real-world perspective on the dynamics of the topics as they affect the learner's community.
- Community members/organizations working on projects that make positive changes in the community that relate to one or more of the SDGs (e.g., recycling).

Inspiring Action

Overall, the intent of the ESD Kits is to inspire and enable young people to take action in their homes and communities. Through active learning, effective facilitation, and strong community partnerships, the ESD Kits can play a role in building a positive and sustainable future for all.

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

TABLE OF CONTENTS

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

OVERVIEW FOR THE FACILITATOR

In this ESD Kit, learners will explore aspects of consumption and production that play a role in their lives and communities. This ESD Kit focuses on the Key Concepts of the *Targets and Indicators* within **Sustainable Development Goal (SDG) 12**: Ensure sustainable consumption and production patterns.

In this ESD Kit, consumption and production are explored through the lens of the consumer and described as interrelated, with consumption influencing production. Topics explored in this ESD Kit include what consumers can control, such as evaluating the sustainability of products, exploring more sustainable uses of materials and products, and disposing of products safely. Most of the attention in the ESD Kit is on consumption and strategies to be a more sustainable consumer.

Hands-on Investigations are used to explore aspects of consumption and production found in learners' daily lives, such as waste production and energy use. Data-focused Investigations are used to call attention to broader features of consumption and production, such as the availability of natural materials. Some Investigations also include opportunities to use technologies for sensing and coding, using the coding language *Scratch*®.

ESD Kit Project: Design an Environmentally Conscious Store

Learners will complete Investigations to learn about consumption and production. They will then complete a culminating ESD Kit project in which they will use what they have learned to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. Learners will prepare a presentation that outlines the decisions they made about design features of their store, and the rationales for those decisions. Their presentation will relate the features of their store to Key Concepts of SDG 12.

Key Concepts

Several Key Concepts for this ESD Kit have been summarized from the SDG 12 Targets and Indicators. Added to those are other Key Concepts that students will need to know to understand fundamental ideas about consumption and production. The Key Concepts for this ESD Kit are: *e-waste, environmentally sound technologies, footprint, fossil fuel, hazardous waste, material consumption, per capita, recycling, sustainable consumption, sustainable production.*

Investigation Descriptions

Key concepts are in italics.

1. Material Goods Around Us. Key Concepts: *material consumption, recycling*

Learners describe material goods around them and at their home to consider *material consumption*. They consider if each item is temporary or permanent, how long they would expect to use each item, and how they might dispose of each item. Discussions of learners' ideas along with the four R's — refuse, reduce, reuse, and *recycle* — will begin connecting consumption and production to learners' daily lives. The United Nations' Sustainable Development Goal 12 is introduced as an overarching theme of the ESD Kit, which looks at how people can consider consumption and production habits to reduce the amount of raw materials they use as well as the amount of waste they produce.

2. Modeling and Assessing Types of Trash Storage. Key Concepts: *environmentally sound technologies*

Learners will build a model landscape where waste is stored to study how materials can potentially pollute groundwater. They will then modify the waste storage landscape to show how the use of more *environmentally sound technologies* reduces human impact on the environment.

3. Plastics Around Us and in Aquatic Environments. Key Concepts: *recycling, footprint*

Learners compare plastic items to learn about the different types of plastics, their possible *footprint*, and what types can be *recycled* in their community. They also will explore the densities of different plastics and whether a type of plastic floats or sinks in water. Impacts of plastic pollution to marine life will also be considered.

4. Packaging Assessments. Key Concepts: *footprint, recycling, sustainable consumption, sustainable production*

Learners assess how goods are packaged and explore ways the environmental *footprint* of the packaging can be reduced, such as *recycling*, to enhance *sustainable production.* Specifically, learners will compare the packaging from an item sold in bulk to the same item packaged as single-serve and consider their choices

for *sustainable consumption.* A facilitator demonstration adds a math component where learners can conduct a cost comparison for a single serve versus bulk item.

5. Electronics and E-Waste.
Key Concepts: *e-waste, hazardous waste, per capita, recycling, sustainable consumption*

Learners consider the electronics they would have in their dream home and think about the lifetime and disposal of those items. The facilitator will introduce *sustainable consumption* and disposal habits such as repairing broken electronics, *e-waste* disposal, and *recycling*. Various data is provided to support a broader examination of e-waste on a global scale, including *per capita* data. Facilitators have the opportunity to find local data for learners to analyze. Learners will also examine data about materials that are found inside electronics and are often considered *hazardous waste*.

6. Carbon Footprint and Energy Efficiency.
Key Concepts: *e-waste, footprint, sustainable consumption, sustainable production*

Learners analyze their carbon *footprint* and consider changes they can make for more *sustainable consumption* practices. They will then explore the efficiencies of different types of light bulbs using a micro:bit to gather evidence as to why certain designs are better in terms of *sustainable production* and *consumption* and which types of bulb may contribute less to *e-waste*.

7. Analyzing Natural and Synthetic Materials in Fashion.
Key Concepts: *footprint, fossil fuel, hazardous waste, material consumption, sustainable consumption, sustainable production*

Learners conduct a variety of hands-on experiments to compare natural and synthetic fabrics and dyes. From their results, learners will consider which materials produce less *hazardous waste* and are better in terms of *sustainable production* and *consumption*. Global data is presented about the carbon *footprint* of the fashion industry as it relates to the rate of *material consumption* and the use of *fossil fuels* for production of fabrics.

8. Irrigation Systems.
Key Concepts: *environmentally sound technology, footprint, material consumption*

Learners will build an automated irrigation system using micro:bit for a houseplant and a hydroponic system for basil as two examples of *environmentally sound technologies* that can reduce carbon and water *footprints* and *material consumption*.

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

MASTER LIST OF MATERIALS

Investigations are intended to be completed in small groups. Materials used in multiple Investigations are marked with asterisks.

Materials by Investigation:

Investigation 1: Material Goods Around Us

Per learner:

- "Items in Your Homes" handout

Investigation 2: Modeling and Assessing Types of Trash Storage

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)
- 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)◊
- Simulated trash (3 scoops)

Simulated trash

- waste generated by facilitator
- colored crepe or tissue paper, preferably red or blue
- baking soda
- *Also used in Investigation 3B

**Also used in Investigations 3B and 7A1

†Also used in Investigations 7A2

‡Also used in Investigation 8A

§Also used in Investigations 3A and 7A2

◊Also used in Investigation 8A

Investigation 3A: Plastics Around Us

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

*Also used in Investigations 2 and 7A2

Investigation 3B: Plastics in Aquatic Environments

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

For Facilitator Demonstrations:

- clear beaker†, or similar
- 3 cups
- spoon
- food coloring*
- salt or sugar

- water

*Also used in Investigation 2

**Also used in Investigation2 and 7A1

†Also used in Investigation 7A1 and 8A

Investigation 4A: Assessing How Items Are Packaged

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.)

Investigation 4B: Comparing Food Packaged as Single Serve Versus in Bulk

For Facilitator Demonstration:

- two identical large paper or plastic bowls
- three-hole punch or screwdriver
- wooden dowel rod, at least three times the length of the large bowls used.
- thin wire or string
- duct tape or similar
- ring stand* or similar
- 1 bulk item and many single serve items, different item than learner portion of the Investigation
- reusable containers (if not consuming opened food items)

For Learner Investigation:

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)

*Also used in Investigation 7A1

Investigation 5A: Electronics in a Home

Per learner:

- drawing or graph paper; or printed floorplan

Investigation 5B1: E-Waste

Per group:

- data sheet for your country

Investigation 5B2: Analyzing E-Waste from Your Country

Per group:

- data sheet for your country

Investigation 5B3: Inside E-Waste

Per group:

- copies of enlarged images from Investigation (optional)

Investigation 6A: Assessing Your Carbon Footprint

Per Learner:

- "Assessing Your Carbon Footprint" handout

Investigation 6B: Testing Light Bulb Efficiency Using a micro:bit

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

*Also used in Investigation 8A

Investigation 7A1: Natural Versus Synthetic

For Facilitator Demonstrations:

- fume hood or a well-ventilated area
- small, 2 cm x 2 cm (about 1" x 1"), pieces of fabric used in the Investigation
- long tongs or a ring stand‡ and clamps
- matches or a lighter
- glass or plastic containers (1 L beakers†, large food containers, etc.), one for each fabric used
- potting soil**
- water

For Learner Investigation:

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)

*Also used in Investigations 2 and 3B

**Also used in Investigation 2

†Also used in Investigations 3B and 8A

‡Also used in Investigation 4B

Investigation 7A2: Analyzing Dyes

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 glasses
- gloves*

*Also used in Investigation 2

**Also used in Investigations 2 and 3A

Investigation 7B: Understanding How the Fashion Industry Impacts the Environment

Per Learner:

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

Investigation 8A: micro:bit-Controlled Automatic Irrigation System

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**)
- 2 AA 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 1 cm 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

*Also used in Investigation 6B

Investigation 8A: micro:bit-Controlled Automatic Irrigation System

For Facilitator Preparation:

- seeds to germinate or buds of basil, a different herb, or similar plant that does not fruit or flower
- EC digital monitor
- pH digital monitor or pH strips*
- nutrient solution, such as General Hydroponic FloraGro (**https://www.amazon.com/s?k=Hydroponics-Flora-FloraMicro-FloraBloom**)
- pH up or pH down solution (**https://www.amazon.com/s?k=General+Hydroponics+pH+Control+Kit+for+a+Balanced+Nutrient+Solution**)

For Learner Investigation:

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**)

*Also used in Investigation 2

**Also used in Investigations 3B and 7A1

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

INVESTIGATION 1: MATERIAL GOODS AROUND US

Facilitator Background

Connection to SDG 12: The goal of SDG 12 is to "ensure sustainable consumption and production patterns…which is all about doing more and better with less" (**https://sdgs.un.org/goals/goal12**). Consumers can make an impact by analyzing and reducing their own *material consumption* and considering areas of excess in their lives. In this introductory Investigation, learners will list items around them, then consider how long items will be used and classify items as luxury or necessity. Learners will also consider how to dispose of the items responsibly, such as through *recycling*, as an introduction to sustainable disposal practices.

Key Concepts: *material consumption, recycling*

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

Connect to the ESD Kit Project: Designing an environmentally conscious store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners should consider the types and amounts of goods a sustainability-conscious store would procure and sell.

> **Notes for the Facilitator:** If planning to complete the ESD Kit Project, it is a good idea to introduce it to learners during this Investigation. The ESD Kit Project revisits the major concepts in the Investigations that can be incorporated in a business model for a sustainable small business (local market, clothing store, repair shop, etc.). Introducing the ESD Kit Project now would allow learners to think about their business designs in advance of starting the project.

PACING GUIDE

PREPARATION
10 minutes reading the facilitator notes and printing "Items in Your Homes" handout
10 minutes creating and printing community maps for extension activity

WHAT TO DO
30 minutes for the Investigation
10 minutes discussing ESD Kit Project (optional)

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.

Notes for the Facilitator: Make a list on the board or a sheet of poster paper as learners call out items.

2. Looking at the class list:

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

Notes for the Facilitator: Circle items that learners consider temporary and underline items that learners consider 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?

Notes for the Facilitator: As a class, discuss options for repairing and discarding items. If an item breaks, it is more sustainable to repair the item than to just dispose of it. If items are going to be disposed of, the class could discuss throwing items away, recycling, composting, reusing/repurposing, donating, incinerating, or others. Write these options on the board or on a new poster paper as learners bring them up. For each new term, ask the learner who mentioned it to briefly explain the disposal method, adding what you can to clarify its meaning. Most disposal methods will be discussed in future Investigations.

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?

Notes for the Facilitator: Foster discussion of best disposal practices, best purchasing practices, and wants versus needs. Introduce the 4 R's for waste prevention — Refuse, Reduce, Reuse, Recycle. Within this discussion, compare the practices your community may follow with what others may follow around the world.

End the discussion by introducing learners to the United Nation's Sustainable Development Goals (SDGs) and specifically address SDG 12 on Responsible Consumption and Production (**https://sdgs.un.org/goals/goal12**).

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?

Notes for the Facilitator: After introducing SDG 12 to learners and discussing the questions above, discuss the Targets and Indicators within SDG 12 and their importance. If possible, have learners read through the SDG Targets and discuss which the leaners consider most important and why.

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?

Notes for the Facilitator: Answers will vary. Encourage learners to think about what makes something a necessity or a luxury to them. Discuss how that might depend on an individual's circumstances. Keep the discussion brief so as to avoid discussing specific learners' personal circumstances.

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

Notes for the Facilitator: Answers may vary, but 'throw away/landfill' may be the most common. This is not a sustainable disposal method for several reasons. First, there is not endless room to place trash, and existing landfills have issues with harmful leachate (water that has leaked through) and gases. Also, the products may contain materials that can eventually run out. Throwing those materials away means they are unavailable for later use. Sustainable disposal methods include recycling, composting, donating, and repurposing.

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

Notes for the Facilitator: Buy/use fewer items in general or buy/use items that are multipurpose, last longer, can be reused, are made from recycled materials, can be recycled, or come from resale shops. In general, sustainability is increased by discarding items by donating them or recycling them.

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.

Notes for the Facilitator: Each Investigation in this ESD Kit will have an extension activity related to a community map. Learners should use the same map throughout the Investigations. The annotated community map can also be used in the ESD Kit Project.

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.

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

INVESTIGATION 2: MODELING AND ASSESSING TYPES OF TRASH STORAGE

Facilitator Background

Connection to SDG 12: Target 12.4 calls for "the environmentally sound management of chemicals and all wastes throughout their life cycle … and [to] significantly reduce their release to air, water, and soil in order to minimize their adverse impacts on human health and the environment" (**https://sdgs.un.org/goals/goal12**). When items are thrown away, waste is transported to a lined landfill, controlled landfill, or trash heap which all vary in how well or if the waste is confined. If the waste storage is open to the environment and allows water to percolate through, it could pollute the groundwater or aquifer, which could be where the community gets its drinking water. If the waste storage confines its contaminants and even can make use of them, it could be considered an *environmentally sound technology*. In this Investigation, learners will model a trash storage facility and explore how it interacts with the surroundings by analyzing the water (leachate) quality inside and outside of the landfill. Learners will then modify the landfill with the goal of reducing the pollution in a nearby well.

Key Concepts: *environmentally sound technology*

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

Connect to the ESD Kit Project: Designing an environmentally conscious store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners should consider the amounts and types of items their store will sell

to reduce waste sent to a landfill and how their store will dispose of its waste. Consideration also may be given to the location of the proposed store in relation to the community's waste storage facility.

PACING GUIDE

PREPARATION
10 minutes reading the facilitator notes
20 minutes preparing simulated trash
5 minutes setting out materials for each group

Notes for the Facilitator: Spending 10–20 minutes learning about the trash storage options in your community, what materials make up the trash in your community and in other parts of your country, and any related trends will help make the introduction discussion more meaningful.

WHAT TO DO
10 minutes to introduce and discuss what 'throwing away' means
50 minutes for the Investigation

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)

Simulated trash

- waste generated by facilitator
- colored crepe or tissue paper, preferably red or blue
- baking soda

Notes for the Facilitator: The first 9 items on the list can be collected individually, or you can purchase Awesome Aquifer Kits (found at https://awesomeaquifer.com/) which include the clear plastic container, small gravel, hand pump, plastic tube, syringe, nylon hose, rubber bands, 2 small plastic cups, food coloring, clay.

In step 7, learners will design and build modifications for the landfill to reduce pollution of a nearby well. Having items such as plastic wrap or aluminum foil would be helpful to create liners for the bottom of the landfill. Plasticene clay can also be used to line the landfill. You may provide learners with other similar materials to use to design and create their modifications.

To create the simulated trash, gather everyday trash items (food waste, tea/coffee grounds, paper, plastics, etc.) and colored crepe paper. Cut the trash items and the colored crepe paper into smaller pieces (< 2 cm), add in about 15 mL baking soda for every 240 mL of simulated trash and mix to combine. Each group will need about 2–3 scoops of simulated trash, with the scoop size being the size of the small mesh container the learners will use as their trash heap.

Credit: L. Brase

What to Do

Notes for the Facilitator: Hand out the simulated trash and gloves to each group. Ask learners to make observations of what they see. Pose and discuss the following questions: What is trash? What materials could make up trash? What happens when trash is thrown away? What is does "away" mean in this case? Where does it go? What happens to it? Reference community-specific information when possible.

1. Construct the model landscape using the Awesome Aquifer Kit or DIY materials.

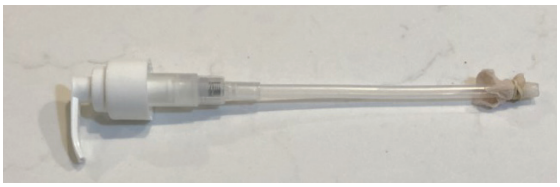
    a. Pour the gravel in the clear plastic kit container and spread it out evenly.

    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.

Notes for the Facilitator: If using materials from the Awesome Aquifer Kit, learners should build the second well as described. If purchasing materials separately, there is the option to build the second well also from a soap dispenser hand pump instead of plastic tubing and the syringe.

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.

Notes for the Facilitator: If the groundwater begins to flow above the gravel, have the learners pump another small cup or two out of the monitoring well (outside the landfill).

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.

Notes for the Facilitator: Discuss the results as a whole group. Learners should have determined the water quality was affected by the installation of the landfill since the water was affected by the trash, citing color and pH as evidence. The quality of the water from inside and outside the landfill were both changed by the installation of the landfill, so the landfill was not successful at containing the pollution from the trash.

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.

Notes for the Facilitator: Answers will vary. Modifications that are successful would result in little or no color or pH change in the water of the monitoring well.

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

Notes for the Facilitator: Answers will vary. Other modifications could include collecting the water (leachate) and pumping it out to a treatment facility, storing the leachate elsewhere, installing a leak detection system, treating the waste first before dumping it into the landfill, and/or sorting out the hazardous materials that produce dangerous leachate.

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?

Notes for the Facilitator: This depends on if the landfill is lined or unlined. If the landfill is lined underneath and capped on top, no water or air can enter and therefore the trash will decompose slower than without water or air. Also, the contamination would be isolated since the cap and liner would form a barrier between the trash and the surroundings. Capped landfills also allow for the collection and use of methane for energy and heating uses, otherwise it would escape into the atmosphere. If the landfill is unlined and only capped, groundwater can still enter the landfill from the sides and pollution can still occur.

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?

Notes for the Facilitator: Hazardous waste contains harmful substances that could leach into water and air, or they could be flammable. For safety reasons and to reduce the impact on the environment, people, and animals these substances are discarded more carefully, guided by the regulations.

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?

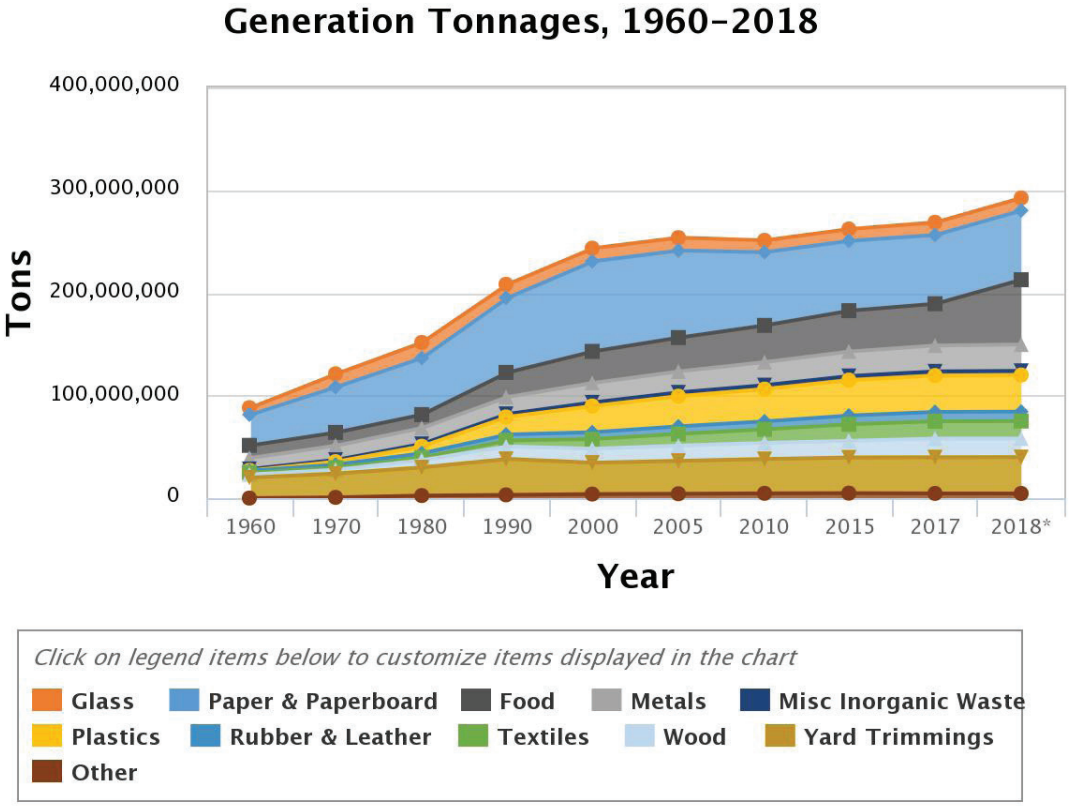
b. Conduct a food audit in your home for one week. How much food is your family eating? How much food is your family throwing away? What does your family do with parts of food that cannot be eaten, such as some fruit peels, leaves, or cores?

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?

Notes for the Facilitator: This data was collected and published by the United States Environmental Protection Agency. You may be able to find similar data for your country or community through a similar organization in your area. Some related global data can be found at **https://bit.ly/3yK4XFb.**

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

INVESTIGATION 3A: PLASTICS AROUND US

Facilitator Background

Connection to SDG 12: Target 12.5 calls for a substantial reduction in "waste generation through prevention, reduction, recycling and reuse" (https://sdgs.un.org/goals/goal12). Plastic makes up a large component of landfills even though some types of plastic can be recycled. Recyclable plastic items are identified by the chasing arrows symbol with a number 1–7 inside, which identifies the type of plastic by the ASTM International Resin Identification Coding System (RIC). In this Investigation, learners will become familiar with the different groups of RIC plastics and what plastic *recycling* is available in their community.

Key Concepts: *recycling*

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

Connect to the ESD Kit Project: Designing an environmentally conscious store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners should consider what types of plastics will be used and/or sold in their store.

PACING GUIDE

PREPARATION
10 minutes reading through the investigation
15 minutes researching and preparing a handout about your community's recycling rules
10 minutes copying handouts
5 minutes setting out materials

Notes for the Facilitator: You can reuse these recycling rules for Investigation 4A.

WHAT TO DO
30 minutes for the Investigation

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

Notes for the Facilitator: Since learners are grouping items, each group of students is referred to as a team instead of a group in this Investigation. If it is possible, learners could each bring in some items.

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.

Notes for the Facilitator: Discuss the similarities and differences between how groups organized their plastic items. Transition into discussing the international numbering system for plastics.

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.

Notes for the Facilitator: As a whole group, go through the handout. Have all groups hold up their #1 recyclables. Discuss "Types of Items" and "Properties" as a class. Share the polymer that makes up that group, Polyethylene terephthalate (PET or PETE) for #1 recyclables, and if the plastic can be recycled in your community. Repeat with the other groups. Polymer names for the RIC groups can be found at **Plastic Recycling Numbers (vandenrecycling.com)**.

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?

Notes for the Facilitator: Tally up each group's reusable and single use categories. Discuss as a whole group the prevalence of single use plastics.

Consider

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

Notes for the Facilitator: #4 plastics are made from low-density polyethylene (LDPE). LDPE plastics are very fragile and tend to get tangled in recycling machinery. These plastics also tend to have additives such as ink/dye, which are expensive to remove. It is cheaper to make these plastics from raw materials than to recycle them. There are however special collection and drop off locations in many communities to encourage recycling of plastic films that are otherwise not compatible with single stream or curbside recycling programs.

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?

Notes for the Facilitator: Answers will vary. This website provides some examples of alternative materials: **https://bit.ly/37HoXx4** . Learners may bring up the idea to reuse single-use items such as plastic water bottles. This is not recommended as they cannot be properly sterilized and may develop cracks in the plastic which create more places bacteria can grow. Additional scratches and cracks also release some of the plastic and harmful toxins into the water inside the bottle.

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?

Notes for the Facilitator: Answers will be specific to your community.

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

Notes for the Facilitator: Recycling rules are specific to the procedures of the organization doing the recycling, so in order to save time and money, rules were created to guide people about how to help recycling go smoothly. For example, some companies will re-sort the items people turn in to be recycled to ensure that only correct items are included. Other companies won't re-sort items. If the recycling company doesn't re-sort items that are incorrectly recycled, those materials could clog or break machines or the entire load could be thrown away into a dump instead of being recycled. Some companies require recyclables to be cleaned out by the consumer prior to recycling, and if they aren't, the load could be contaminated and tossed into a landfill instead.

