Energy Transfer:

Laboratory for Primary Level Students

Teacher Manual

WS2

WOMEN SUPPORTING
WOMEN IN THE SCIENCES

Mission Statement

This laboratory will teach energy transfer concepts to a target audience of elementary/primary-aged students (ages ~6-12) through experiments related to energy transformation and energy absorption.

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1. Introduction to WS2 Laboratories

1.1. Information about WS2

Women Supporting Women in the Sciences (WS2), an international organization unifying and supporting graduate and professional-level women and allies in science, technology, engineering, and mathematics (STEM), was awarded an American Physical Society (APS) Innovation Fund in 2020 to form international teams to design and distribute low-cost physics and materials science lab kits to 5000 primary and secondary school students, predominantly in eastern Africa. The lab kits are intended to utilize local resources and include topics that are especially relevant to young girls in order to spur their interest in STEM subjects. The international teams, which designed the content found in these laboratory manuals, worked with WS2 Partners in eastern Africa in order to successfully deliver and teach the science lab kits to their local communities through 2022. WS2 gratefully acknowledges the hard work of the teams in the creation of this lab kit content. For more information about WS2, please visit our website at ws2global.org.

WS2 is sponsored by the APS Innovation Fund, Northwestern University Materials Research Science and Engineering Center, and Northwestern University Multicultural Student Affairs. WS2 Partners receiving lab kits are representatives from Makerere University (Uganda), Masinde Muliro University of Science and Technology (Kenya), Mbeya University of Science and Technology (Tanzania), Mkwawa University College of Education (Tanzania), Nelson Mandela African Institution for Science and Technology (Tanzania), University of Dar es Salaam (Tanzania), University of Dodoma (Tanzania), and University of Rwanda (Rwanda). The APS, Materials World Modules, SciBridge, and Projekt Inspire have provided valuable input on WS2 lab kit design. WS2 especially thanks WS2 Partner representatives (John Bakayana, Pendo Bigambo, Daudi Mazengo, Lawrence Robert Msalilwa, Celine Omondi, Marcellin Rutegwa), Tom Coon and students of Haile-Manas Academy (Debre Birhan, Ethiopia), and Carla Johnston and students of Frank Bergman Elementary School (Manhattan, KS, USA) for piloting the lab kits with small focus groups in late 2021. WS2 also tremendously thanks the virtual lab kit design team that created the content for this lab manual.

1.2. Using this Guide

This manual is to be used by the teacher of the laboratory, and it is similar in content to the student manual but may contain additional material, like: Overview, Fundamental Physics and Materials Science Concepts Covered, Practical Skills, Background on Main Topics, Summary of Experiments, Results, Teacher Pre-Lab, Troubleshooting. These additional sections are intended to provide the teacher with the background and foundation critical for successfully implementing this laboratory kit in the classroom. It is recommended that the teachers of this laboratory go through the guide from beginning to end to familiarize themselves with the laboratory content prior to teaching the laboratory to students. Questions about the laboratory content can be directed at any time to ws2global.org@gmail.com, using the subject line "Question about Lab Kit Content".

IMPORTANT NOTES:

- This laboratory is intended for use with primary-level students (ages ~6-12), but depending on the specific students' educational background, the content may need to be modified by the teacher to be made simpler or more complex. The teacher is encouraged to also cover the laboratory content at the pace that works best for the students; some younger students may need more time and attention from the teacher and/or facilitator to go through the questions and experiments, while older students may be more independent and require less attention from the teacher and/or facilitator. Thus, the content covered, depth of coverage, and pacing are left to the teacher's and/or facilitator's discretion.
- The content in this lab manual may not fit into the specific curriculum of the school in which it is being taught. It is up to the facilitator(s) and teacher(s) whether they would like to introduce new content or skip certain sections that are not applicable to their classrooms.
- In certain areas, modifications to the supply list may need to be made depending on the availability of the supplies in the specific area in which the lab is being taught. We have attempted to list some alternatives in the supply list, but we understand this list of alternatives is not exhaustive.
- In the experiments, the students are split into groups of three to four. If supplies allow, students may instead be split into groups of two.

1.3. Key Vocabulary

- Energy: The ability to do work
- Energy transfer: The movement of energy from one location or object to another
- Heat transfer: The movement of heat from one location or object to another (heat is always transferred from warm objects to cold objects)
- Atmosphere: The gases surrounding the Earth
- Greenhouse gas effect: When gases become trapped and heat up an environment

1.4. Key Questions

- What is heat transfer?
  - Answer: Heat transfer is when heat moves from warm objects to cold objects.
- What are greenhouse gases?
  - Answer: Greenhouse gases are those that get trapped in the atmosphere, like carbon dioxide or methane.
- How can greenhouse gases impact the Earth?
  - Answer: Greenhouse gases trap heat and keep the Earth at a livable temperature for people. Too many greenhouse gases can increase the temperature of the earth. Many things on Earth can't survive at higher temperatures, so an increase of a few degrees can hurt plants and animals!