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?

Notes for the Facilitator: Some answers could include to decrease the amount of plastic use in general, decrease the production of non-recyclable plastics, increase the ratio of recyclable plastics used compared to non-recyclable plastics, eliminate single use plastics, increase participation in recycling by making recycling more convenient, institute more policies that mandate recycling, and increase the rate of plastic reuse.

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

Notes for the Facilitator: Answers will vary; they could include using reusable water bottles and reusable bags, requesting no straw or plastic silverware when ordering takeout, or other ways of implementing the 4R's.

Extensions

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

Notes for Facilitators: Some ideas and instructions for toys can be found at **https://www.arvindguptatoys.com/toys.html**.

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				

Notes for the Facilitator:

International recycling Number	Types of Items	Properties	Polymer	Can it be recycled?
1	Plastic bottles (water, soft drinks, cooking oil), dispending containers, biscuit trays	clear, strong, and lightweight	Polyethylene terephthalate (PET or PETE)	Yes; widely recycled. (check specifically for your community)
2	Packaging, milk containers, cleaning agents, shampoo bottles, freezer bags, ice cream containers	stiff, hardwearing, usually opaque	High-density polyethylene (HDPE)	Yes; widely recycled. (check specifically for your community)
3	Fruit trays, bubble wrap, plastic piping, vinyl flooring, cabling insulation, roof sheeting	*No commonalities?? rigid or soft*	Polyvinyl chloride (PVC)	Varies (check specifically for your community)
4	Plastic bags, food wrapping, trays, containers	Lightweight, low cost, versatile, rips/breaks/ melts easily	Low-density polyethylene (LDPE)	Rarely (check specifically for your community)
5	Potato chip bags, bottle lids, single-use face masks, food tubs, furniture, houseware, medical, rope, automobile parts, toys	Tough and resistant	Polypropylene (PP)	Often No (check specifically for your community)
6	Styrofoam, Food takeaway containers, plastic cutlery, cups, egg tray, pill bottles	Lightweight, structurally weak	Polystyrene (PS)	Often No (check specifically for your community)
7	Water cooler bottles, baby cups, fiberglass, nylon	Diverse	Other plastics (e.g. acrylic, polycarbonates, polylactic fibers)	No (check specifically for your community)
Unlabeled				No

INVESTIGATION 3B: PLASTICS IN AQUATIC ENVIRONMENTS*

Facilitator Background

Connection to SDG 12: Target 12.4 aims to "achieve the environmentally sound management of chemicals and all wastes throughout their life cycle… and significantly reduce their release to air, water, and soil in order to minimize their adverse impacts on human health and the environment" (**https://sdgs.un.org/goals/goal12**). Although some types of plastic can be recycled, most plastic is thrown away and either makes its way to a landfill or ends up polluting rivers and oceans and impacting animals, therefore increasing the *plastic footprint* (or areas that are impacted). In this Investigation, learners will explore the densities of different plastic items to predict where the item would end up in the water column if the item was in an ocean. Learners will also consider impacts of *plastic pollution* to ocean animals.

Key Concepts: *plastic footprint, plastic pollution*

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.

Connect to the ESD Kit Project: Designing an Environmentally Conscious Store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners should consider the amount and types of plastic items in their store — in items for sale and used in other processes, such as packaging and advertising — and how they will ensure the plastics are properly disposed to reduce the impacts on animals and the environment.

PACING GUIDE

PREPARATION

10 minutes setting out materials and fill up water tanks

10 minutes printing and cutting up the Ocean Feeder Cards

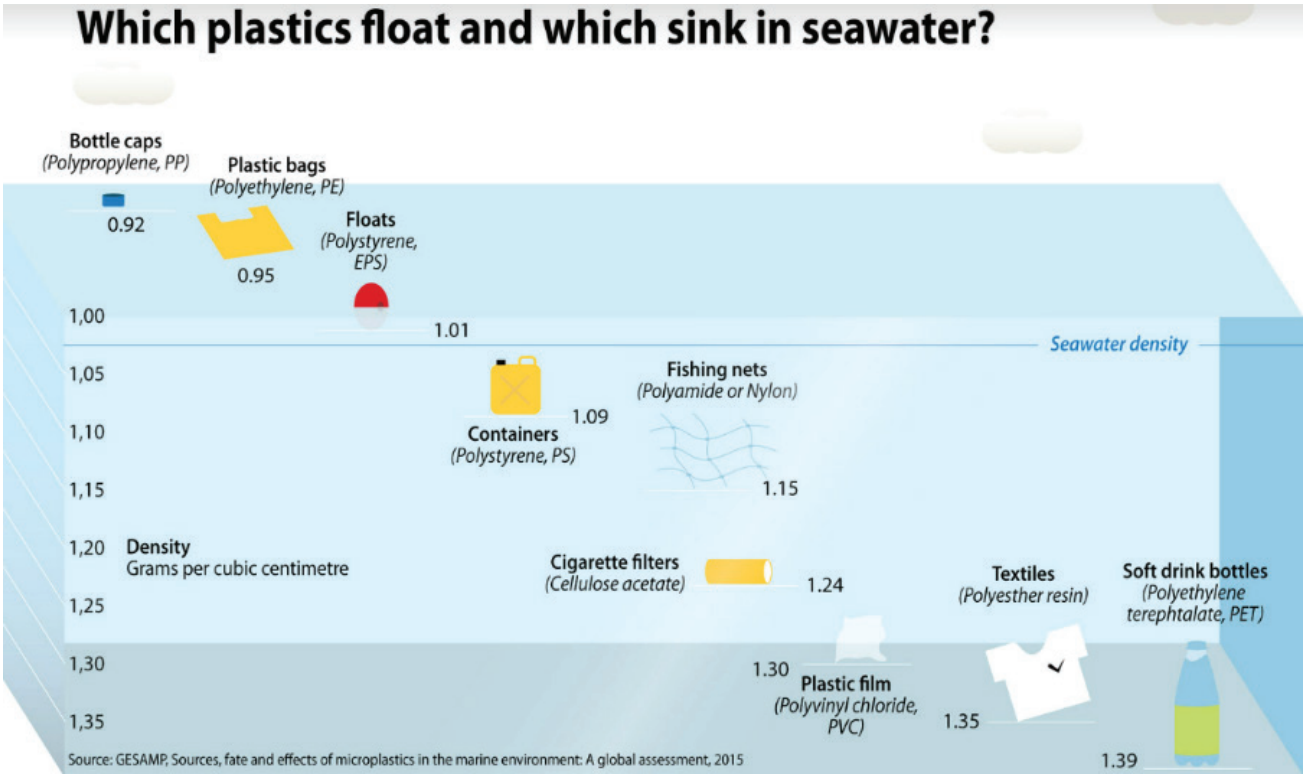
WHAT TO DO

5 minutes for introduction discussion

40 minutes for the Investigation

Introduction

A lot of plastic that is thrown away ends up in the watershed, and ultimately the ocean as marine debris. In 2015, it was estimated that 8 million tonnes of plastic enters the oceans every year (Eriksen et al. 2014; Lambeck et al. 2015) Some plastics float in sea water, others sink, and some remain neutrally buoyant (in other words, they will hover at various depths rather than completely sink or float). A factor that affects the buoyancy and location of the plastic debris in the water column is density. Density is an important property of all materials, whether solid, liquid, or gas. It is the ratio of a material's mass to its volume; in other words, it is a measure of how much mass is in a given space. Density can be calculated by dividing an object's mass by its volume (D=M/V) and is the same value for a certain type of material, regardless of the size or shape of the object.



Credit: Maphoto/Riccardo Pravettoni, https://www.flickr.com/photos/gridarendal/32211531572

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

For Facilitator Demonstrations:

- clear beaker, or similar
- 3 cups
- spoon
- food coloring
- salt or sugar
- water

Notes for the Facilitator: The plastic items must be able to fit in the plastic bin and be submerged completely. You may want to experiment with submerging items in water ahead of time to ensure there are a variety of objects that sink and float for each group.

What to Do

Facilitator Demonstration:

Notes for the Facilitator: It is recommended that this demonstration be done after learners complete step 2c of the Learner Investigation procedure.

1. Set out three clear cups.
2. In the second cup, put two spoonfuls of salt. In the third cup, put four spoonfuls of salt. Leave the first cup empty.
3. Fill the cups up with similar amounts of hot water.
4. Stir in the salt until it is all dissolved.
5. Add different food coloring to each cup so they can be easily distinguished from each other.
6. Pour some of the first cup (no salt) into the clear beaker.
7. Add some of the water from the second cup into the beaker. This saltwater should move to the bottom of the beaker, forming a layer below the water.
8. Add some water from the third cup (most salt) into the clear beaker. This saltwater should move to the bottom of the beaker, forming a layer below the two previously formed layers.
9. The colors should appear all stacked on top of one another.

Learner Investigation:

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?

Notes for the Facilitator: Discuss learners' thoughts as a whole group.

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.

Notes for the Facilitator: Ensure the leaners fully submerge each item. If it is not fully submerged, an object may appear to float due to surface tension.

c. Why do you think some objects floated and others sank?

Notes for the Facilitator: Discuss the findings as a whole group. Which items floated? Which items sank? What causes an item to sink or float? Discuss density and refer to the introductory material as needed. If possible, carry out the density demonstration explained below.

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.

Notes for the Facilitator: The density of natural salt water can vary from 1.01–1.25 g/mL depending on location and depth.

- 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.

Notes for the Facilitator: When comparing materials, items with a higher density will sink while items with a lower density will float. So, items that have a density greater than 1.00 will sink in fresh water and items with a density greater than 1.03 will sink in ocean -like salt water.

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?

Notes for the Facilitator: Transition into asking students and then discussing how plastics get into bodies of water. Discuss impacts on animals such as entanglement and consumption.

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.

Notes for the Facilitator: Introduce the concept of feeding zones. Write the zones vertically for the learners to see: surface = top of the water column, pelagic = open water, benthic = sea 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.

Notes for the Facilitator: Discuss answers as a whole group. Draw or project a water cross section and go through the answers for each zone. Surface feeders: black-footed albatross and western gull, could be affected by #2 HDPE plastics, #4 LDPE plastics, #5 PP plastics, #6 PS plastics, #7 other types of plastics. Pelagic feeders: black-footed albatross, giant sea bass, ocean sunfish, black sea turtle, and the common dolphin could be affected by #2 HDPE plastics, #4 LDPE plastics, #5 PP plastics, #6 PS plastics, #7 other types of plastics. Benthic feeders: giant sea bass, giant pacific octopus, and the southern sea otter could be affected by #1 plastics, #3 plastics, #6 plastics, #7 other types of plastics.

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?

Notes for the Facilitator: The plastics will pollute the Ocean at the surface, floating throughout the ocean, or at the bottom. The western gull is a surface feeder, so any RIC 2, 4, 5, 6, and 7 plastics may impact it. The sea otter is a benthic feeder, so any RIC 1, 3, 6, and 7 plastics may impact it.

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?

Notes for the Facilitator: Answers will vary. Some other examples besides entanglement and consumption could be the fishing debris can continue to capture and kill marine animals; fishing debris can damage marine habitats; fishing debris can breakdown and contribute to the microplastic pollution; fishing debris items that float can travel, potentially carrying and spreading invasive species.

Extensions

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

Notes for Facilitators: Some ideas and instructions for toys can be found at **https://www.arvindguptatoys.com/toys.html**.

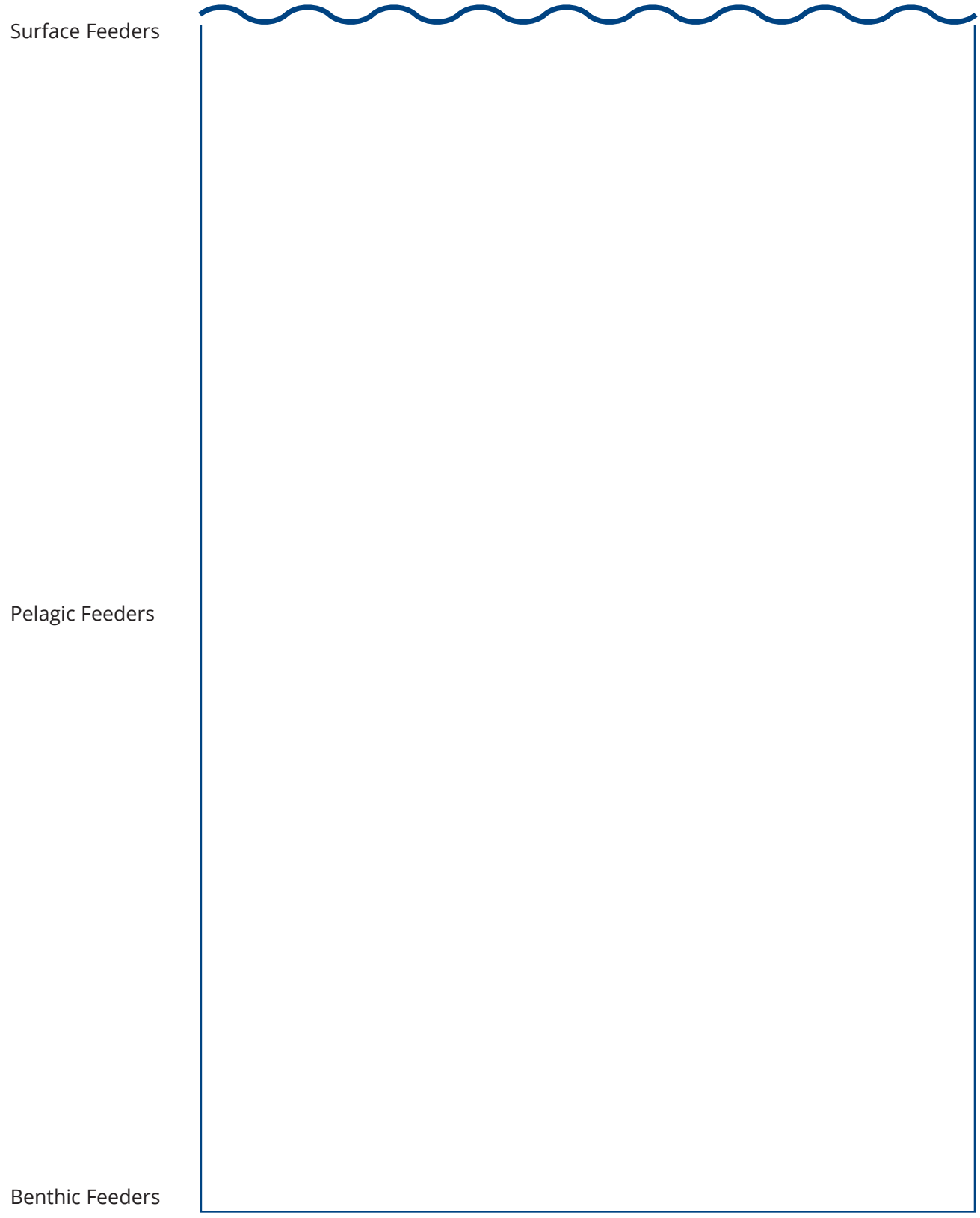
2. **Applying Concepts:** Examine a map of your community and identify rivers, streams, bays, and/or oceans that could provide a way for waste and pollution to move within your community. Research locations as needed. Color code or label the waterways and add these colors/symbols to the Map Key.

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

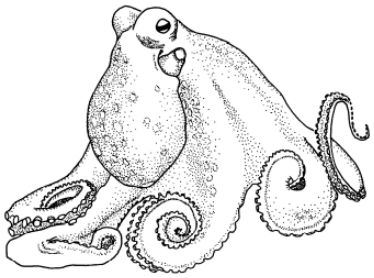
Black-footed albatross — **Surface and Pelagic Feeder**
Phoebastria nigripes size: wingspan up to 7 ft. (215 cm) and 7.7 lbs. (3.5 kg)

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

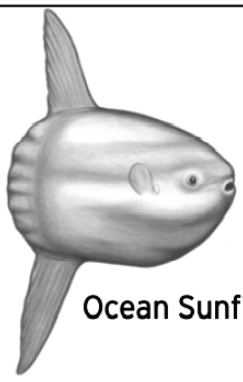


Giant Pacific Octopus

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.

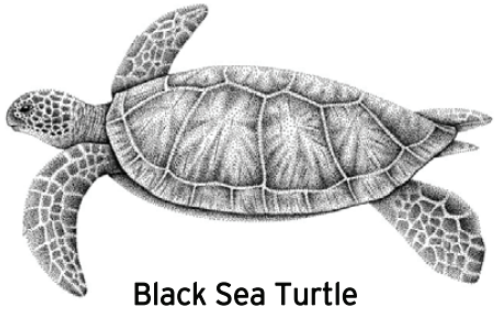
Diet: clams, abalone, rockfish, crabs, other octopuses
Feeding Strategy: catches food with suckers and crushes with beak
Habitat: reefs and pilings



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

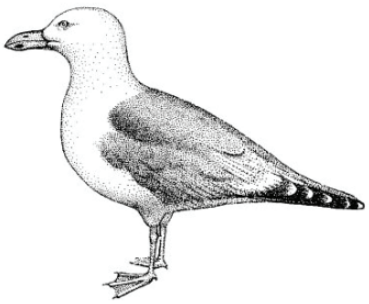


Black Sea Turtle

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.

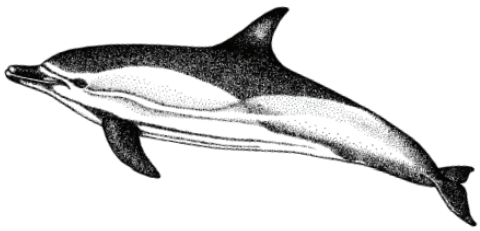
Diet: jellies, invertebrates, sea plants, algae
Feeding Strategy: uses sharp beak to cut and tear its food.
Habitat: open water



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

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

INVESTIGATION 4A: ASSESSING HOW ITEMS ARE PACKAGED

Facilitator Background

Connection to SDG 12 Target 12.5 calls for a substantial reduction in "waste generation through prevention, reduction, *recycling*, and reuse" (**https://sdgs.un.org/goals/goal12**). The packaging industry generates a lot of waste that often ends up at landfills. *Sustainable production* practices would reduce the environmental *footprint*, or impact, of packaged goods by reducing the amount of packaging, using recyclable materials to package goods, making reusable packaging, or eliminating packaging altogether. This would also reduce the environmental footprint of plastic since plastics are one of the most common materials to produce packaging. In this Investigation, learners will assess common types of packaging and explore ways the environmental footprint of packaging can be reduced.

Key Concepts: *sustainable production, footprint, recycling*

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

Connect to the ESD Kit Project: Designing an Environmentally Conscious Store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners should consider how their store will package and sell goods with a low carbon footprint.

PACING GUIDE

PREPARATION

10 minutes reading through the investigation

15 minutes researching and preparing a handout about your community's recycling rules (also used in Investigation 3A)

WHAT TO DO

5 minutes discussing the introduction material

20 minutes conducting the Investigation

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.)

Notes for the Facilitator: In the days leading up to the investigation, collect many different types of packaging from your home, the building you are in, and so on. All components of a package count as one item. For example, the plastic the item was wrapped in, the box it is sold in, the box it is mailed in, and shipping paper to reduce movement could be considered one packaging item.

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?

Notes for the Facilitator: As the groups are discussing, give each group 5 items and your community's recycling rules.

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?

Notes for the Facilitator: After the learners have had time to assess their 5 items, discuss as a class what eco-friendly means and what learners think makes an eco-friendly package.

Consider

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

Notes for the Facilitator: Answers will vary, but could include eliminating unnecessary or short lifespan packaging, using less packaging in general, making packaging from recyclable materials, communicating the ability to be recycled easily, made from a single material (not multiple materials adhered together, which makes materials harder to recycle), placing mailing stickers directly on boxed items instead of boxing items again or wrapping them, buying from a store so there is less need for packaging, avoiding a gift wrap option.

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

Notes for the Facilitator: Answers may vary but could include that the items could be fragile, and the packager wants to ensure the items stay intact; items could be food and the packager doesn't want the items to get contaminated or spoil; items could be small or loose and the packager wants the items to stay consolidated.

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

Notes for the Facilitator: Natural items tend to have less packaging than processed items as shown in a grocery store/market. Many natural items have skins or coverings that can serve as their own natural packaging (orange peel, banana peel, watermelon rind, mango skin, etc.).

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?

Notes for the Facilitator: Consumers that are sustainability-conscious may be more likely to purchase items in bulk, items that have less packaging, more natural items or items that are less processed, local items, and so on. Advertisers could convince buyers based on price, size, convenience, popularity, and so on. Advertisers for sustainable products could add labels communicating the sustainability or "green" features of the product.

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.

Notes for the Facilitator: If learners are completing Investigation 3, the packaging audit can be completed at the same time as the food audit.

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?

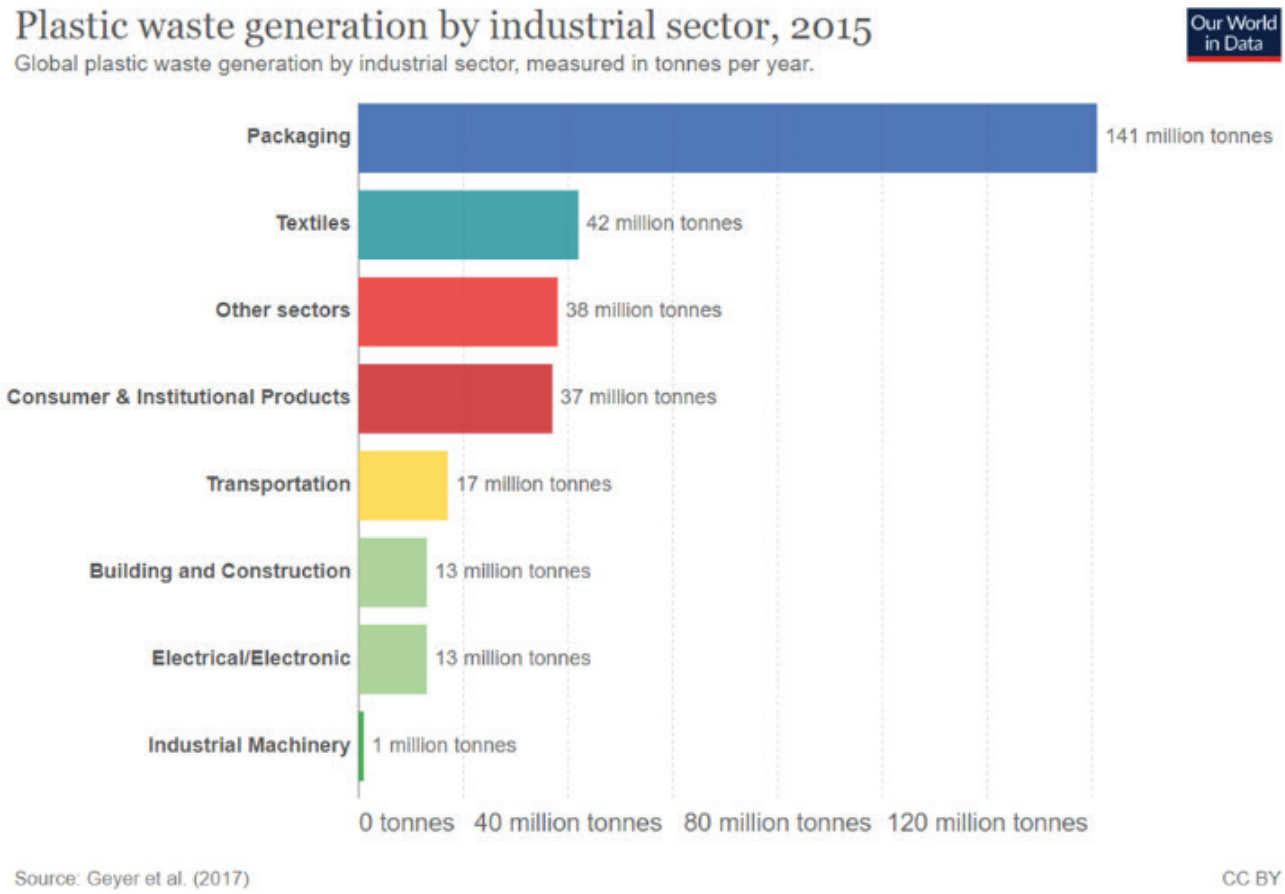
Notes for the Facilitator: Approximately 47% (141 million tonnes divided by 302 million tonnes, times 100).

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

Notes for the Facilitator: Packaging is used to store and keep food fresh, as well as provide containers for shipping; since these are two commonly used products and services, a lot of packaging is required. Plastics tend to be flexible and durable, so they make for reliable packaging materials.

    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?

Notes for the Facilitator: Answers will vary but may include the relative amount of waste now versus 2015 (stating more, less, or the same). Answers should include a justification for the relative amount stated, such as an increase in the amount of plastic waste could be explained by an increase in population size or an increase in the amount of plastic production occurring annually.



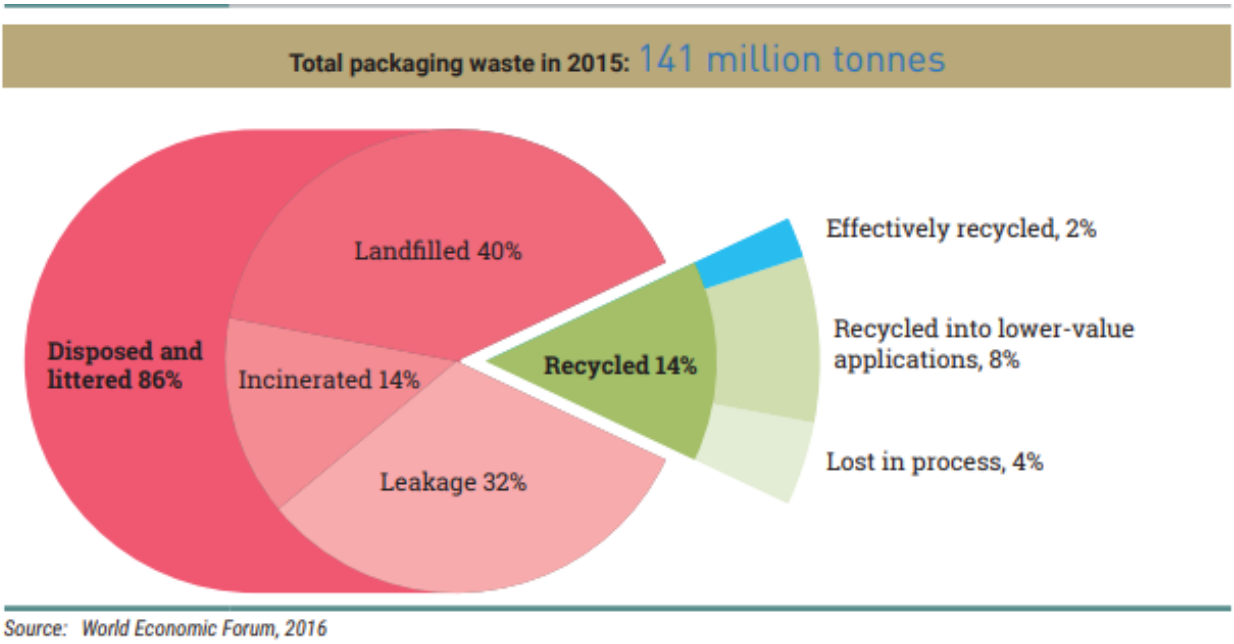
Credit: Our World in Data, https://ourworldindata.org/faq-on-plastics

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?

Notes for the Facilitator: Answers will vary but could include that not everyone has access to recycling services (note that this is global data), that most recyclables can only be recycled if properly cleaned or broken down, or that people are not aware of what is recyclable.



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

Facilitator Background

Connections to SDG 12: Target 12.5 calls for a substantial reduction in "waste generation through prevention, reduction, recycling, and reuse" (**https://sdgs.un.org/goals/goal12**). Learners discovered in Investigation 4A that many items aren't packaged sustainably due to the use of non-recyclable materials and/or excess packaging. In addition, many carbon emissions are released while making packaging, causing many common packaging materials to have a high carbon *footprint*. In this Investigation, learners will compare the packaging for the same food when served in bulk and in single serve portions and discuss *sustainable production* techniques to determine which items are better for *sustainable consumption*. A consumer can be knowledgeable about which products leave a low carbon footprint as the items that a consumer purchases influence what items a business sells and a company produces.

Key Concepts: *sustainable production, sustainable consumption, footprint*

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

Connect to the ESD Kit Project: Designing an Environmentally Conscious Store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners will be able to consider how items are packaged while deciding they types of items their store will sell.

PACING GUIDE

PREPARATION
10 minutes setting out items for groups
10 minutes reading through investigation
20 minutes preparing scale for demonstration

WHAT TO DO
30 minutes for Investigation 4B
10 minutes for class demonstration

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)

Notes for the Facilitator: If scales are not available, learners measure the volume of the food instead. The same food item can be used for all groups, or a different one can be used by each group. If the learners will consume the food at the end of the Investigation, be sure to implement safe handling practices and use sterile bowls throughout the Investigation.

For the Facilitator Demonstration:

- two identical large paper or plastic bowls
- three-hole punch or screwdriver
- wooden dowel rod, at least three times the length of the large bowls used.
- thin wire or string
- duct tape or similar
- ring stand or similar
- 1 bulk item and many single serve items, different item than learner portion of the Investigation
- reusable containers (if not consuming opened food items)

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?

Notes for the Facilitator: Tell learners the cost of both items.

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?

Notes for the Facilitator: After learners have made a prediction, show them the new item you will test.

    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?

Notes for the Facilitator: Empty the bulk item into one bowl of the balance. Save the packaging to weigh later. Slowly add the contents of the single serve packages into the other side of the balance until they are equal. On a scale, weigh the total amount of single serve packages and then the weight of the bulk package.

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?

Notes for the Facilitator: The cost of the single serve item per gram is usually higher compared to the bulk item. The justification for the higher price is that the consumer is paying a higher price due to the packaging and convenience of single-serve packaging.

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

Notes for the Facilitator: Items that will be used up quickly, that you have room to store, and food items that have a long shelf-life may be better purchased in bulk. Food items that can be frozen would also be beneficial to buy in bulk, if there is access to a freezer.

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

Notes for the Facilitator: If the items will perish before their use and can't be preserved, or the bulk quantity is simply too much to be used, then it may be better to purchase smaller servings.

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

Notes for the Facilitator: Answers will vary but could include that packaging could be made from recyclable materials, could be reusable, or could use less packaging in general.

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.

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

INVESTIGATION 5A: ELECTRONICS IN A HOME

Facilitator Background

Connection to SDG 12: Target 12.5 aims to "substantially reduce waste generation through prevention, reduction, *recycling*, and reuse" (https://sdgs.un.org/goals/goal12). Electronics are one of the fastest growing waste streams, which is unhealthy due to the hazardous materials found inside electronics that can leach into the environment and can be considered *hazardous waste*. Electronic waste, also called *e-waste*, includes outdated or unwanted electronics including things such as refrigerators, televisions, and cell phones. In this Investigation, learners will consider electronics they would have in a dream home and the lifetime of those items. They will learn about local policies and procedures to dispose of e-waste and think about how to reduce the amount of e-waste in their life.

Key Concepts: *recycling, hazardous waste, e-waste*

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

Connect to the ESD Kit Project: Designing an Environmentally Conscious Store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners should consider what electronics they will have in their store and the repair, replacement, and disposal procedures they can put in place.

PACING GUIDE

PREPARATION
5 minutes reading through the Investigation
15 minutes looking up local e-waste rules and regulations

WHAT TO DO
30 minutes for the Investigation

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?

Notes for Facilitators: Depending on learners' previous knowledge of floorplans, you may have them design their own floorplan or give them the attached floorplan to fill in with furniture, electronics, and so on.

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.

Notes for the Facilitator: Have a discussion of all the different electronics learners would want in their dream apartments. Be sure to tie in kitchen appliances, washer and dryers, lamps, cords, chargers, headphones, flashlights, and other items that learners may not initially consider.

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?

Notes for the Facilitator: Discuss some answers as a whole group. Introduce the term *product lifetime.* Inform learners of local procedures for discarding e-waste and any rules and regulations that must be considered. Investigate the benefits of repairing electronics, such as by sharing https://www.ifixit.com or other similar websites. Discuss safety concerns when considering repairing an electronic device such as unplugging the device from its power source, wearing proper non-conductive clothing, keep away from water, and so on.

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?

Notes for the Facilitator: Answers could include higher consumption rates, shorter life span, more frequent updated models instead of just software updates, limited or no repair options, or new kinds of electronics and innovations in available features.

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

Notes for the Facilitator: Electronic devices contain potentially harmful metals and chemicals, which makes them hazardous to throw away. When electronics are incorrectly discarded, those chemicals and metals can end up in the soil, air, and water, where they can do harm.

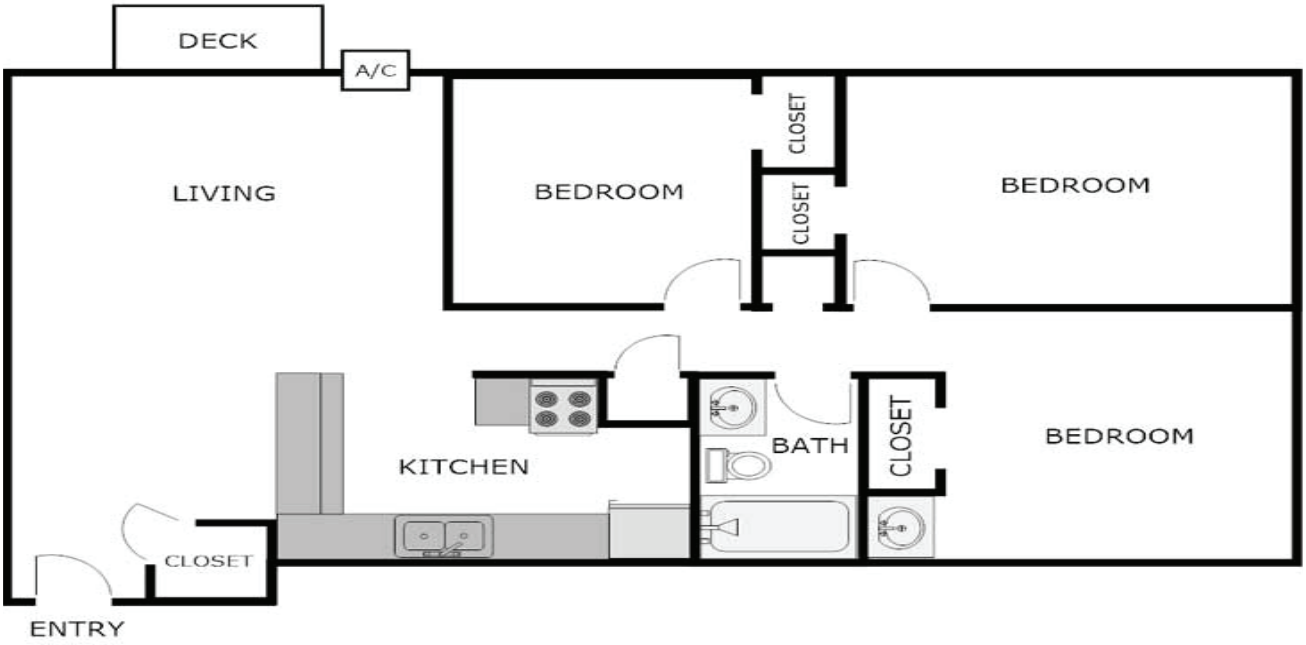
3. How could you and others in your community reduce your e-waste?

Notes for the Facilitator: Answers could include reduce the amount of electronics purchased, don't update electronics frequently or unnecessarily, use rechargeable batteries, repair electronics instead of replacing them, buy electronics from a resale shop, donate or gift working electronics you otherwise would discard.

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.

DESIGNING YOUR DREAM APARTMENT



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

INVESTIGATION 5B: E-WASTE (DATA-FOCUSED ACTIVITY)

Facilitator Background

Connection to SDG 12: Target 12.4 pushes to "achieve the environmentally sound management of chemicals and all wastes throughout their life cycle…and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment" and indicator 12.4.2 specifically addresses "hazardous waste generated *per capita*" (https://sdgs.un.org/goals/goal12). Electronics have become a large component of global waste which is problematic environmentally and economically. There are hazardous materials inside electronics that can pollute the environment if not properly disposed of, and there are valuable resources inside electronics that could be extracted and reused. *E-waste* analyses are becoming more prevalent and are shaping legislation around the globe. In this Investigation, learners will explore and compare international e-waste statistics and explore data about valuable materials inside electronics that could be reclaimed during *recycling*.

Key Concepts: *recycling, per capita, hazardous waste, e-waste*

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

Connect to the ESD Kit Project: Designing an Environmentally Conscious Store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners should consider what legislation may be in place in their country that would impact their store's e-waste disposal strategy. Learners should also consider safety aspects of handling e-waste and other hazardous materials that are in their store.

PACING GUIDE

PREPARATION

10 minutes reading through the Investigation

10 minutes finding and reading over your country's data sheet (for Investigation 5B2)

WHAT TO DO

20 minutes for Investigation 5B1

15 minutes for Investigation 5B2

20 minutes for Investigation 5B3

INVESTIGATION 5B1: ANALYZING E-WASTE INTERNATIONALLY

Materials

Per group:

- data sheet for your country

Notes for the Facilitator: Find your country's data sheet on e-waste: **https://globalewaste.org/map**. Select the most recent year and a previous year with data for the learners to compare. Print both sheets for the learners to use.

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?

Notes for the Facilitator: In 2019, large equipment (26%) and temperature exchange equipment (23%) contributed most to international e-waste (*Global E-waste Monitor 2020).*

   b. Which categories of EEE do you think contribute the least to e-waste? Why do you think so?

Notes for the Facilitator: In 2019, small IT (7%) and lamps (2%) contributed the least to international e-waste (*Global E-waste Monitor 2020).*

   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?

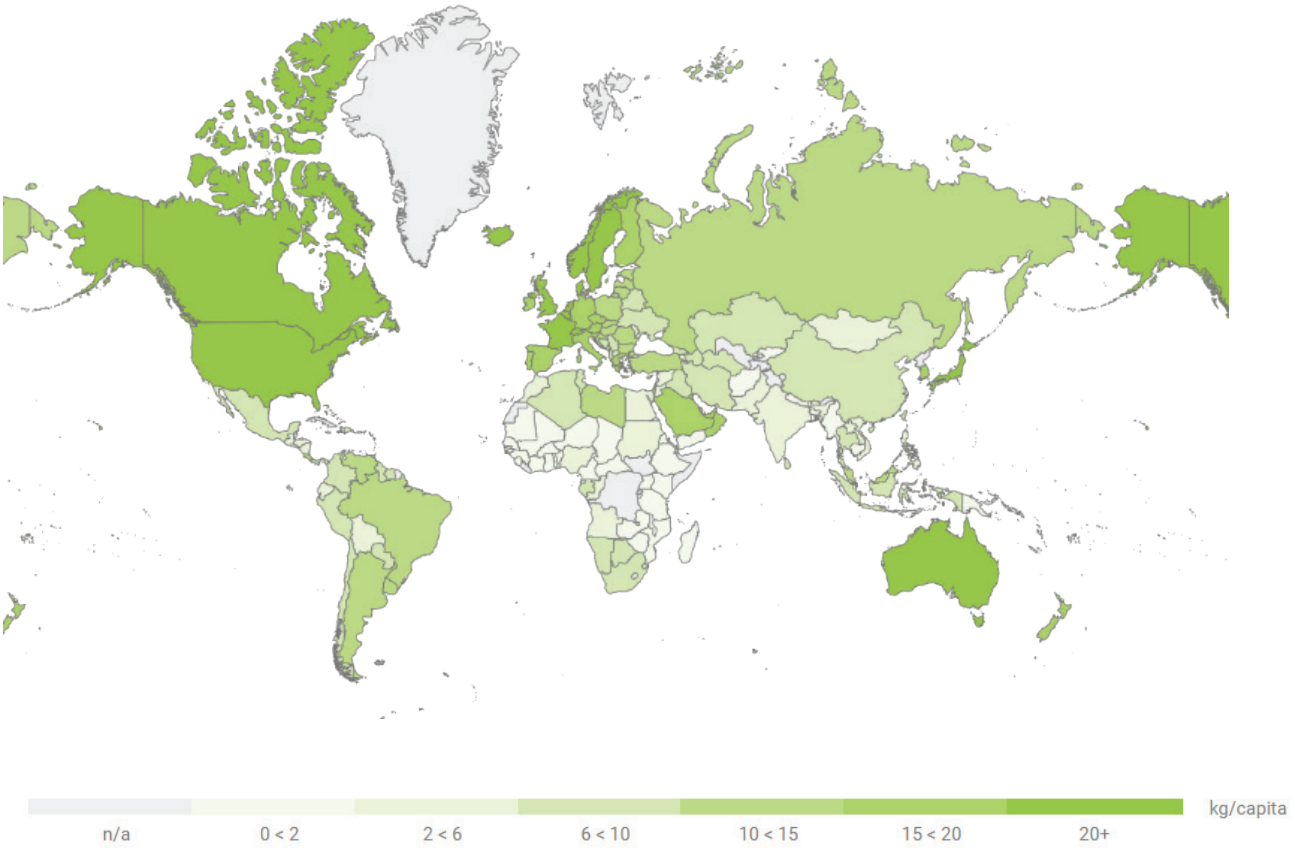
Notes for the Facilitator: Discuss the local policies and procedures for e-waste.

   d. Why are there special methods to discard EEE? How is e-waste different than regular waste?

Notes for the Facilitator: Discuss the learners' answers to Steps 1 and 2 as a whole group. If you completed Investigation 5A, the discussion can be briefer. If you did not complete Investigation 5A, spend time familiarizing the learners with EEE and e-waste by facilitating a more in-depth discussion.

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.

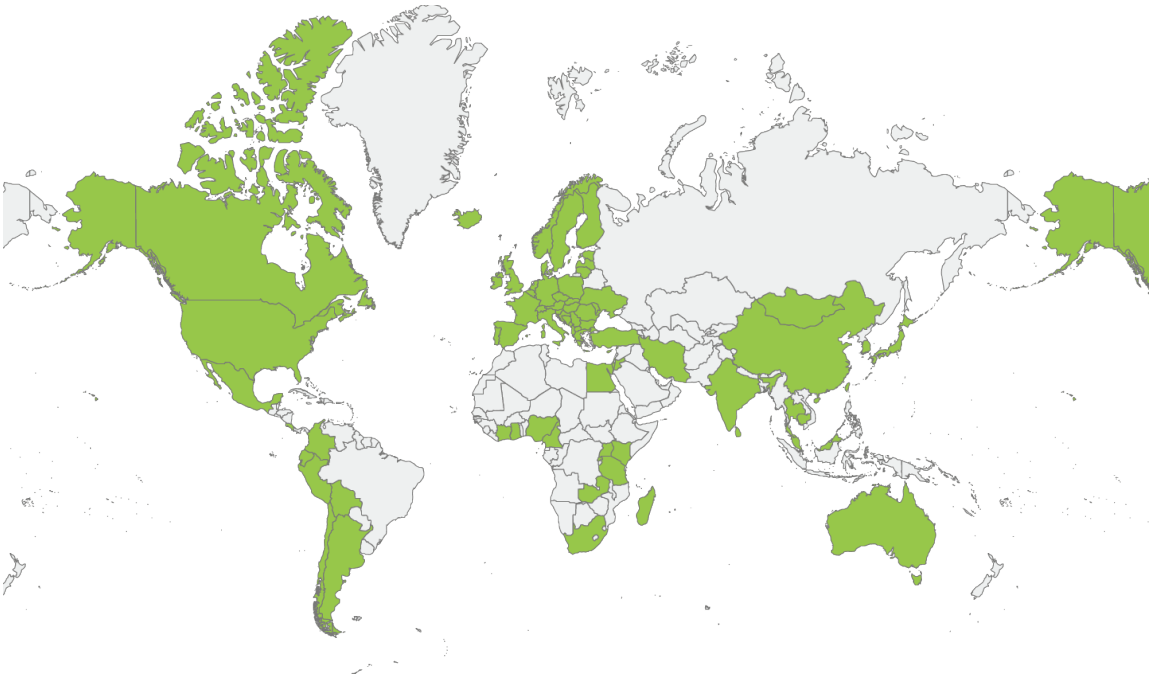
c. Which continent(s) shown on the map generated the least amount of e-waste per capita in 2019? Identify the areas on the map.

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?

Notes for the Facilitator: The trend of miniaturization has led to less waste when analyzed by weight.

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

Notes for the Facilitator: The demand and technological advances will continue to increase the amount of EEE produced, which will cause an increase in e-waste due to EEE being obsolete. The amount of e-waste-related legislation and recycling rates are increasing, which will help recover materials from e-waste.

INVESTIGATION 5B2: ANALYZING E-WASTE FROM YOUR COUNTRY

Materials

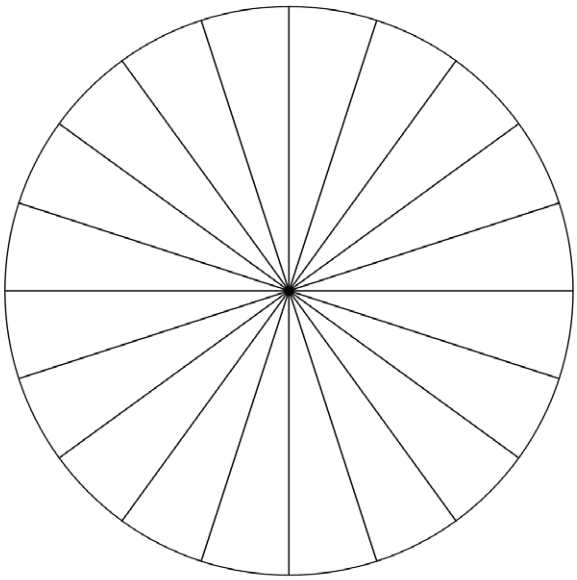
Per group:

- 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 above?
   - **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 above?
   - **d.** In the most recent data, what is your country's e-waste collection rate? How does it compare to the three countries above?
   - **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.

Notes for the Facilitator: Answers will vary. Consider making your own to show learners. Discuss any discrepancies.

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

Notes for the Facilitator: Establish priorities for policy makers to reduce e-waste generation, prevent improper treatment of e-waste, promote recycling, create green jobs in refurbishment and recycling sectors, quantify e-waste statistics or fund others to do so, and allocate adequate financial resources to e-waste related issues.

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

Introduction

E-waste has become a growing concern due to the potentially toxic components that are inside many electronics and electrical equipment (EEE). If electronics aren't disposed of properly, hazardous materials can leach out of electronics and pollute the environment. Many countries have national legislation about how e-waste should be safely discarded to reduce pollution from its harmful components. E-waste has also become an economic concern due to the wastefulness of valuable resources. Inside EEE there are valuable materials that can be reused if EEE are properly recycled.

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?

Notes for the Facilitator: Related information to help facilitate a discussion can be found at Export.gov (**https://bit.ly/3FNpgmK**) and the European Commission (**https://bit.ly/3FNSTUV**).

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

Notes for the Facilitator: Miners or others that are responsible for finding or sourcing the materials within electronics. Manufacturers that make the components of electronics in which hazardous materials are used. Also, those who work in facilities where electronics are recycled, as these individuals take electronics apart to reclaim materials from them.

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.

Notes for the Facilitator: A periodic table that displays elements found in EEE and other information described can be found on page 58 of The Global E-waste Monitor 2020 report at: **https://www.itu.int/en/ITU-D/Environment/Documents/Toolbox/GEM_2020_def.pdf**.

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

Notes for the Facilitator: A majority of elements are found in electronics.

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

Notes for the Facilitator: 9 elements found within electronics are precious, including: copper, ruthenium, rhodium, palladium, silver, osmium, iridium, platinum, and gold.

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

Notes for the Facilitator: Circuit boards in cars and computers contain gold. Silverware and jewelry can be made from platinum, silver, or gold. Wiring and older plumbing fixtures are often made of copper.

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?

Notes for the Facilitator: These elements can be extracted during the recycling process so they can be reused to make new products.

e. What happens if EEE isn't recycled?

Notes for the Facilitator: Electronics that are thrown away end up in landfills, where, if they break down, the elements within them are returned to the environment; this often takes a very long time. If electronics are neither recycled nor thrown away, the elements within them are neither recycled nor returned to the environment.

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)

Notes for the Facilitator: Discuss as a whole group what these items are and show pictures if possible.

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?

Notes for the Facilitator: Discuss that ore is where a valuable metal is found in profitable amounts naturally, and it is typically the ore that is mined, and from the ore that the material is extracted.

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

Notes for the Facilitator: Answers will vary. The elements are listed from left to right on the table, in general, from most concentrated to the least concentrated within products.

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.

Notes for the Facilitator: Copper, silver, and gold.

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

Notes for the Facilitator: Mobile phones.

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

Notes for the Facilitator: The amount of gold in electronics is greater than that in mined ore. A lot of ore would need to be mined to obtain the gold needed for electronics. For reference, the overall abundance of gold in Earth's crust is only 0.0013ppm (**https://www.rsc.org/periodic-table/element/79/gold**) and economic gold **ores are typically 1-10ppm** (note that 1ppm is equal to 1 gram per metric ton, so for a mine with 1ppm gold concentrations for each gram of metal, 1 ton of rock has to be excavated and processed).

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

Notes for the Facilitator: The same general trend that a lot of ore would need to be mined to obtain enough metals to make these products. While the concentration of silver in its ore is higher than the concentration of silver in two of the listed electronics, at 216ppm (or grams per ton), a half-metric ton of rock would still have to be processed roughly to supply that amount of metal.

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

Notes for the Facilitator: Copper is the most common metal in the electronics listed. Answers for why may vary but could include that copper is a good conductor of electricity, may be easiest to find in nature, or may be cheapest to mine. For comparison with the value given for gold above, copper has an overall abundance of 27 ppm in Earth's crust.

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?

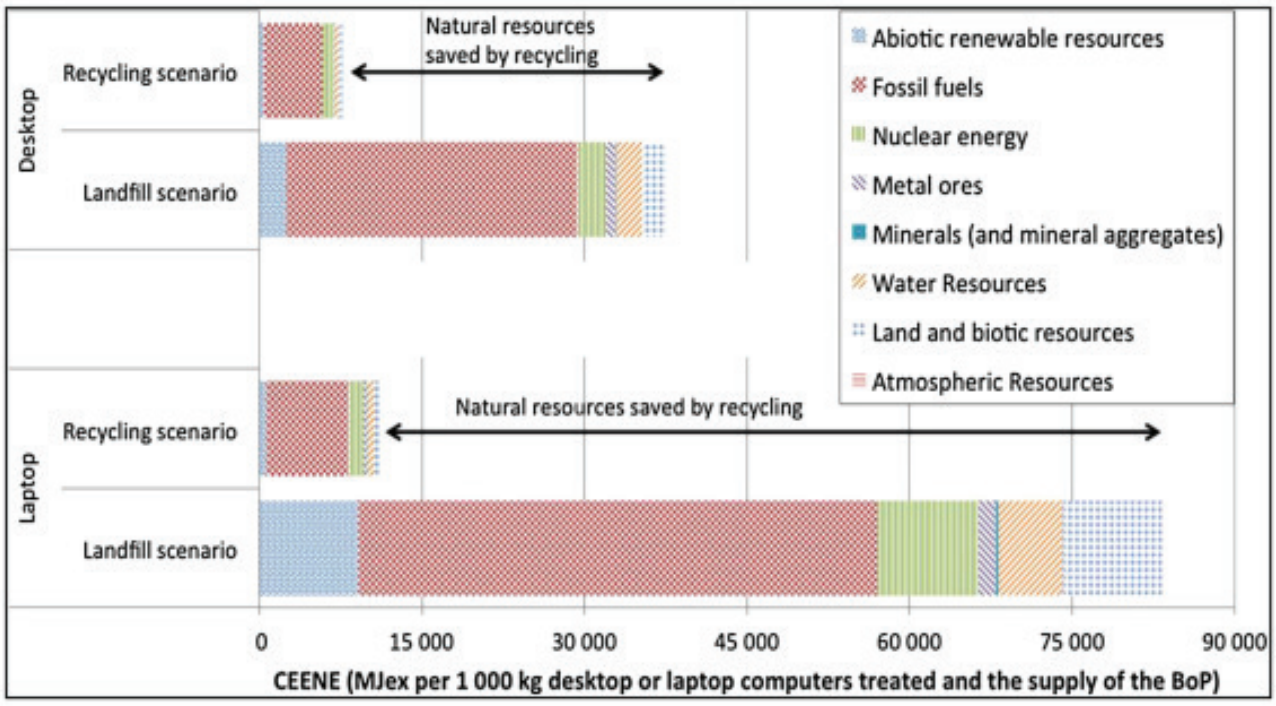
k. Notes for the Facilitator: Recycling electronics reduces the amount of new resources that need to be located and mined, which can be expensive and disruptive/destructive to the environment.

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



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?

Notes for the Facilitator: Aa laptop that is recycled has a CEENE score of about 12,000, while a laptop that is thrown away has a score of about 83,000.

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

Notes for the Facilitator: Every resource on the key except atmospheric resources are represented in the landfill scenario bar for the laptop. Every area of the bar on the graph is thinner for a recycled laptop versus one that is thrown away, so all types of resources are saved.

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

Notes for the Facilitator: Recycling a laptop would allow the parts and resources within it to be used to make other things. Less new resources would need to be used if recycled parts are being reused.

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?

Notes for the Facilitator: The laptop that is thrown away has a fossil fuel CEENE score of about 47,000, while the recycled laptop's fossil fuel CEENE score is around 8,000. The fossil fuel score for the laptop being thrown away is approximately 6 times (600%) higher than that for the recycled laptop.

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

Notes for the Facilitator: Each sector is larger for the laptop that is thrown away, approximately: 10 times (1000%) higher for abiotic renewable resources; 4.5 times (450%) higher for nuclear energy; about double for metal ores and minerals; 3 times (300%) higher for water resources; and 8 times (800%) higher for land and biotic resources.

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

Notes for the Facilitator: The CEENE score of a laptop is higher than that of a desktop, mainly due to the laptop's production using more fossil fuels. While both types of computers require significant fossil fuels for general transportation purposes, processing of reclaimed metals and plastics, the main difference is due to the extra energy and resources needed to process laptop batteries.

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?

Notes for the Facilitator: The CEENE score for a desktop that is thrown away is less than half that of a laptop that is thrown away. This is mostly accounted for by the use of fossil fuels, nuclear energy, and land and biotic resources. An important consideration is that the CEENE score is based on energy per 1000 kg of computer. An average desktop tower weighs more than a laptop. Fossil fuels are used in mining, processing, and manufacture of many of the components in laptop and desktop machines. Being smaller, laptops have higher concentrations of these materials per mass as well (**https://bit.ly/3U5UImU**).

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?

Notes for the Facilitator: Recommended precautions for EEE and hazardous material handlers include wearing personal protective equipment (PPE) such as goggles, masks, gloves, and so on; materials should be disassembled under appropriate conditions such as under a fume hood; properly contained during transportation, and safety measures should be in place in the event of an incident.

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

Notes for the Facilitator: Recycling EEE makes our world a more sustainable place as we are not using raw materials for a single-use and therefore are using resources more sustainably. When e-waste makes its way into landfills, components of EEE can be leached by water and contaminate soil and groundwater, can react chemically with other materials in the landfill, vaporize, and contribute to uncontrolled fires.

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.

Notes for the Facilitator: Costs were pulled from **https://www.indexmundi.com/commodities/** and **https://tradingeconomics.com/commodities** and compiled on 1/13/2022.

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

Notes for the Facilitator: To calculate the total cost, multiply each material's amount of e-waste by its market price, then add together all of these values.

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

Facilitator Background

Connection to SDG 12: Target 12.8 calls for people everywhere to "have the relevant information and awareness for sustainable development and lifestyles in harmony with nature" (**https://sdgs.un.org/goals/goal12**). An initial step all individuals can take to live more sustainably is to assess the amount of greenhouse gases that are emitted by lifestyle choices, which can be calculated as carbon *footprint*. Individuals can then adjust their lifestyle to reduce their carbon footprint. Businesses, schools, public buildings, and others can also assess their carbon footprint and work to reduce it. In this Investigation, learners will analyze their carbon footprint and become more aware of the impacts of their daily choices.

Key Concepts: *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.

Connect to the ESD Kit Project: Designing an environmentally conscious store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners can consider how their store will have a low carbon footprint.

PACING GUIDE

PREPARATION
10 minutes reading through the Investigation
5 minutes copying the handout

WHAT TO DO
20 minutes for steps 1 and 2
20 minutes for remainder of Investigation

Introduction

Every person, organization, and product directly release greenhouse gases or indirectly affects the release of greenhouse gases to the atmosphere. The most common greenhouse gases released by human activities are carbon dioxide (79% of emissions), methane (11% of emissions), and nitrous oxide (7% of emissions). The total amount of greenhouse gas emissions resulting from the actions of an individual (or an event, or business) can be estimated. While not all greenhouse gases contain carbon like carbon dioxide and methane do, and some greenhouse gases are "stronger" (have a higher "global warming potential") than others, a *carbon footprint* tries to estimate the overall impact of all greenhouse gases as if they were released as carbon dioxide. An item or person with a high carbon footprint negatively impacts the environment more than an item or person with a low carbon footprint. Three general areas that have been determined to be the main contributors of greenhouse emissions are household, food, and transportation.

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.

Notes for the Facilitator: Give the learners time to fill out the handout on their own.

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?

Notes for the Facilitator: Facilitate a class discussion about the assessment, what contributes to carbon footprints, learners' answers and scores, and solutions learners could take to reduce their carbon footprint.

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?

Notes for the Facilitator: Answers will vary. Heating and cooling is often a major contributor to the carbon footprint of a building. Installing automatic thermostats, using heavy window blinds, changing the materials the building is made of or its exterior color might be some adjustments that could lower the building's carbon footprint in terms of temperature control.

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?

Notes for the Facilitator: Meat products have large carbon footprints because animals like cattle and sheep produce methane gas, which all ends up in the atmosphere. They are also consumers which means they have to eat plants to obtain the energy they need. The energy from plants is then converted into an animal's mass but energy is lost between each trophic level (or link in the food chain). The land, water, and energy needed to grow plants for direct consumption by humans is often significantly less than for the same number of calories obtained from eating an animal that had to eat plants (it gets worse the higher up in the food chain an animal). Additionally, it takes more energy to process the animals for consumption. There are lots of online articles on this topic and they are all generalizations that make specific assumptions so if you look for specifics you are likely to find conflicting numbers. However, the basic facts about the loss of energy through the food chain will always be true. Regarding the carbon footprint of meat products, there is interesting research being conducted on ways to reduce the methane production by ruminants like cattle and sheep and it is also important to consider that grazing/feeding practices can vary substantially by region and may have a significant impact on overall footprint (in other words, not all food of the same type has the same footprint).

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)

Facilitator Background

Connection to SDG 12: Target 12.6 aims to "Encourage companies, especially large and transnational companies, to adopt sustainable practices" (**https://sdgs.un.org/goals/goal12**). A way for companies, businesses, and individuals can improve their sustainable practices is to use energy efficient products, appliances, and processes. A product that is used everywhere is the light bulb. They light up rooms, stadiums, parking lots, and so on when it is dark. They signal drivers, airplanes, boats, and so on, letting them know when and where to move. They also identify when appliances, electronics, and so on are running or are turned off. Using the energy efficient light bulbs would reduce energy waste and therefore boost *sustainable consumption*. Energy-efficient lighting would also reduce *e-waste* due to being more durable and therefore also help improve *sustainable production*. In this Investigation learners will examine different types of light bulbs to recognize how energy can be wasted and determine the most efficient type of light bulb.

Key Concepts: *sustainable consumption, sustainable production, e-waste*

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.

Connect to the ESD Kit Project: Designing an environmentally conscious store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners can consider incorporating energy efficient products into their store and possibly into their inventory of goods to sell.

PACING GUIDE

PREPARATION

10 minutes reading through the Investigation

10 minutes setting out materials for groups

WHAT TO DO

40 minutes for the Investigation

Introduction

Lighting accounts for 15% of electricity consumption worldwide.[1] Light bulbs convert electricity into light. Some types of bulbs do this more efficiently than others. By using more efficient light bulbs people can reduce energy consumption. Light bulbs generate heat as well as visible light. Since the purpose of a light bulb is to emit light, the heat is wasted energy. To compare the efficiency of various

light bulbs two measures are examined: 1) How much electricity is consumed. and 2) How much light is emitted. The measure of electrical power is the watt (W). The measure of light is the lumen (LM). When you buy a bulb, the package typically indicates values for both these measures. These numbers may also be printed on the bulb itself.

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

Notes for the Facilitator: This Investigation can use any types of light bulbs. If possible, include incandescent, LED, and fluorescent bulbs for more varied results and a rich discussion of light bulb efficiency. The description of this activity assumes that you are familiar with how the micro:bit works. If not, the Appendix About micro:bit has pointers to information and tutorials to get you started.

What to Do

1. Think about light used in buildings.
   a. What types of lights are there in the room?

Notes for the Facilitator: lamps, overhead lights, the windows to let in the sunlight, etc.

   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?

Notes for the Facilitator: Lights in a classroom are generally fluorescent tube lights whereas lights at home are generally incandescent, compact fluorescent (CFL), which is a similar technology to the fluorescent tubes but CFLs fit standard sockets and don't need a separate ballast), or LED bulbs. Fluorescent tube lights are also used in some homes, particularly in kitchens, workshops, garages, or basements.

   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.

Notes for the Facilitator: Provide groups with the packaging from the bulbs or information from the packaging if possible. It may be helpful to call out any language about "watt equivalent" or "watt replacement" on the packaging for CFL and LED bulbs. This is provided to help consumers more familiar with the light provided by incandescent bulbs pick a replacement but does not reflect the watts consumed by these more efficient bulbs.

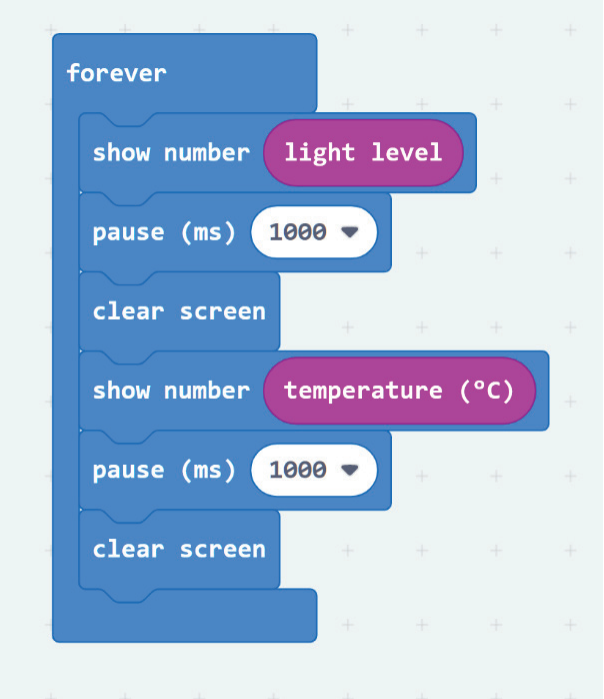
5. Calculate the number of lumens per watt by dividing the lumens by the number of watts for each bulb. This is a measure of the bulb's efficiency. A greater number of lumens per watt means the bulb is converting more of the electricity it consumes into light compared to a bulb that generates fewer lumens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

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

Notes for the Facilitator: Lead a class discussion about the different types of bulbs in the room; differences in bulbs in terms of appearance, lumens, watts, and so on; the calculated efficiencies of the bulbs; and how the efficiencies of the bulbs compare to each other. If comparison includes turning the lights on, unless care was made to select bulbs with the same color temperature (e.g., soft white, warm, daylight, or temperatures given in Kelvin, may be used on packaging to reflect this), the color of light from the bulbs may be very different. Bulbs of all types are available in different temperatures so learners should not worry too much about differences in the color of the light.

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:*

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

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.*

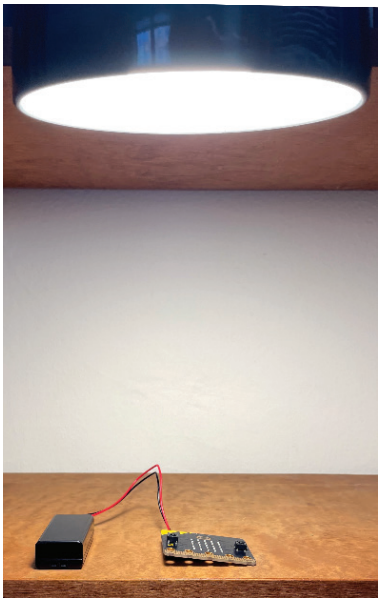
Notes for the Facilitator: While fluorescent and LED bulbs are much cooler than incandescent bulbs, they do generate heat and should be handled with care.

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

Notes for the Facilitator: The micro:bit can safely operate at temperatures up to 70° C, but there is no reason to allow it to go higher than 45° C since the point of the activity will be clear.

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?

Notes for the Facilitator: Answers will vary depending on the bulbs tested.

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

Notes for the Facilitator: Answers will vary depending on the bulbs tested. The incandescent bulb should have the largest rise in temperature.

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

Notes for the Facilitator: Answers will vary depending on the bulbs tested. Incandescent bulbs should be ranked the lowest for efficiency since they give off the most heat. Learners should include heat emitted and light emitted in their evidence.

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

Notes for the Facilitator: The materials used to create the different types of light bulbs vary, although most contain glass and metal. Incandescent bulbs also contain a nonreactive (inert) gas, while CFL bulbs contain a small amount of mercury. In addition to the mercury vapor in CFLs, both CFLs and LEDs involve electronics which use significant amounts of other toxic and valuable metals. Since these materials can be hazardous, CFL and LED bulbs are harder to recycle compared to incandescent bulbs (which still may require special recycling processes due to the mixture of metal and glass).

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.

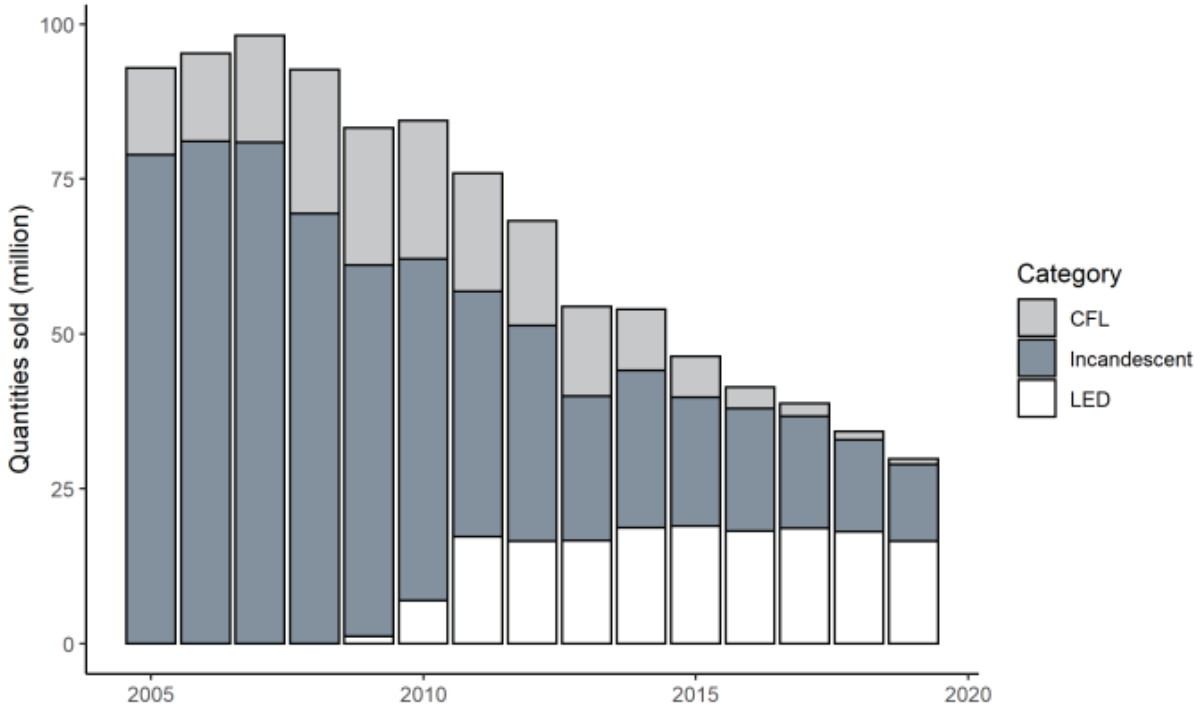


Figure 3: Quantity of light bulbs sold over time

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?

Notes for the Facilitator: The number of light bulbs sold has decreased between 2007 and 2019. The lifetime and durability of LED and CFL bulbs are much longer than incandescent bulbs. Therefore, the frequency of light bulb purchases decreased. This should be a global trend. Learners may think the population in Japan decreased and therefore the need for light bulbs decreased. However, the Japanese population did not change much between 2005–2019. If the learners cite a possible population decrease, they may think this trend is specific to Japan.

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.

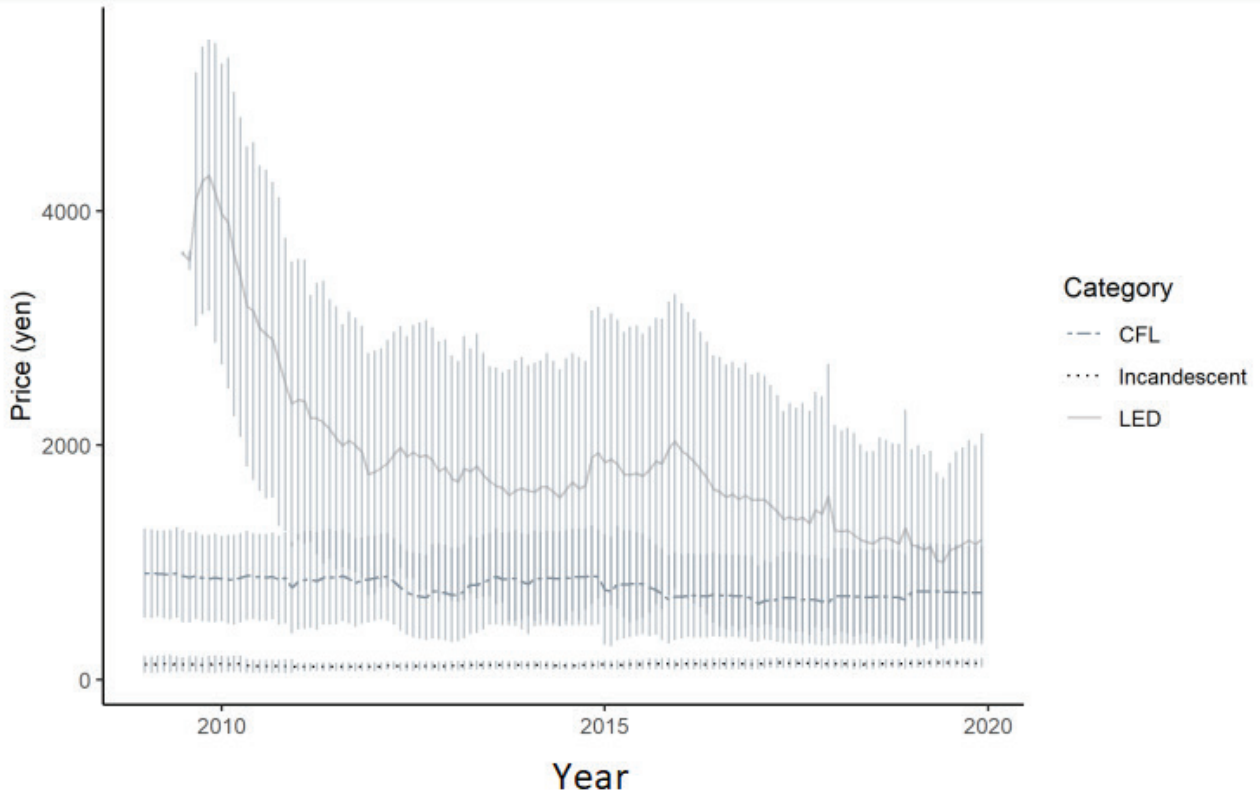


Figure 4: Price of light bulb products over time

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?

Notes for the Facilitator: The price of CFL and incandescent bulbs has remained the same and the price of LED bulbs has decreased.

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?

Notes for the Facilitator: Although the cost of LED and CFL bulbs are higher than incandescent bulbs, they are more cost efficient in the long run. They last longer and therefore consumers don't need to purchase LED or CFL bulbs as often. Also, the energy cost is lower since LED and CFL bulbs utilize the energy use mostly for light whereas incandescent bulbs have energy loss through heat production.

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?

Notes for the Facilitator: Incandescent bulbs are built to use electricity to heat their metal coil, which, in turn, generates light. This is why incandescent bulbs get so warm. Other lightbulbs rely on other ways to produce light, such as chemical reactions, as in a CFL bulb.

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.

Notes for the Facilitator: A good source of information on the EM that you may want to share with learners can be found at: **https://www.uib.no/en/hms-portalen/75292/electromagnetic-spectrum**.

ESD KIT: CONSUMING SUSTAINABLY

Sustainable Development Goal 12: Responsible Consumption and Production

INVESTIGATION 7A: NATURAL VS. SYNTHETIC

Facilitator Background

Connection to SDG 12: Target 12.4 tasks us with achieving "environmentally sound management of chemicals and all wastes throughout their life cycle" (**https://sdgs.un.org/goals/goal12**). Using natural materials instead of synthetic materials could eliminate the need to deal with *hazardous waste*. In the fashion industry, producers could choose natural fabrics and dyes over synthetic, human-made products, which would greatly reduce waste to the environment. In this Investigation, learners will analyze different natural and synthetic materials to understand why producers may choose to use certain materials.

Key Concepts: *hazardous waste*

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

Connect to the ESD Kit Project: Designing an Environmentally Conscious Store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners can consider whether their store will use natural or synthetic materials and the environmental effects of each option.

PACING GUIDE

PREPARATION

10 minutes making copies of handouts
10 minutes setting up materials for groups
10 minutes preparing staining solutions
30 minutes preparing Demonstration #2, 4 weeks in advance

WHAT TO DO

40 minutes for Investigation 7A1
10 minutes for Facilitator Demonstration 1
5 minutes for Facilitator Demonstration 2
30 minutes for Investigation 7A2
20 minutes for Investigation 7A3

INVESTIGATION 7A1: ANALYZING FABRICS

Materials

For Facilitator Demonstration #1:

- fume hood or a well-ventilated area
- small, 2 cm x 2 cm (about 1" x 1"), pieces of fabric used in the Investigation
- long tongs or a ring stand and clamps
- matches or a lighter

For Facilitator Demonstrations #2:

- small, 2 cm x 2 cm, pieces of fabric used in the Investigation
- glass or plastic containers (1 L beakers, large food containers, buckets etc.), one for each fabric used in the Investigation
- potting soil
- water

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)

Notes for the Facilitator: Prepare the stain solutions by mixing ketchup with water and mustard with water until smooth and thin enough that they can be transferred using pipettes. Prepare for the Facilitator Demonstration #2: Decomposition Demonstration. Bury each fabric in potting soil 4 weeks ahead of doing the Investigation with learners. Keep the soil moist and the samples in a warm environment, if possible.

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.

Notes for the Facilitator: If learners are having trouble thinking of fabric types, they can check the tags on their clothes and other cloth items in the room (e.g., backpacks, cleaning cloths, curtains).

   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.

Notes for the Facilitator: There are five major natural fibers and 23 synthetic fibers commonly used in garments or household items. Natural fibers can be animal-based like silk and wool, or they can be plant-based like cotton, linen, and bamboo. Some common synthetic fibers include acetate, acrylic, lyocell, nylon, polyester, polypropylene, polyvinyl chloride (PVC), rayon, and spandex. GlobalSpec provides a more complete list of synthetic fibers and fabrics and related information (https://bit.ly/3FQRn4z). Fabric can be made using one type of fiber or made with multiple types of fibers and would be called a blended fabric.

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.

Notes for the Facilitator: Rubbing the PVC pipe with fabric will cause a buildup of charges on both the fabric and the pipe. Students will experiment with the buildup of charges on the fabric. Learners can experiment with the buildup of charges on the pipe by placing it near, but not touching running water, their hair, or an aluminum can.

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.

Facilitator Demonstration 1:

1. Burning Fabrics: Under a fume food or in a well-ventilated area, hold a small piece of fabric using tongs or secure it using a ring stand or similar.

2. Light the fabric and have the learners make observations.

3. If possible to do safely, stop the burning (by blotting it on a fire blanket or similar) once a third or so of the fabric has been burned. Have the learners take observations of the burned fabric.

4. Repeat for all fabrics used in this Investigation. Safety Note: some fabrics produce harmful gases when burned, so it is important to conduct this demonstration under a fume hood or in a well-ventilated area.

Notes for the Facilitator: Share the procedure with learners before showing the results. When natural fabric is burned, it will turn to ash, while most synthetic fabric will melt. Some synthetic fibers will also ignite.

Facilitator Demonstration 2:

1. If you prepared the decomposition demonstration, unearth the results or have the learners unearth the results. Learners can either examine the results themselves in rotating groups, or you can share the results as a class.

INVESTIGATION 7A2: ANALYZING DYES

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

Notes for the Facilitator: This Investigation will work with dye, but inks may produce more vibrant results due to being more concentrated. An example of a dye set ideal for this Investigation might include 3 red (1 natural and 2 synthetic) and 5 blue (2 natural and 3 synthetic) dyes. In place of dye, ink bottles or marker ink can also work. The process of chromatography works best with acetone but will also work with isopropanol or water instead. The chromatography strips should be cut so that they will hang from a rod at the top of the container and just touch the chromatography solution.

Credit: L.Brase

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

Notes for the Facilitator: Dye can be made from natural or synthetic materials. Different materials can be used to create natural dyes of the colors above such plants, seeds, grass weeds, leaves, stems, roots, flowers, insects, and minerals.

Introduce the next activity by describing chromatography, which is a method by which a substance can be separated into the components that make it up. The solvent (acetone or water in this Investigation) uses capillary action to travel up the chromatography paper. As it travels, it moves the smaller, lighter components added to the paper up the paper faster than the heavier, larger components. This separates the lighter and heavier components, allowing them to be seen separately.

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.

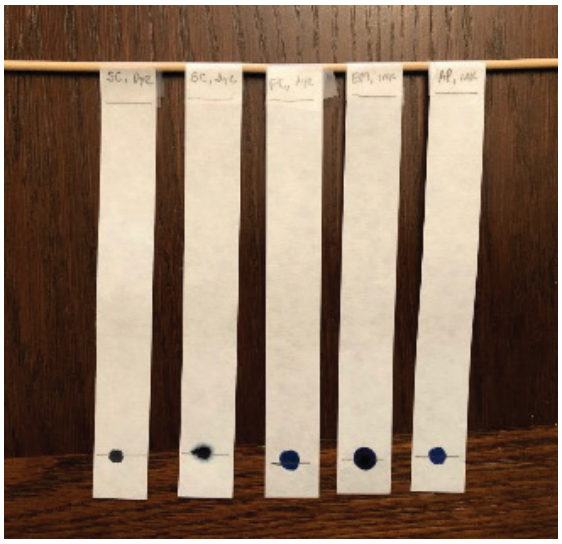
Credit: L.Brase

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.

Notes for the Facilitator: In the images, five different blue dye were examined. Learners should test the same color samples in the same container. If there is room to test multiple colors at the same time, instruct them to do so. Alternatively, if learners are working in groups, each group can test a different color.



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.

Notes for the Facilitator: The acetone moves up the strips via capillary action, which is due to the attraction between the acetone and the fibers that make up chromatography strip.

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

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

Notes for the Facilitator: All learners examine the same color dyes, or have different groups examine different colors. Multi-fiber fabric has a variety of fabrics together. The handout "Dyeing Multi-Fiber Fabric" is set up for a six layered multi-fiber fabric. Adjust the tables as necessary to match the fabric the learners will use. Alternatively, you can also use swatches of different types of fabric, just make sure learners leave the swatches in the dye for the same amount of time.

Each group will need a container with natural dye, and a container with the same color synthetic dye. To reduce the occurrence of unwanted staining of clothing, it would be best for the facilitator to prepare these containers instead of the learners. Follow the instructions as directed on the dye containers. Unless instructed by the directions on the dye, dyes at room temperature will be sufficient although dyes that are warm or hot (above 20˚C (about 70˚F)) will produce more vibrantly colors.

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.

Notes for the Facilitator: If different groups looked at different colors, you could have learners observe each other's results before discussing as a 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.

Notes for the Facilitator: Answers will vary. Learners should discuss the relative amounts of dye each fabric took up.

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.

Notes for the Facilitator: Answers will vary. Learners should use evidence from their observations as support for their claims.

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

Notes for the Facilitator: Benefits of natural fibers/fabrics could include having a lower carbon footprint than synthetic fibers, durable, absorbent, insulated, and hypoallergenic. Drawbacks include being costly or potentially more expensive than synthetic fabrics, absorbent, and less stain resistant. Availability of the plant or animal materials used to make these fibers may also be a drawback, since they take time to grow. A limitation of natural fibers is you aren't able to change the fibers to fit a need.

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

Notes for the Facilitator: Synthetic fibers and fabrics differ widely and are created for a specific purpose. Some synthetic fabrics are stain-resistant or waterproof, and most are usually cheaper than natural fabrics. Some drawbacks include a high carbon footprint, and they are essentially plastic and so therefore won't decompose when discarded.

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?

Notes for the Facilitator: Natural fibers are generally the more sustainable option when compared to synthetic fabrics. They require far fewer chemical additions during production and usually require less water (although cotton does require a lot of water to farm and produce). Natural fabrics are usually more durable, which means less fabric in general is consumed. Natural fabrics also decompose when discarded.

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?

Notes for the Facilitator: Answers will vary depending on colors, inks, and dyes used. In test runs, the synthetic dyes and inks had more separation between colors due to a higher number of ingredients and therefore molecule sizes/travel ability. The natural dyes/inks tended to cluster more and due to less ingredients and therefore similar traveling ability of the molecules. Other information that could be useful would be the ingredients or a materials list that makes up each dye or ink.

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

Notes for the Facilitator: A benefit of using natural dyes, and materials in general, would be the lower environmental risk when dyes or materials that are dyed are disposed of since they are biodegradable. While "natural," plant and animal-derived dyes can be toxic or cause allergic responses. A drawback of using natural dyes could be the expense as usually natural dues are more costly at a commercial scale and can sometimes require more water and energy use. Additionally, natural dyes can take more time and sometimes resources (particularly land) to produce as plants or the natural material needs to grow and then be harvested. Note that natural dyes require mordants, or additional chemicals that help the dye bind to the fabric and some of these are quite toxic. Another limitation is that natural dyes do not work as well on synthetic fibers. There is also a limit to the types of colors you can get from natural sources.

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

Notes for the Facilitator: Synthetic dyes are usually much cheaper than natural dyes. They also can usually be used on a variety of fabrics, whereas some natural dyes are more limited in their application. Synthetic dyes are more light-fast and thermally stable and usually more consistent since they don't rely on natural materials, which inherently have more variety. They can also be used to create many colors not possible from natural dyes. Synthetic dyes are human-made compounds traditionally derived from petrochemicals (although more recent research is looking into developing synthetic dyes from more sustainable, plant-based chemicals) and are classified based on their solubility and chemical properties. While some are classified as being safe for use in human foods, others have distinct human health impacts and can cause skin irritation, cancer, or genetic mutations. When used industrially, significant environmental harm can occur when dyes are released into local water systems. Dye releases used to be common in the United States (the Nashua River was infamous for this) and such releases still occur in other countries; you could tell what color materials are being dyed based on the color of the river that day. These dyes decrease the transmission of sunlight through water, which can decrease photosynthesis and reduce dissolved oxygen levels, and alter the water pH. Released in large quantities in waste water, dyes can accumulate on lands and in rivers, or get concentrated in upper levels of the food chain through biomagnification, which cause ecological problems. There is active research into using microbes to biodegrade these chemicals and reduce the environmental burden.

Extensions

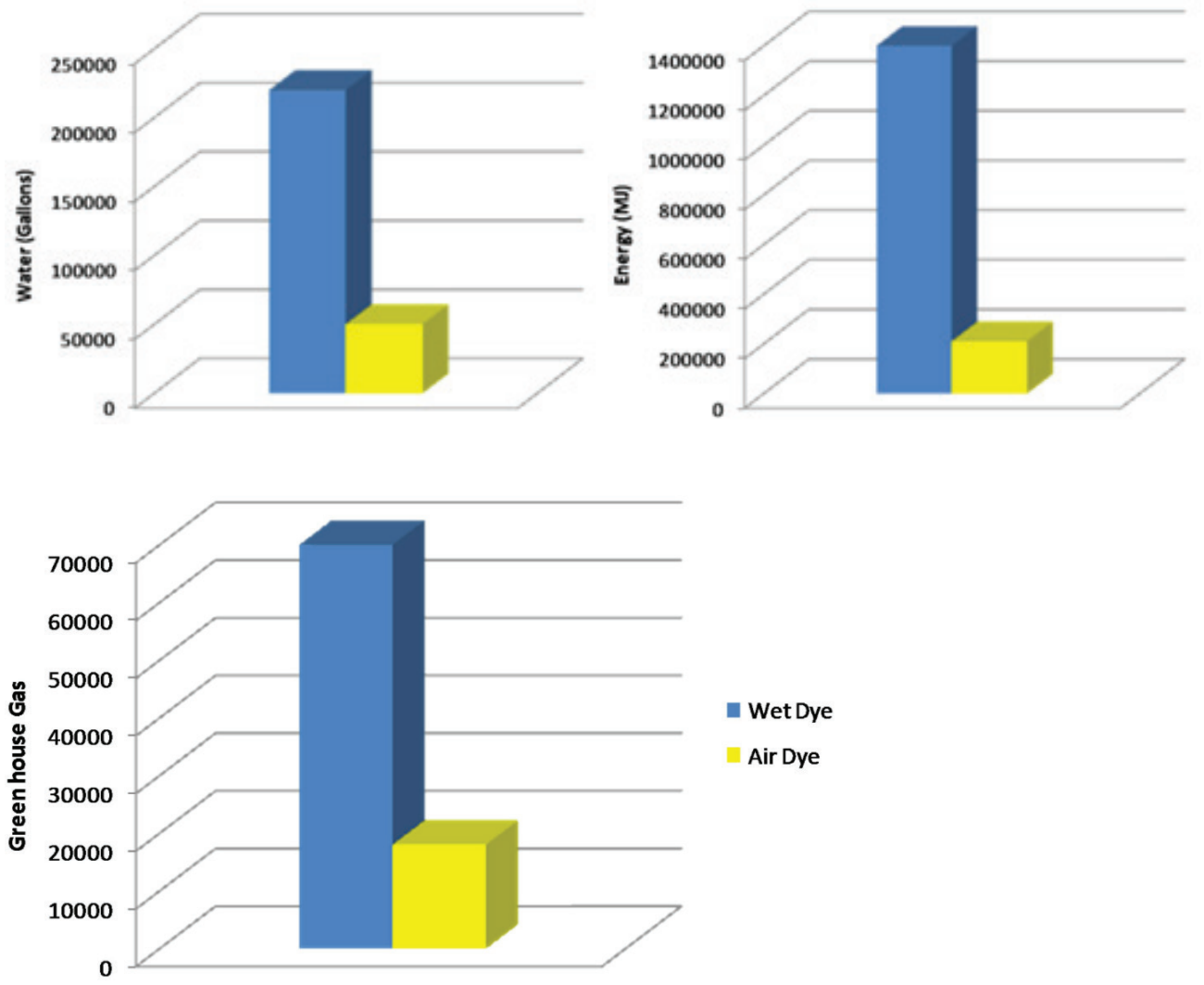
1. **Testing Variables:** Obtain a small piece of clothing, like socks or a bandana, made mostly from natural materials like cotton, linen, and so on. Write down all the materials from the tag. These will be your experimental variables. Make a prediction about what would happen if you buried it under 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.

Notes for the Facilitator: Some scientists are doing a similar experiment using underpants to assess soil health. These experiments can be discussed with attention to what kinds of fabrics are used and why. For example: **https://bit.ly/38umaYw**, **https://bit.ly/3sHzDTF**, **https://bit.ly/3FSh2tj**.

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**

Notes for the Facilitator: Wet dye requires more water and energy and causes a greater production or release of greenhouse gases than does air dye. Air dyeing is more sustainable because it has less of a negative effect on the environment.

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?

Notes for the Facilitator: Some direct impacts include health diseases like respiratory problems, asthma, allergy, nausea, skin and eye irritation that are caused by contacting textile dyes that are released in the air or into the soil.

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

Notes for the Facilitator: Some indirect impacts include health diseases such as heart diseases and gene mutation which are caused indirectly through the food chain. Textile dye enters the food chain through a water source, soil, plants, microorganisms, or animals.

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

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

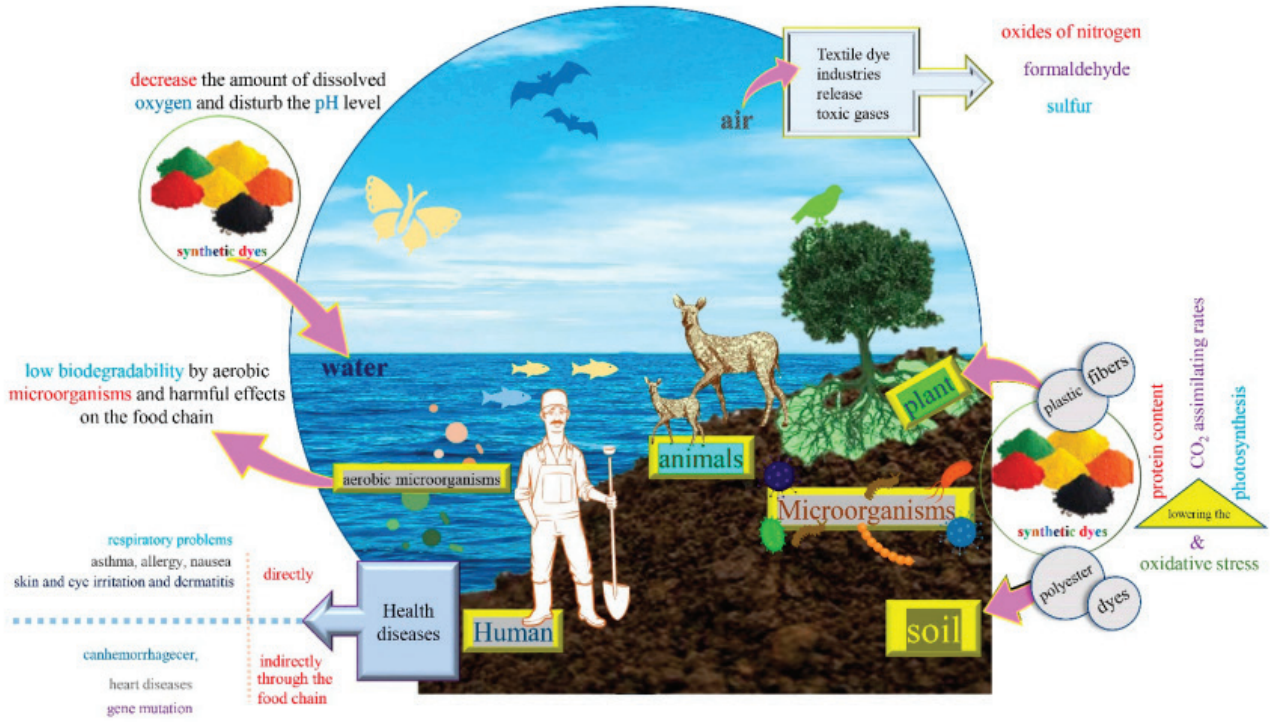


Figure 2. Direct and indirect impacts of textile dyes on several substrates.

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)					
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)

Facilitator Background

Connection to SDG 12: Target 12.5 calls for a substantial reduction in "waste generation through prevention, reduction, recycling, and reuse" (**https://sdgs.un.org/goals/goal12**). The fashion industry is a leading waste contributor and has high *material consumption* and carbon *footprint* during the production, usage, and disposal of fabrics. Certain fabrics are derived from *fossil fuels*, which is also harmful to the environment. In this Investigation, learners will examine data around the fashion industry, sometimes analyzing data *per capita*, to learn about *sustainable consumption* and *sustainable production* best practices.

Key Concepts: *material consumption, footprint, fossil fuels, per capita, sustainable consumption, sustainable production*

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.

Connect to the ESD Kit Project: Designing an Environmentally Conscious Store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners can consider implementing best practices related to fabrics.

PACING GUIDE

PREPARATION

5 minutes making copies of the handout, "SANVT Infographic"

10 minutes printing copies of "Potential Sources and Major Possible Transfer Pathways of Microfibers" diagram from **https://bit.ly/3TaVvmc**

WHAT TO DO

30 minutes for the Investigation

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.

Notes for the Facilitator: The lifecycle and environmental impacts of a cotton t-shirt are described in a Ted-Ed video (**https://www.youtube.com/watch?v=BiSYoeqb_VY**).

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).

Notes for the Facilitator: Energy consumption could include fiber production, yarn production, fabric production, wet treatment such as bleaching and dying, confectioning (or construction), wholesale transport, distribution, retailing, use transportation, use-phase laundry, and end of life management (e.g., disposal, recycling). Most energy use occurs prior to retail sale. Figure 2 in Peters et al. 2021 (**https://bit.ly/3FNZe2K**) details the energy consumption during garment lifecycles.

2. Have you heard of the term ”fast fashion”? What do you think it means? What may be an example of fast fashion?

Notes for the Facilitator: Fast fashion is the mass production of cheap, disposable clothing by producers and excessive consumerism by consumers. Garment quality is declining, so our clothing looks more faded, shapeless, or worn out after less time. Also, trends and clothing collections are changed quickly so people are encouraged to continually purchase new items to stay up to date.

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?

Notes for the Facilitator: Most countries that are yellow, orange, or red are those colors for more than one factor. Wages and income seems to be directly correlated to textile expenditure. Energy consumption and GHG emissions also seem to have the same trend as textile expenditure.

b. Examine map e) Textiles Expenditure. Which countries spend the most money on textiles? Why do you think this is?

Notes for the Facilitator: Australia and countries in North America and Europe spend the most on textiles. There is a correlation between wealth and textile consumption, as seen in Figure e) and f).

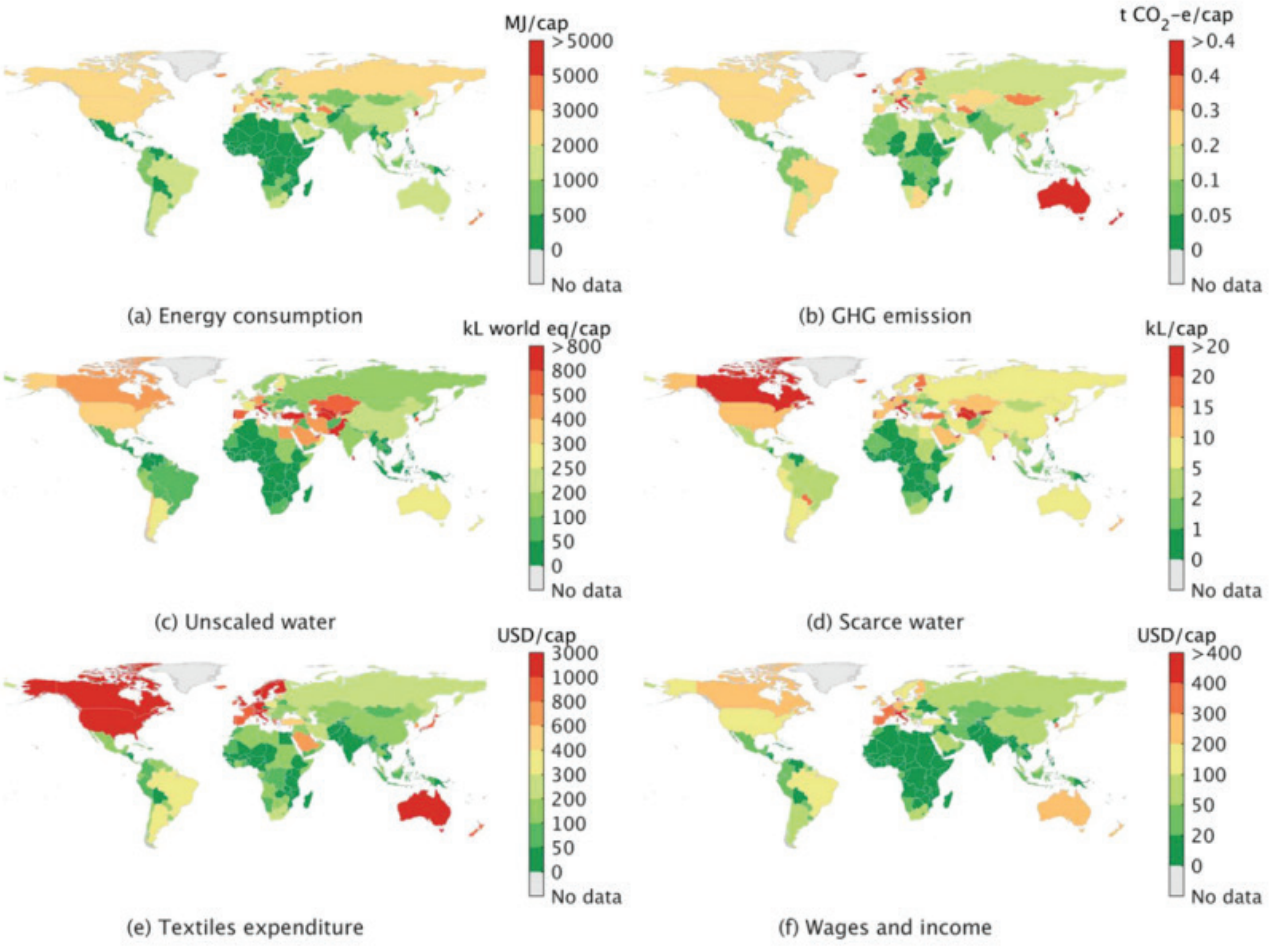
c. Examine the continent where you live. Compare your continent to others for each map.

Notes for the Facilitator: Answers will vary by location.

d. Using evidence from the maps, predict which continents or countries likely have the largest “fast fashion” industry. Explain your answer.

Notes for the Facilitator: Countries that spend more on textiles may be more likely to have fast fashion, because this requires people to buy clothing more often, which would lead to more spending.

PER CAPITA FOOTPRINTS FOR THE CLOTHING AND FOOTWEAR SECTOR IN 2015



nts of 189 countries for the clothing and footwear sector in 2015. (a) Energy (b) Carbon, (c) (unscaled) water use, (d) AWARE-scaled ector, (f) wages and income.

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.

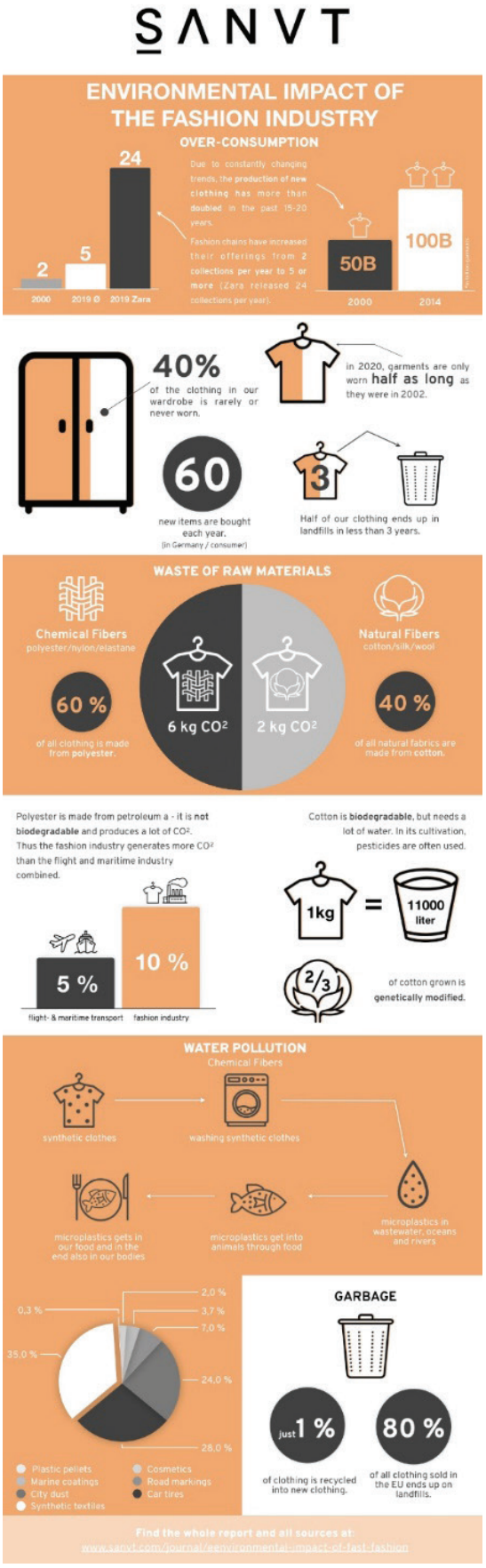
Notes for the Facilitator: Answers will vary.

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

Notes for the Facilitator: Making clothing that lasts longer would reduce energy and raw material usage. Longer-lasting clothes or repurposing old clothing would also cut down on the amount of trash ending up in landfills. Using natural materials to make clothing would better ensure that they break down when thrown away.

   c. What are you still left wondering?

Notes for the Facilitator: Discuss the infographic and the questions with the whole group.



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?

Notes for the Facilitator: Textile consumption has increased from 15 million metric tons to 90 million metric tons.

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

Notes for the Facilitator: The use of cotton has risen slightly over time, but the percent of textiles made of cotton has decreased from 70% to 30%. Factors causing cotton use to decrease could include cost to grow, harvest, or produce clothing with it.

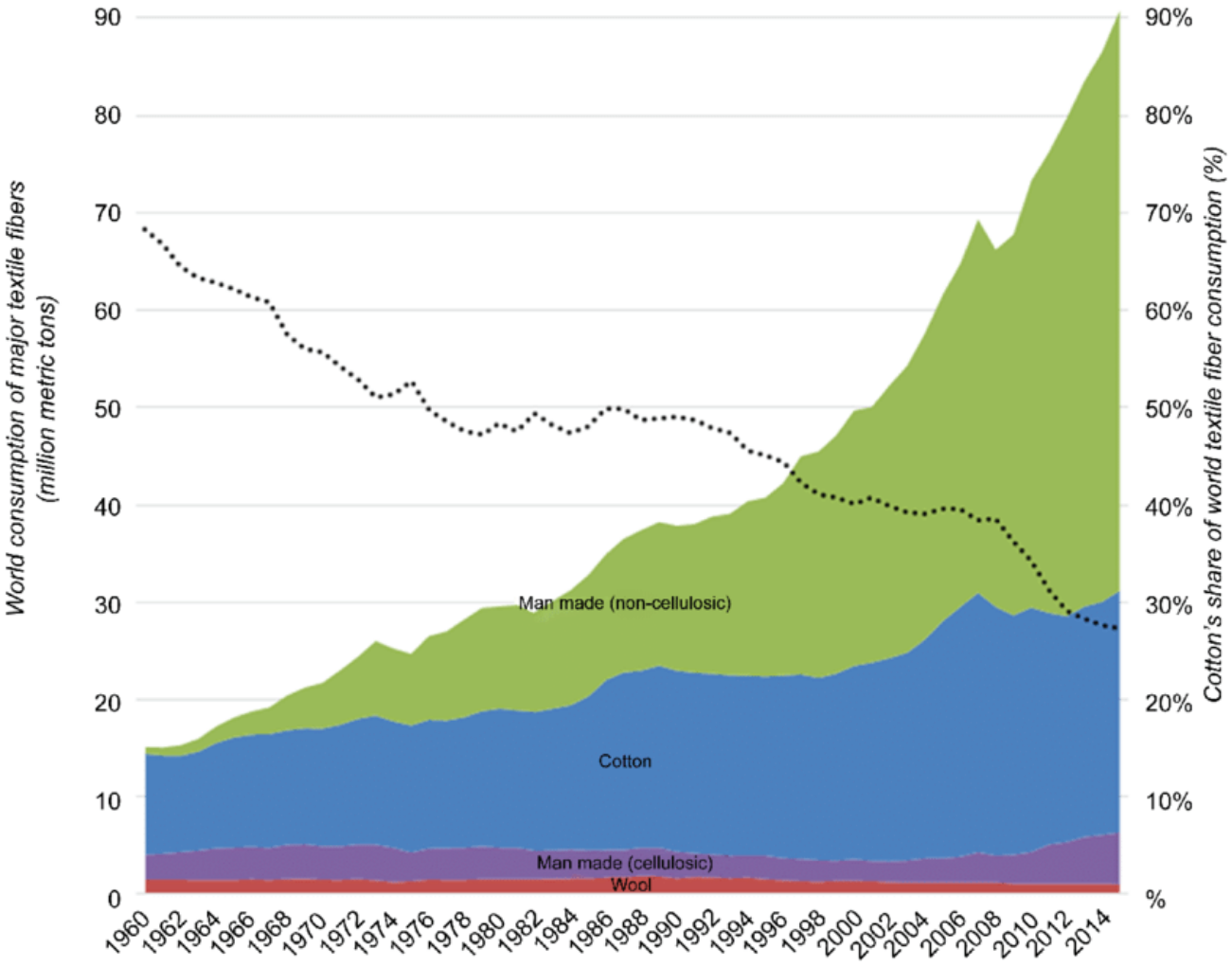
   c. How has the world consumption of man-made (cellulosic) textiles changed throughout the years?

Notes for the Facilitator: The relative amount of these textiles has stayed the same over time. Such fibers are made from wood pulp, with rayon/viscose, lyocell, acetate, modal, and others

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?

Notes for the Facilitator: Non-cellulosic textile use has increased from about 2 million metric tons to 60 million metric tons, while the use of man-made cellulosic fibers has remained about the same. Non-cellulosic textiles may be cheaper or easier to produce than cellulosic textiles.

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?

Notes for the Facilitator: Polyester production has grown from approximately 5 million tonnes per year to 55 million tonnes per year.

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

Notes for the Facilitator: Polyester production has increased more than any other fabric type between 1980–2015.

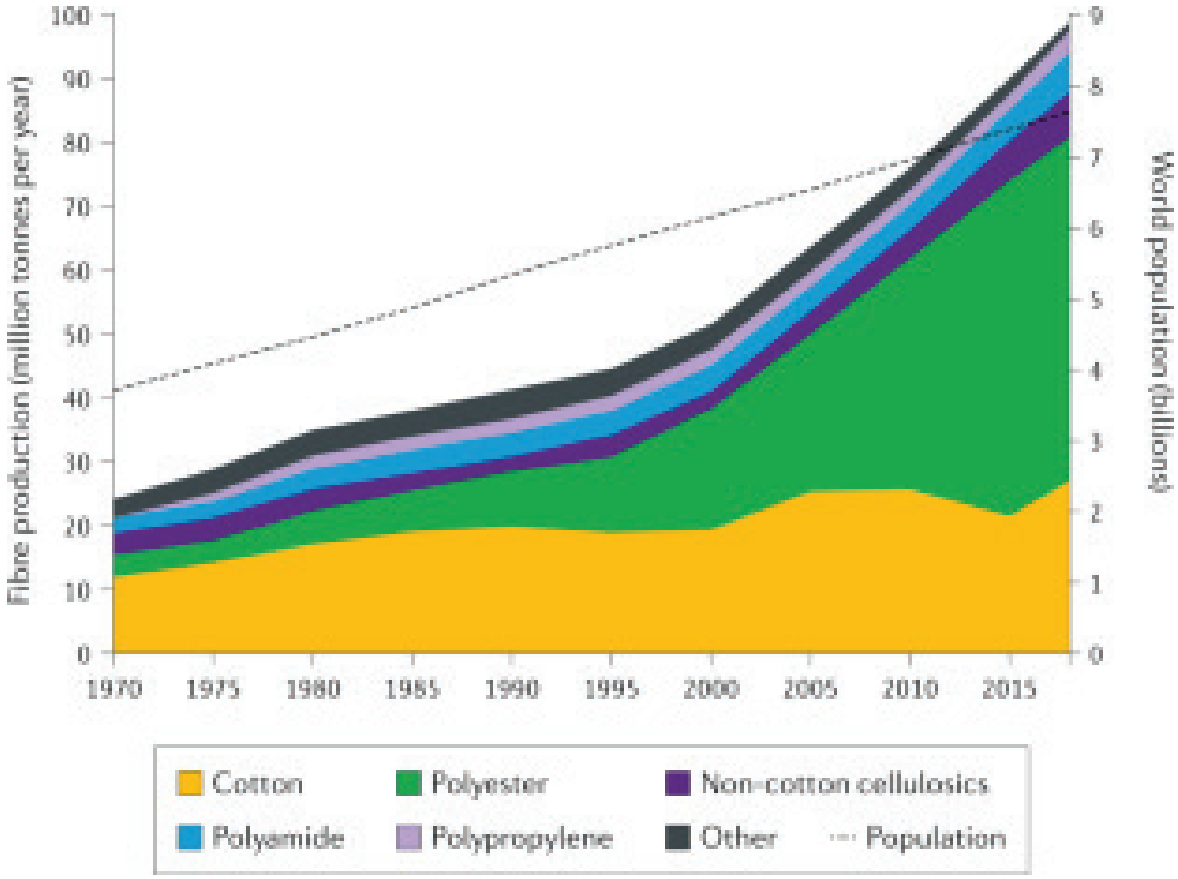
    c. Examine the total production of fabrics and the global population between 1970 and 1995. What do you notice?

Notes for the Facilitator: The world population has grown consistently from 1970–1995, as shown on the graph. Fabric production rose at about the same rate during this time.

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

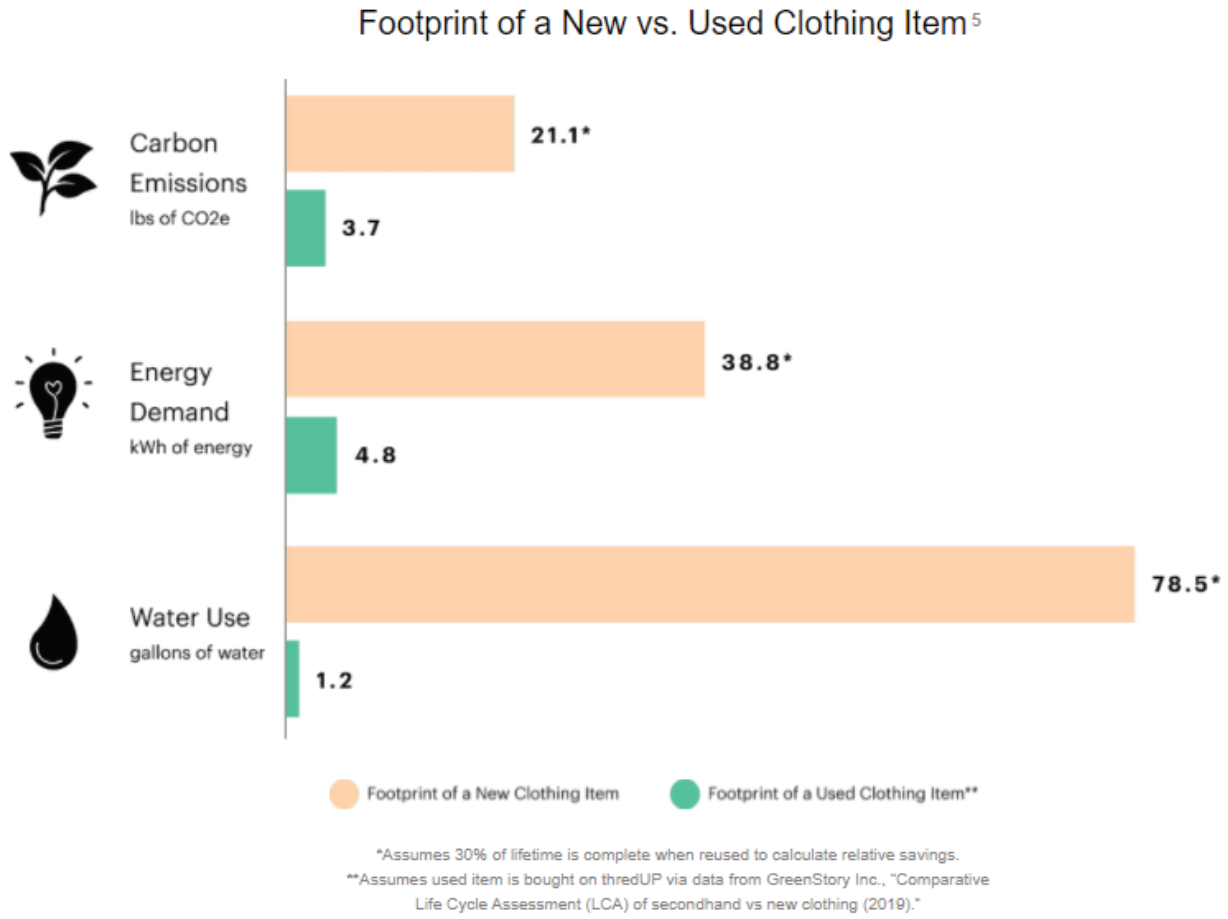
Notes for the Facilitator: Between 2000 and 2015, the overall production of fabric has increased much more quickly than the rate of population growth, mainly due to an increase in polyester production.

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

Notes for the Facilitator: The production of new clothing uses more water and energy and cause greater carbon emissions than does used clothing. Reusing clothing causes less harm to be done to the environment, which is more sustainable than using more resources to make more clothing. However, due to the amount of clothing generated and disposed of as a result of "fast fashion" significant amounts of clothing end up in landfills and of the clothes that are donated for reuse, a significant fraction gets exported (particularly to sub-Saharan African countries), which can cause economic and waste problems in those locations.

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**.

Notes for the Facilitator: You can either display the diagram to the whole group or print copies for each learner.

Microfiber is also the name of a type of fabric which is made up of very fine yarn. It may be useful to point out the distinction to learners if they bring up this type of fabric.

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

Notes for the Facilitator: The making of fabrics could cause release of microfibers to enter the environment as it is being cut or sewed. Microfibers may also be released when fabrics are worn or washed. Then, when fabrics are disposed of, they may be burned or placed in landfills, which could also cause microfibers to be released into the environment.

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

Notes for the Facilitator: Microfibers can be found in water, soil, air, and food.

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

Notes for the Facilitator: If microfibers are breathed in or consumed by organisms, it may make them ill, since microfibers are typically not digestible and can prevent organisms from getting the nutrients they need. Microfibers often contain plastics that cannot degrade and build up in the environment, which can take up space normally used by plants, animals, and fungi.

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?

Notes for the Facilitator: Using natural fibers only, especially skipping the petroleum-based polymer step of production would prevent more microfibers from being made and entering the environment.

Consider

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

Notes for the Facilitator: Sustainable practices generally emphasize characteristics and practices such as quality over quantity; reuse and repair what you already own; recycle, donate, and buy secondhand clothing; rent and borrow occasional wear items; research ethical brands.

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

Notes for the Facilitators: Promote sustainable fabrics and brands, by removing sales tax or giving tax deductions; create regulations about discarding clothing, information shared on labels, require companies to share waste and materials, and others.

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

Facilitator Background

Connection to SDG 12: Target 12.2 calls for "the sustainable management and efficient use of natural resources" and Target 12.a aims to "strengthen scientific and technological capacity to move towards more sustainable patterns of consumption and production" (**https://sdgs.un.org/goals/goal12**). Automatic systems can reduce *material consumption* and therefore have a lower carbon and water *footprint*, among other benefits, such as convenience. Automatic systems are used in homes and businesses and outside on farms and in space. In this Investigation learners will build an automatic irrigation system for a houseplant.

Key Concepts: *footprint, material consumption*

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

Connect to the ESD Kit Project: Designing an Environmentally Conscious Store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners could consider using automated technologies in their store to improve efficiency.

PACING GUIDE

PREPARATION
20 minutes setting out materials for groups
10 minutes stripping wire

WHAT TO DO
50 minutes for the Investigation

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

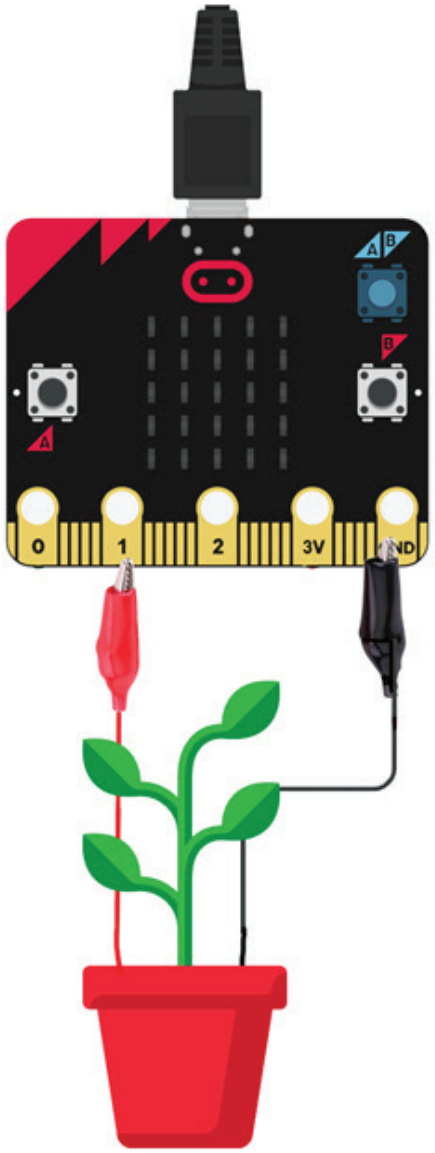
Notes for the Facilitator: Each group will need a potted plant of the same type and approximately the same size. The soil used needs to be dry. If you will be using bagged soil, you should lay the soil out in a warm location to dry the day before the Investigation to ensure it is dry.

Each group will also need 4 pieces of insulated copper wire. Solid wire is preferred over stranded wire for ease in inserting into soil. Each wire should have about 1 cm (about 0.5") of the insulation stripped from each end. The wire can either be stripped by the learners, or you can strip the wire ahead of time.

Once the program has been downloaded to the micro:bit, the micro:bit will need a power source. It can remain connected to the computer, but for long term projects, we recommend using a USB power adapter.

What to Do

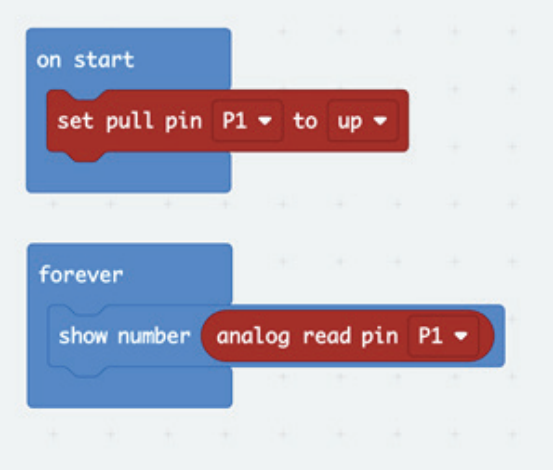
1. Set up a system using wires to allow a micro:bit to tell whether plant soil is wet or dry.
   a. Connect a black alligator clip wire to ground (GND) and red alligator clip wire to PIN 1.
   b. Attach the other end of each alligator clip wire to a stripped end of insulated copper wire.
   c. Insert 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.

Notes for the Facilitator: Setting PIN 1 on start will stabilize the readings of the sensor wires.



Credit: Logo Foundation

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

Notes for the Facilitator: If learners aren't seeing 1000, check to ensure the program is downloaded to the micro:bit and the program was coded correctly.

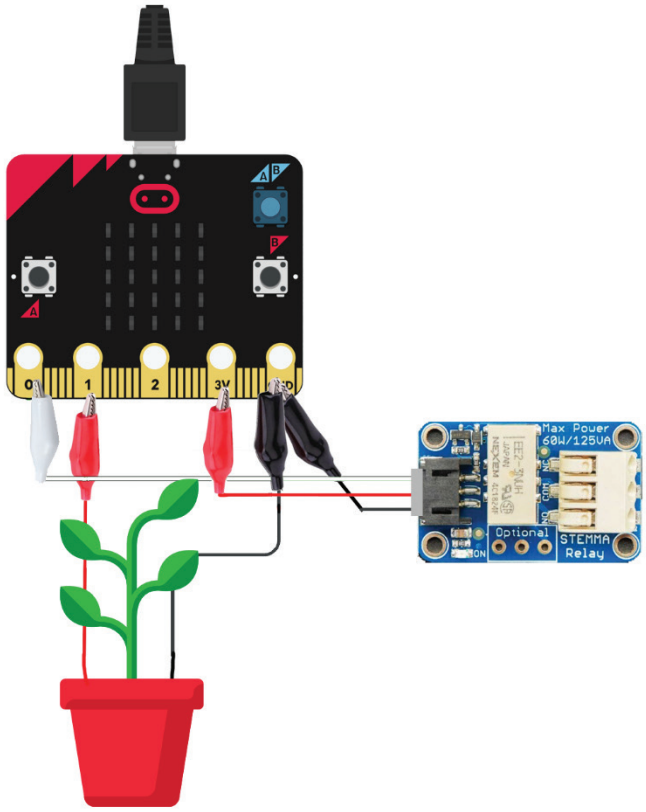
4. Slowly add water to the soil until the number displayed on the micro:bit changes. Wait until the number stabilizes. When the soil is moist, the micro:bit should display a value around 700.

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.

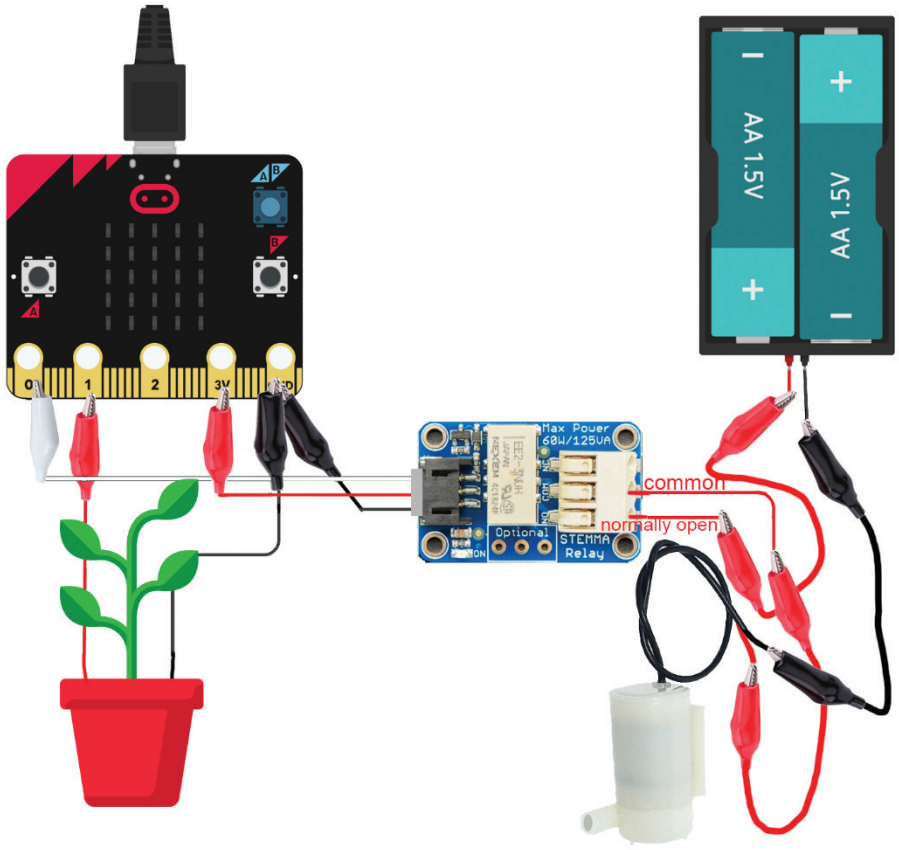
a. Push one piece of insulated copper wire into the middle terminal on the relay, labeled “Common” underneath the board, or COM on top.

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.



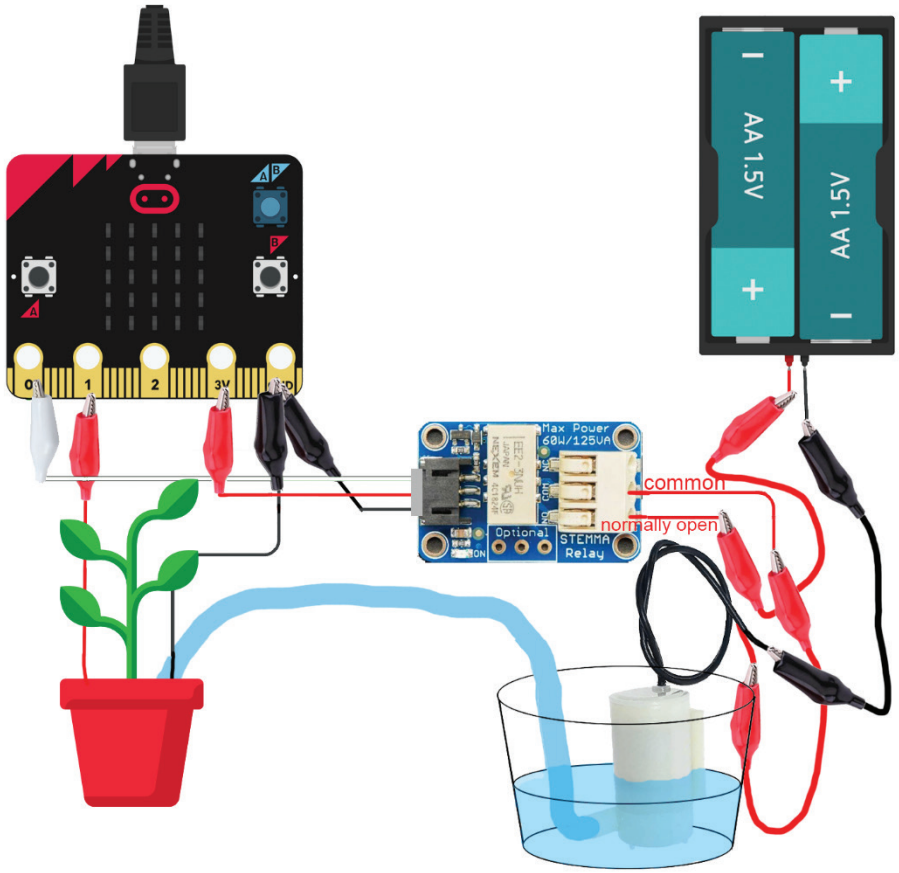
Credit: Logo Foundation

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.

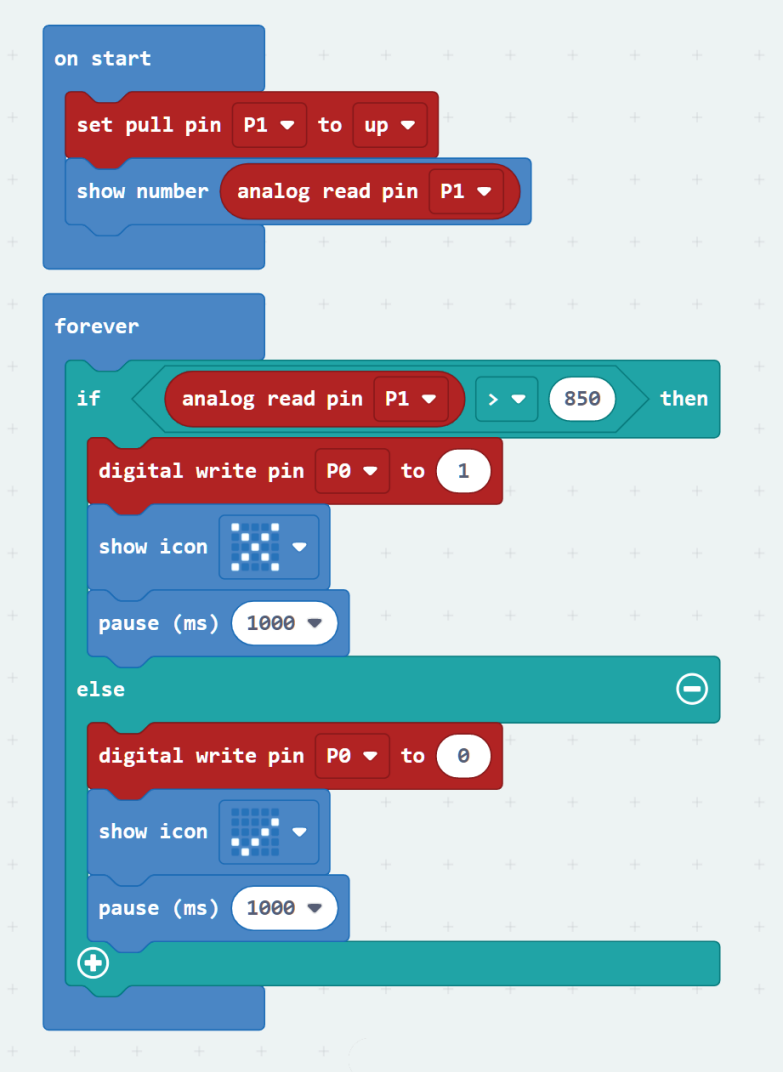
11. Change the MakeCode program to allow the micro:bit to make a decision about when to turn on and off the pump.

    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.

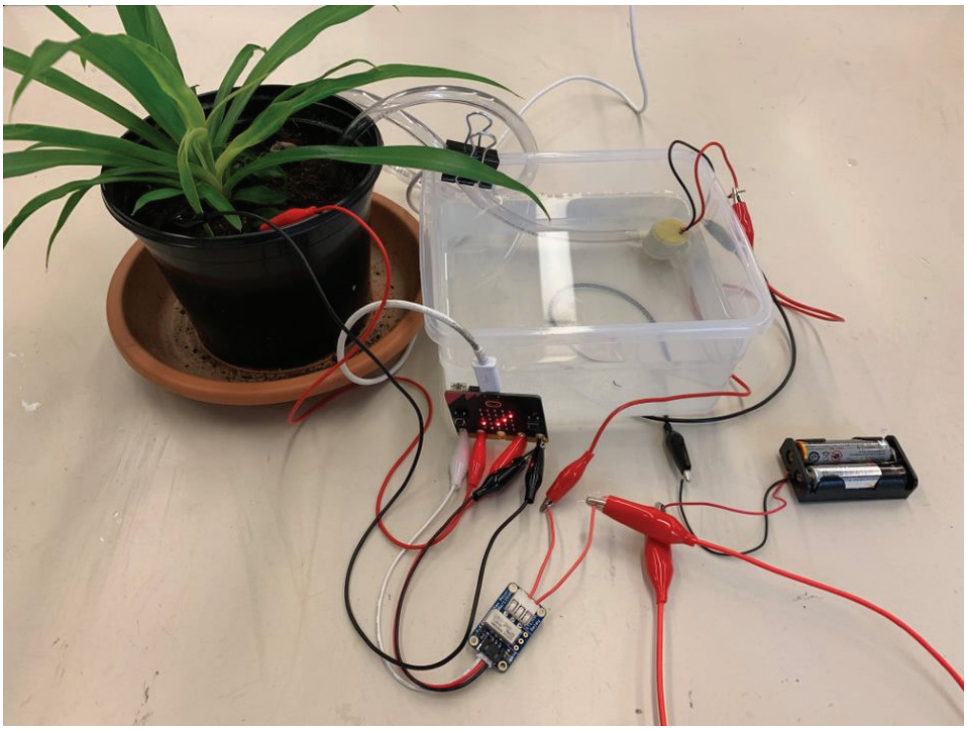
    c. In the "else" block, turn off the pump.

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?

Notes for the Facilitator: In this irrigation system, the water is delivered directly to the plant roots under the soil. In more traditional watering, the water is added on top of the soil or over the plant. This can cause water to fall onto leaves, which can cause less water to make it to the roots.

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

Notes for the Facilitator: Pros — don't need to check on the plants, don't need to physically water the plants on your own, the soil moisture will always remain within a range near the ideal level. Cons — the battery power could run out without you knowing, there could be system malfunctions since it is electronic, there is more work up front with setting up and calibrating the system, it isn't as aesthetically pleasing, the water within the tank needs to be kept full with nutrient-rich water, and it is more expensive due to excess equipment.

3. How does this technology contribute to sustainability?

Notes for the Facilitator: Since this technology only waters a plant when the soil is dry, it conserves water. It also relieves the gardener of constantly checking on the plant and having to water it.

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.

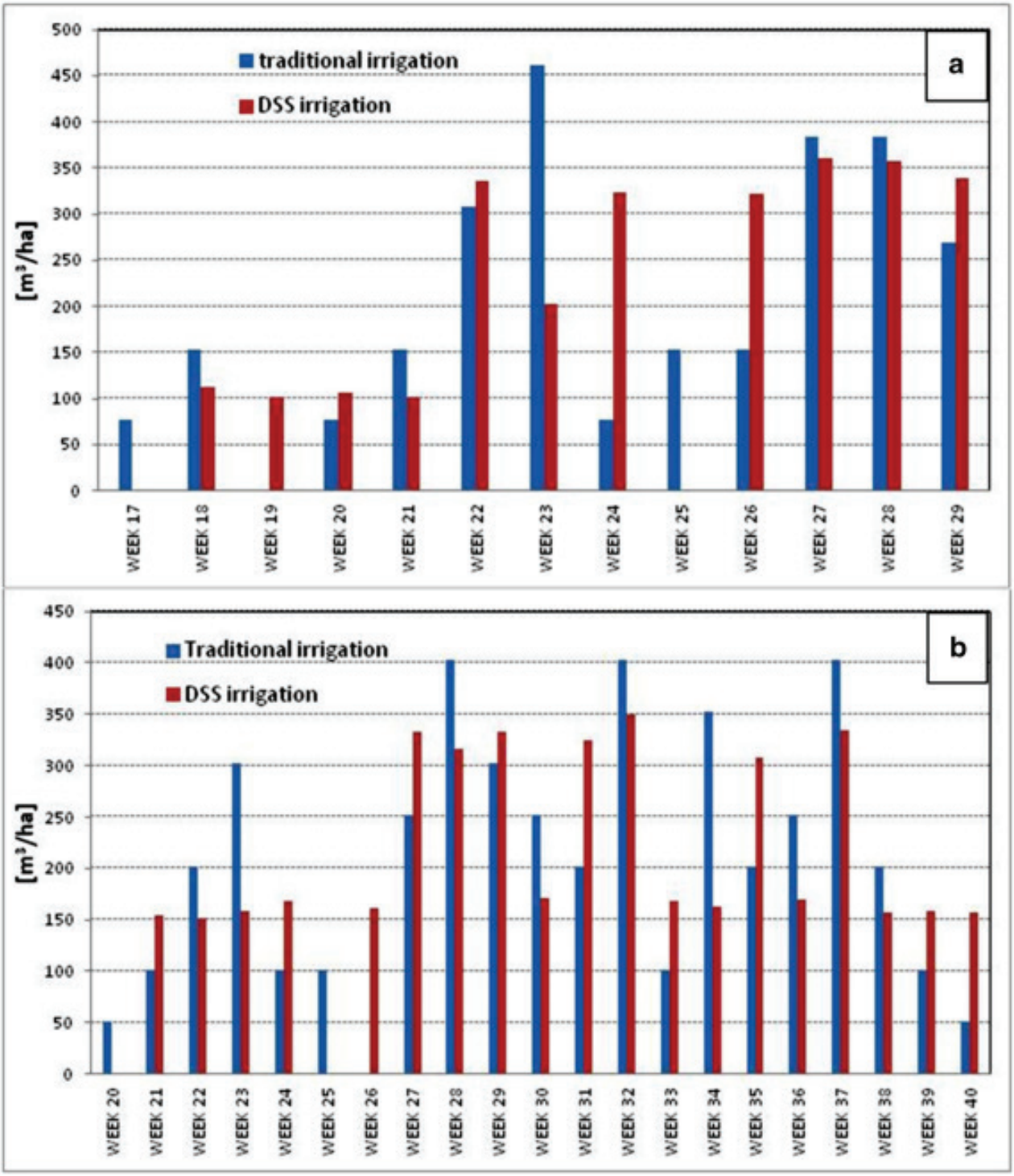
Notes for the Facilitator: To implement a similar system on a larger scale, like a garden or on a farm, the system would need a larger water source such as a pond or a river. Larger equipment would also need to be acquired, such as a larger pump. Also, the energy source would need to be increased and be accessible in the middle of a field.

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).

Notes for the Facilitator: The DSS system does not automatically water the plants, it only provides the data to the user.



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?

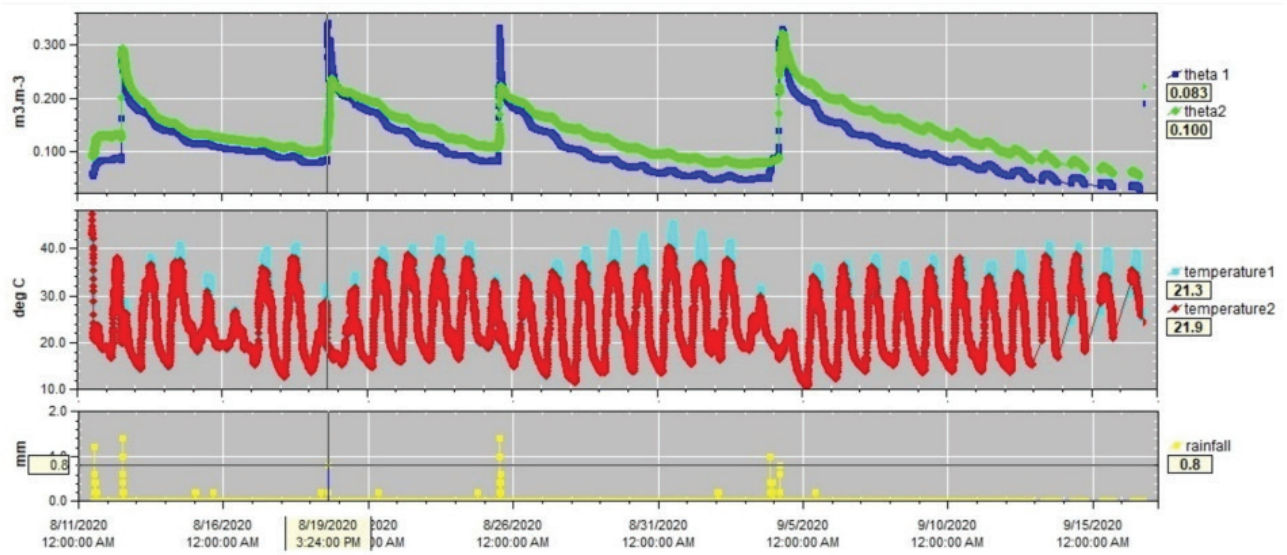
Notes for the Facilitator: Both charts show a wide range of water use from week to week. On average, the eggplants were watered more than the zucchini.

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

Notes for the Facilitator: The DSS system used less water than the traditional irrigation system. The DSS system monitors the soil moisture, so farmers would know when the plants required more water and when they did not.

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?

Notes for the Facilitator: The moisture quickly increases, as evidenced by the spikes, four times and then it gradually decreases. This is most likely due to rainfall or watering events.

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

Notes for the Facilitator: The temperatures fluctuate often due to differences in daytime and nighttime temperatures. There is also sight variation in the high and low temperatures, with some of the lower temperatures correlating with rainfall events, visible if the temperature graph is compared to the rainfall graph below it.

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

Notes for the Facilitator: There are select rainfall events that were captured between August 11 and September 17. They varied in intensity in terms of mm of rainfall and duration of the rainfall event.

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?

Notes for the Facilitator: The plants were most likely watered naturally on 8/11, 8/12, 8/25, and 9/4 due to the spikes in the rainfall graph which correspond with the spikes in the moisture sensors. It seems the only time there was a spike in the soil moisture sensors that would result from being watered by the farmer occurred on 8/19.

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

Facilitator Background

Connection to SDG 12: Target 12.2 calls for "the sustainable management and efficient use of natural resources" and Target 12.a aims to "strengthen scientific and technological capacity to move towards more sustainable patterns of consumption and production" (**https://sdgs.un.org/goals/goal12**). Hydroponics is a sustainable growing technique that can reduce the amount of water used. Growing plants directly in nutrient rich water eliminates water loss to soil. Additionally, hydroponic systems can be implemented anywhere- they are not dependent on local growing conditions. Due to these benefits, hydroponic systems can be considered an *environmentally sound technology*. In this Investigation, learners will build hydroponic systems to grow a plant.

Key Concepts: *environmentally sound technology*

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

Connect to the ESD Kit Project: Designing an Environmentally Conscious Store: The goal of the ESD Kit Project is to create a business model and design an accompanying store that promotes responsible production, consumption, and disposal strategies. After this Investigation, learners could consider incorporating an environmentally sound technology into their business model.

PACING GUIDE

PREPARATION

10 minutes preparing plant buds, if using already grown plant buds
20 minutes preparing the plant buds days in advance, if germinating plant buds
20 minutes testing the water quality and determining appropriate amounts of the pH and nutrient solutions.
20 minutes setting up materials for groups

WHAT TO DO

30 minutes for the Investigation

Materials

For Facilitator Preparation:

- seeds to germinate or buds of basil, a different herb, or similar plant that does not fruit or flower
- EC digital monitor
- pH digital monitor or pH strips
- nutrient solution, such as General Hydroponic FloraGro (**https://www.amazon.com/s?k=Hydroponics-Flora-FloraMicro-FloraBloom**)

- pH up or pH down solution (**https://www.amazon.com/s?k=General+Hydroponics+pH+Control+Kit+for+a+Balanced+Nutrient+Solution**)

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)

Notes for the Facilitator: It is recommended the students grow basil or a similar herb. You may either use plant buds that already have been prepared or germinate your own. If you germinate your own buds, read the instructions on the seed package for how many days it will take the seeds to germinate. Research ideal growing conditions for the plant you have chosen for learners to grow. For basil, ideal conditions include 18–21°C (65–70°F), pH 5.5–6.0, EC 1.0–1.6 mS.

Test the water you plan to have learners use in their hydroponic system. Use a digital meter to test the electrical conductivity (EC), which measures the density of salts in the water. If the EC of your water is too high, you will need to use filtered or distilled water. Use a digital meter or pH strips to test the pH of the water. pH up and down solutions may need to be available for learners to adjust the pH. Determine how much solution should be added in Step 2a and 2d.Determine the appropriate amount of nutrient mix to add in step 3b.

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.

Notes for the Facilitator: During preparation, you could determine the correct amount of nutrient mix to add ahead of time to eliminate learner error.

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

Notes for the Facilitator: Share the ideal pH range with learners. For basil, the ideal pH range is 5.5–6.0

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.

Notes for the Facilitator: During preparation, you could determine the correct amount of the pH solution to add ahead of time to eliminate learner error. Be sure in your testing that you have added the nutrient mix first. Some nutrient mixes adjust the pH.

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.

b. Cut two wicks approximately the length from the top of the bottle to at least halfway down the water level.

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.

Notes for the Facilitators: If the growing medium is too fine to stay within the mouth of the 2L bottle, use a paper napkin or small bit of paper towel as plug around the wicks at the mouth of the bottle.

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?

Notes for the Facilitator: Plants need light, air, water, nutrients, and structural support. Plants grown in hydroponic systems and in soil get light from the sun or a growing light and get air naturally. Plants grown in hydroponic systems get water from the reservoir. The nutrients are dissolved in the water. A growing medium supports the plant and its roots. Plants grown in soil receive water that soaks into the soil, usually from rain or irrigation. The soil also contains nutrients that can be supplemented. The soil also supports the plant and its roots.

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

Notes for the Facilitator: In a garden or farm field, soil is mostly used for supporting plants as they grow. There are some components of soil that are nutrients that promote plant growth. In a hydroponic system, the growing medium supports the plant and nutrients are added to the water.

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?

Notes for the Facilitator: The hydroponic system built has parts of the roots exposed to air. Some growing media have pockets of air, similar to soil. Many hydroponic systems use a pump to infuse oxygen into the water, like in an aquarium.

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

Notes for the Facilitator: Hydroponic systems use less water and can grow plants in controlled growing conditions, especially if the natural environment is arid or otherwise does not support crops.

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

Notes for the Facilitator: Depending on the design, hydroponic systems need more equipment such as growing lights, air pump, growing trays, and so on. which can cause the initial cost to be high. Also, hydroponic systems tend to use more electricity when lights are used. Growing large plants hydroponically requires more specific systems, which are usually more expensive and more time intensive.

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

Notes for the Facilitator: Beneficial situations include when growing plants in a location where good soil is not available, in small spaces, or year-round (since the grower controls the light, temperature, and other conditions.). In a hydroponic system the grower can also control the nutrient availability, conserve water, and avoid weeds and insects. Newer vertical hydroponic systems can grow more food per area of land than traditional farming or flat hydroponics.

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.

Notes for the Facilitator: Different design plans to build an aquaponic system can be found at **https://www.trees.com/gardening-and-landscaping/aquaponic-plans**.

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.

Notes for the Facilitator: Not all questions or sections below will be used by all learners. Learners will need to consider questions that are relevant to the store they are observing.

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.

> **Notes for the Facilitator:** Throughout the Investigations, there have been Extension activities in which the learners add sustainability-related locations to a community map. Learners can now use the map they have created to help them choose where their store will be located.

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.

Notes for the Facilitator: You should be familiar with the basics of *Scratch*® so as to be able to assist learners with their activities and projects. You can achieve this by following *Getting Started with Scratch,* working on the same tutorials that learners will use.

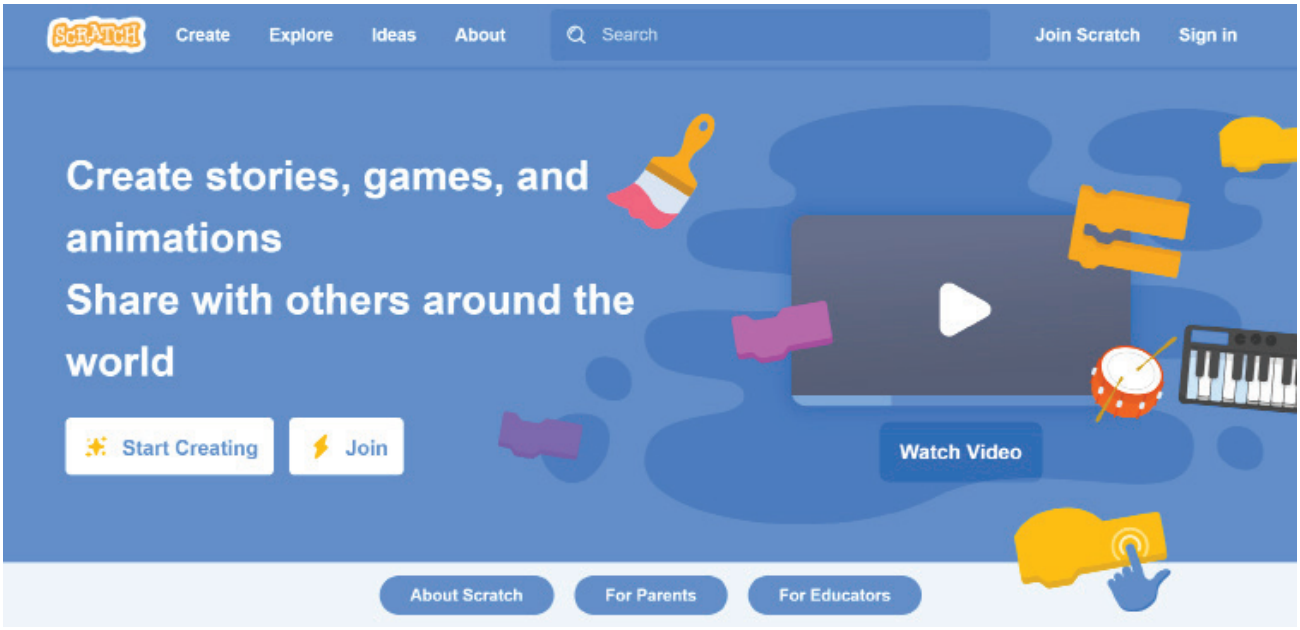
Scratch Tips and Techniques goes into detail about topics that are directly relevant to ESD Kit activities, especially how to incorporate data into *Scratch*® projects and create interesting and novel visualizations of that data. There are links to sample *Scratch*® projects that both facilitators and learners can look at, learn from, and remix.

Some of the Investigations include suggestions for optional *Scratch*® activities. In your preparation to facilitate Investigations, review the *Scratch*® activity and look at any sample *Scratch*® projects that are linked to it.

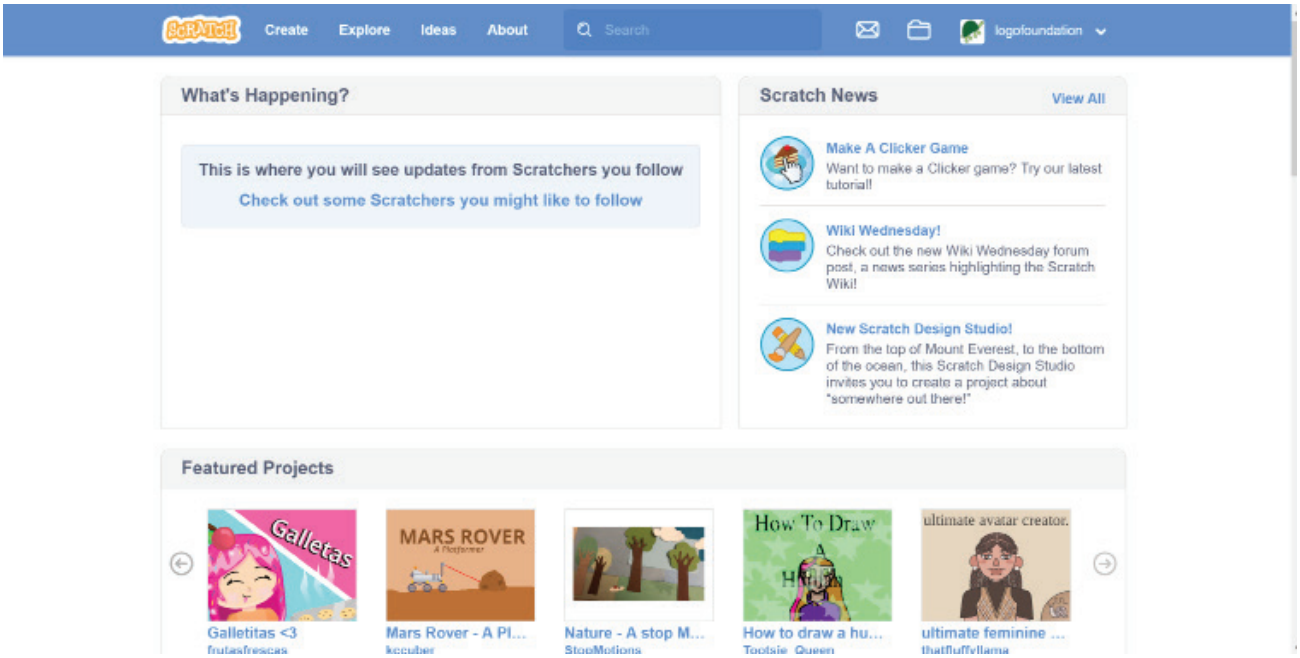
Getting Started with *Scratch*®

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.

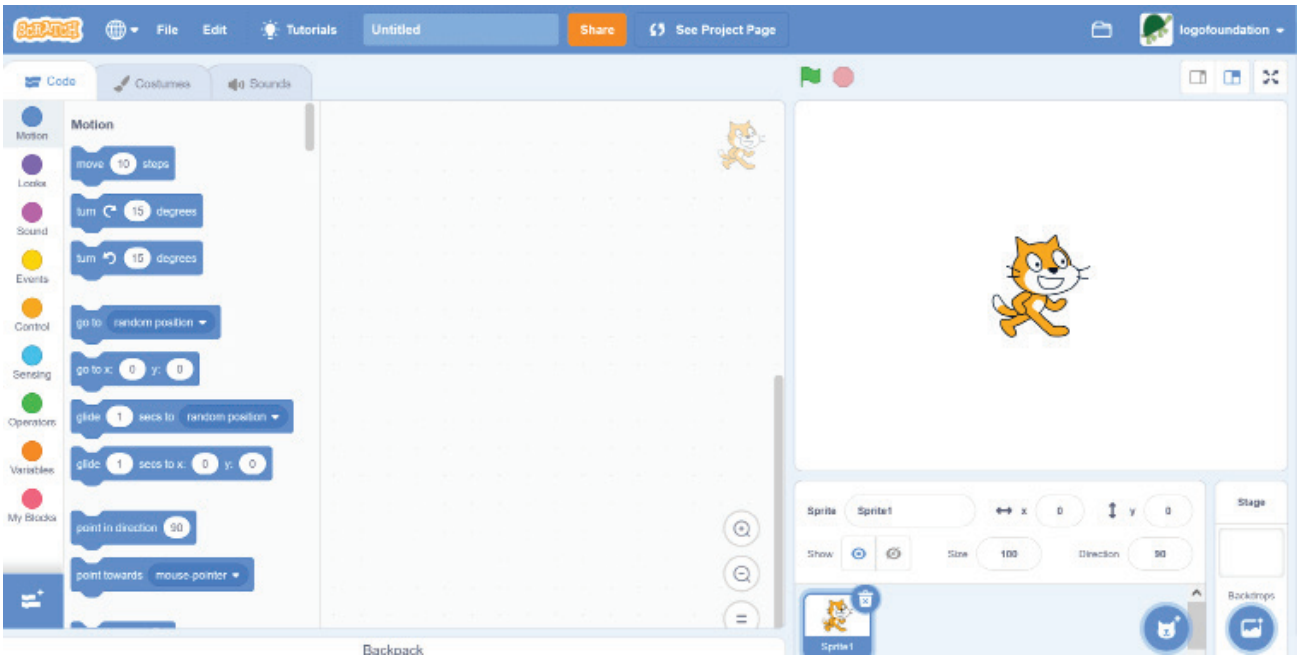
To get started, go to the *Scratch*® website: **https://scratch.mit.edu/** This is what you'll see:



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:

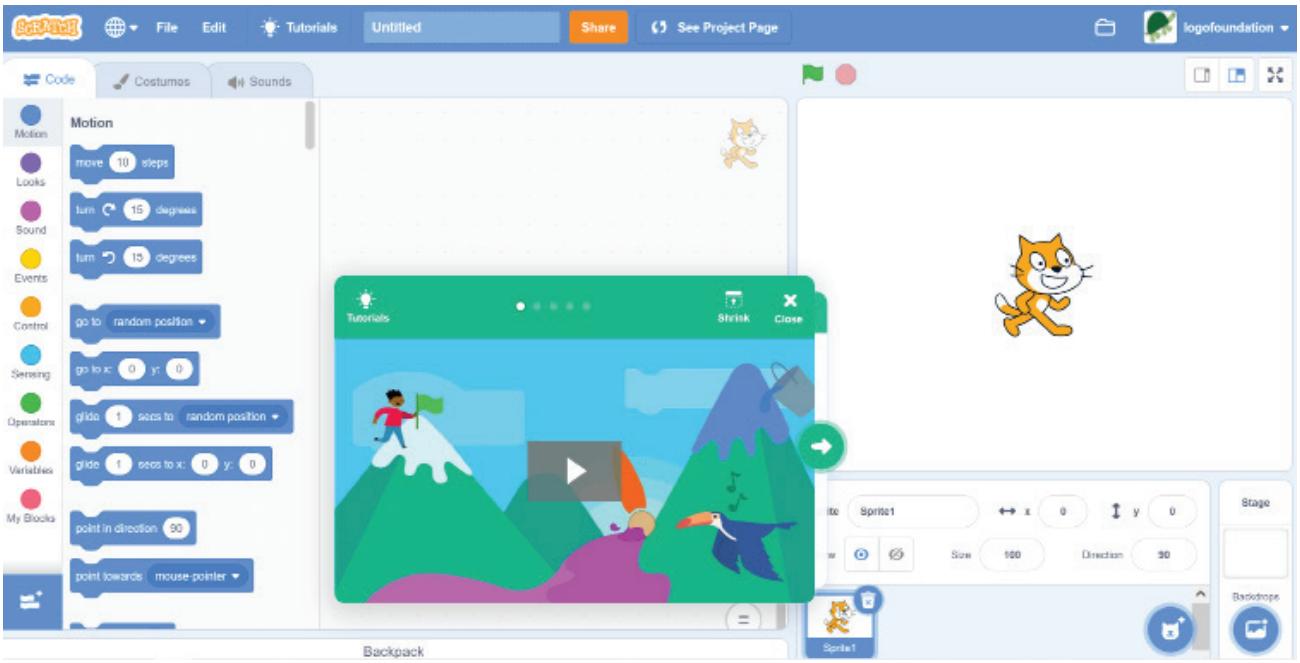


Your username appears at the upper right. You can browse the **Featured Projects** and other projects that appear as you scroll down the page. To get started yourself, click on **Create** at the upper left. This will take you to the *Scratch*® Editor. Your screen will look like this:



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.

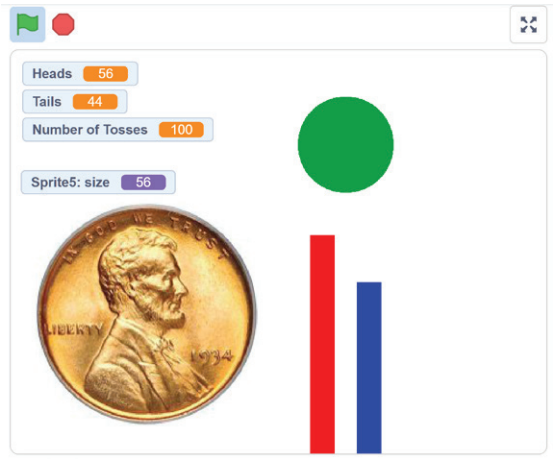
For example, look at the *Scratch*® project Coin Toss: **https://scratch.mit.edu/projects/486312136/**

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/**

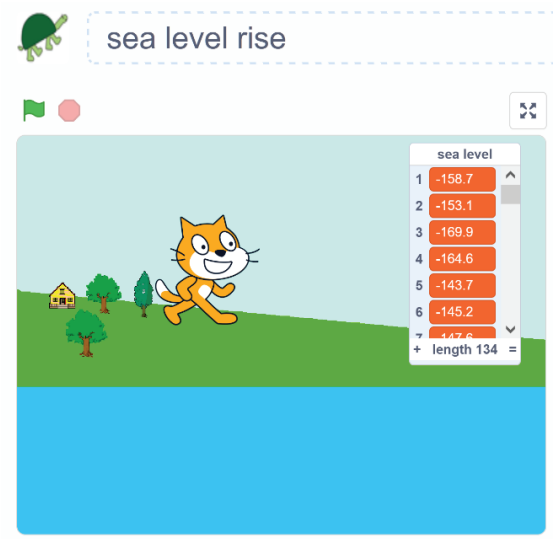
The coin is flipped 100 times and the visual representations of the proportions of heads and tails emerge dynamically. In addition to a bar chart, the size of the green circle increases and decreases based on the percentage of heads up to that point.

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

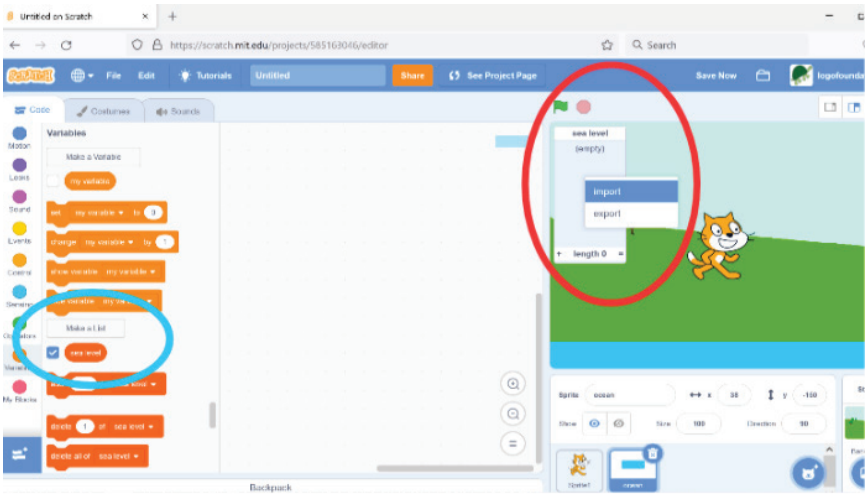


In the coin tossing projects, the program generates the data for the visualizations. You can also bring outside data into a *Scratch*® project.

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.



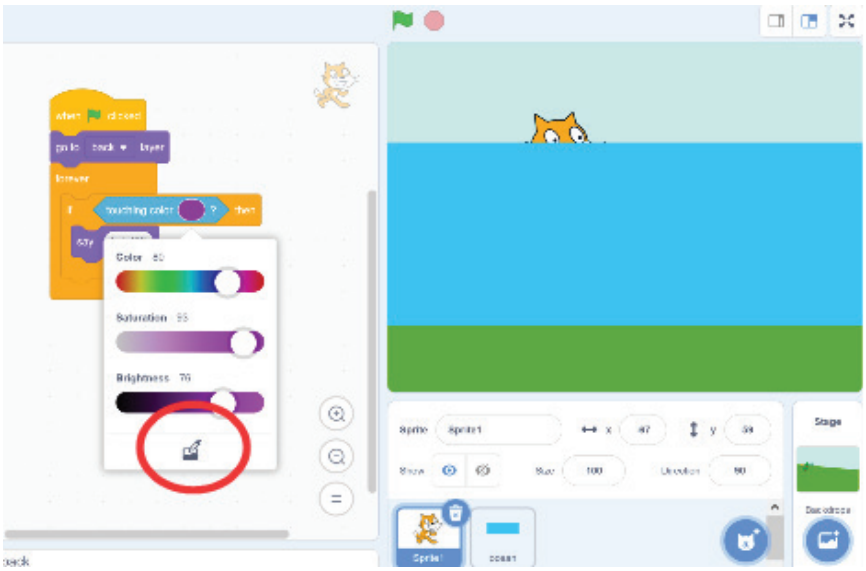
Once the data is imported, you may have to do some touching up. Often a .csv file will have a label in the first row of each column. This label will be imported into the *Scratch*® list along with the data below it. To remove this label and leave only data in the list, click on that first item. An X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

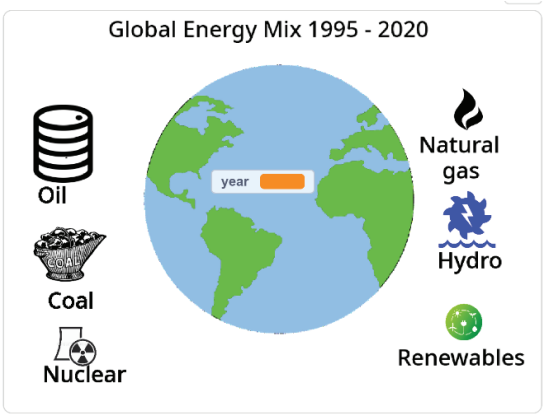
To see more about how the program works, go to the code tab of the ocean sprite, and look at the comments attached to the code for an explanation.

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.

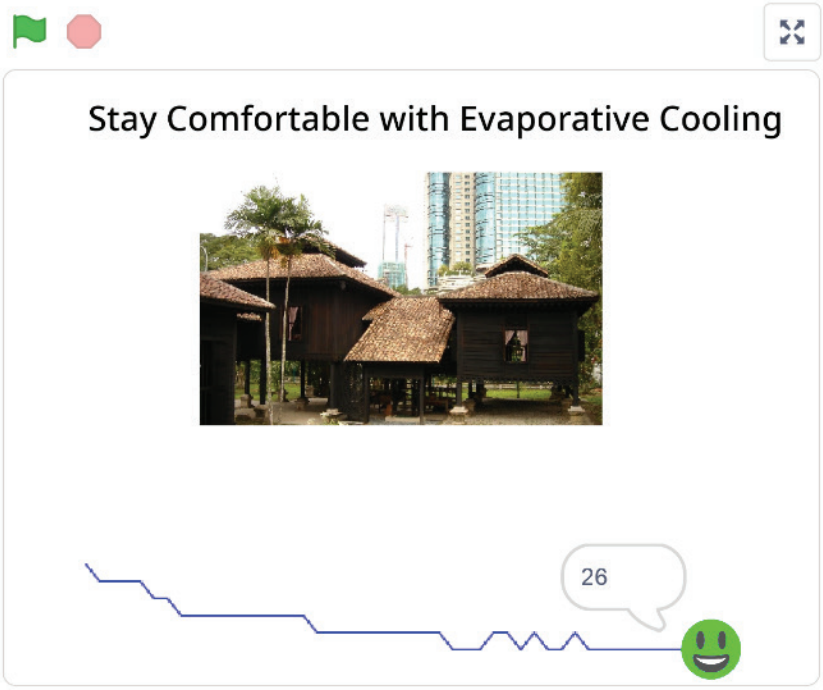


Investigation 4: Understanding Our National Energy Mix looks at the distribution of different energy sources over time. The data are represented by line graphs. The *Scratch*® project *Global Energy Mix* **https://scratch.mit.edu/projects/573662932/** visualized that same data by increasing and decreasing 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.

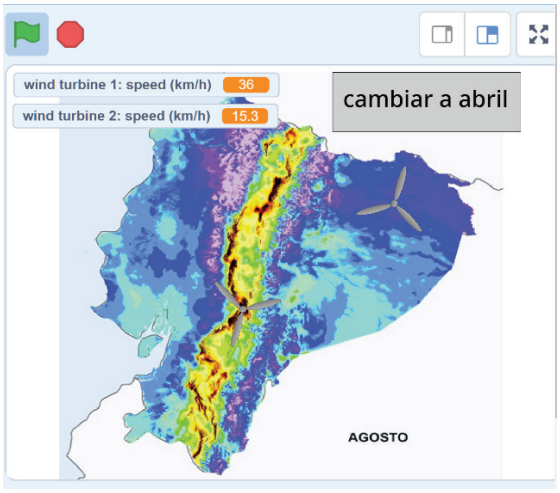


Making Your *Scratch*® Project Interactive

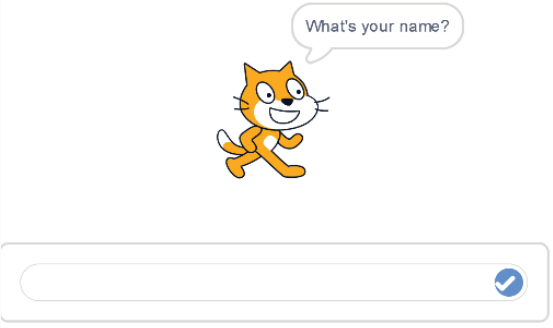
Anyone who uses an interactive *Scratch*® program can affect the course of action, what appears, and the sounds, voices, and music that are heard. Here are some examples:

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.

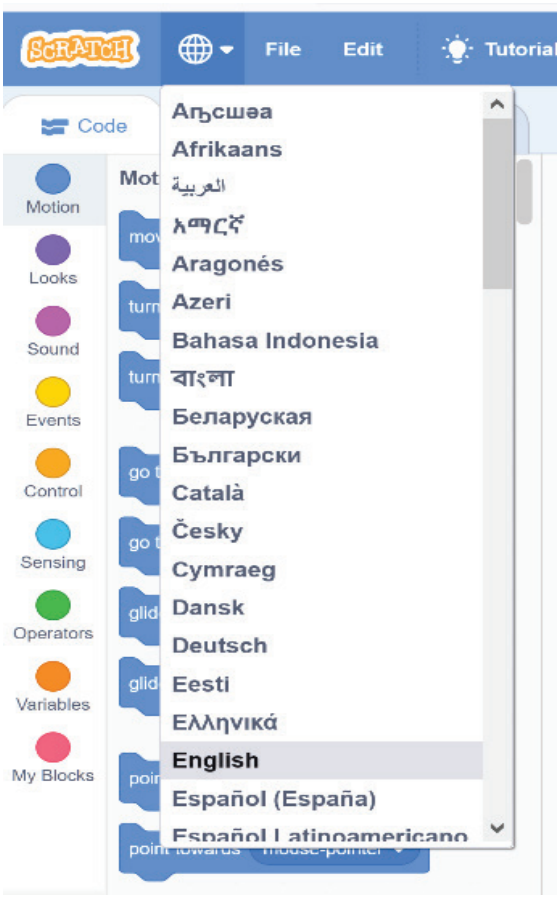
Look at the Sensing section of the Blocks Palette for some additional ways to make your *Scratch*® project interactive.

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.

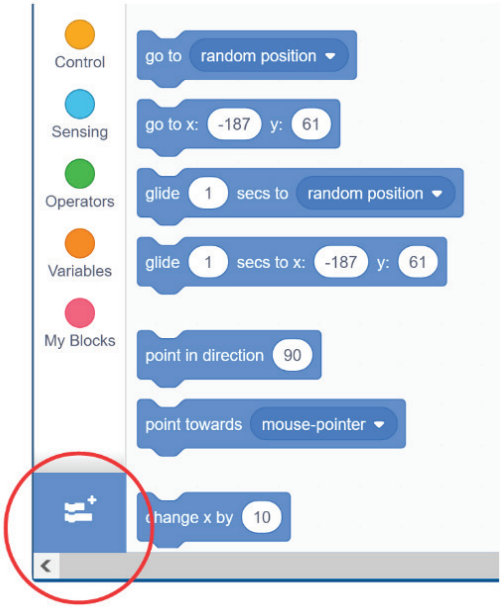
This feature does not change the text that the user has written on backdrops or sprite costumes, or text written into the **ask**, **say**, or **think** blocks. There is a separate translation extension to change these features.



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.

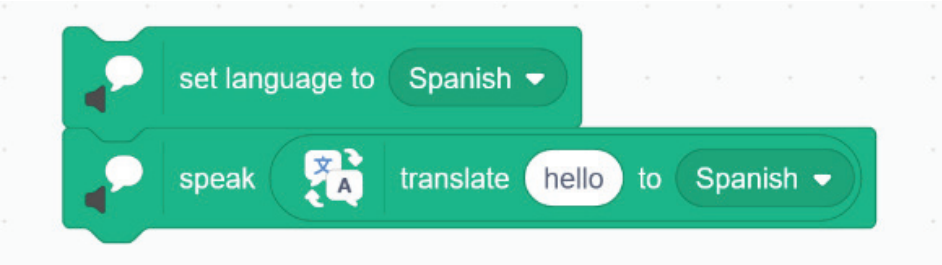
To use an extension, click the icon at the lower left of the *Scratch*® Screen. This brings you to a page where you can select the extension you want to load.



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

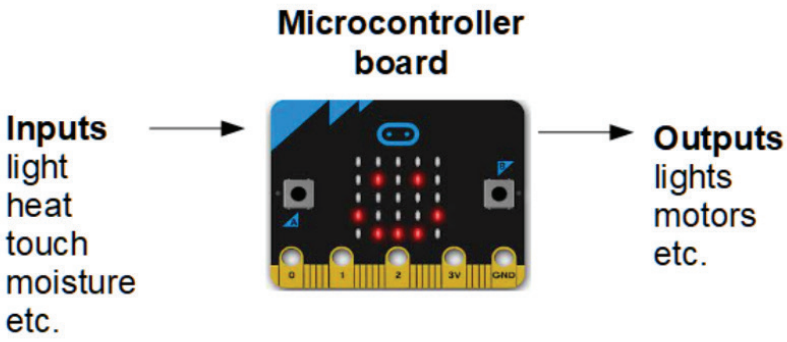
1. designed for education and has extensive support for teachers and students,
2. relatively low cost, and
3. widely available around the world.

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.