1.5. Purpose

The purpose of this lab is to demonstrate the impact of greenhouse gases in the environment and how energy transfer plays a role in our lives. Energy is part of our everyday lives; it is constantly changing and moving. Like when the Sun can heat up our bodies on a hot summer day, when we eat and digest food, or when we burn wood for fire, energy is transformed for practical purposes all around us every day.

1.6. Overview

Through this laboratory, elementary aged students (ages ~6-12) are going to be taught about heat transfer and the greenhouse gas effect. They will work on two experiments to observe how well different materials absorb energy from the Sun and simulate the greenhouse gas effect in the classroom.

1.7. Fundamental Physics and Materials Science Concepts Covered

The laboratory introduces topics of energy transfer and transformation. Whether the students are warming up outside in the sunlight or eating food so that they have the energy to run around and think about their studies, energy transformations are important and happen all around us. These basic concepts related to energy and heat are critical and relevant to numerous fields including Biology, Physics, Chemistry, Materials Science, and Engineering.

1.8. Practical Skills

- Students will learn how to conduct experiments to test which types of materials heat up the fastest in the Sun.
- Students will learn about the greenhouse gas effect, which is relevant to the Earth's climate and global warming.
- Students will connect energy transfer concepts to everyday experiences at school and home (e.g., warming up in the Sun).

2. Background on Main Topics

2.1. Energy and its Transfer

The Sun is an extremely powerful source of energy; for centuries people have used the Sun as a source of reliable and renewable energy to cook food and warm themselves. Energy is the ability to do work or make something move or change in some way. Have you ever been chilly in the shade or indoors, but when you go outside you feel an instant warmth? That is the power of the Sun's energy! The Sun's energy gets to you by energy transfer, which is the movement of energy from one location or object to another. This transfer of energy, especially thermal energy like heat, can occur in different ways.

What is heat transfer?

Heat transfer is when heat moves from one object to another. The heat always moves from the warmer object to the colder object. There are different types of heat transfer, including convection, conduction, and radiation (see Figure 1). You experience all three of these types every day! Convection is the transfer of heat through gas or a liquid in a pattern called a convection current. You may experience convection when it's windy near the ocean or sea, when water boils, or when the blood moves around your body. Conduction is the transfer of heat from one object to another by direct contact. Examples of conduction are when you heat a pan on a stove, your feet become hot when you walk on hot rocks or pavement, or when a spoon becomes hot in soup or

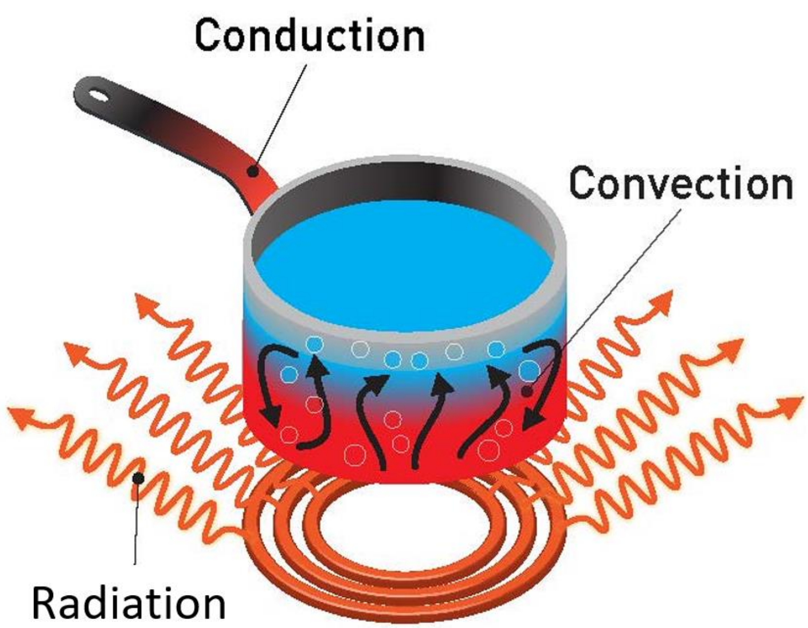

Figure 1. Conduction, convection, and radiation are three types of heat transfer. When you boil water in a pot, all three types are working to heat up the water and the pot! This Photo by Unknown Author is licensed under CC BY.

tea. Radiation is the transfer of heat through space. You may experience radiation from sunlight or from feeling warm by a fire. As you may know from cooking foods or trying to cool off on hot days, some materials are better at getting hot than others. This means they are good at transferring heat.

Do some materials transfer heat faster than others?

Everything around us is made from materials. Think of your home and the many materials the items in your house are made from like wood, metal, plastic (sometimes called polymer), ceramic, and maybe even living matter. Heat moves through different types of materials in different ways, making some materials better at heating up than others. For example, heat moves quickly through metals making them perfect as a container for boiling water or cooking food. Think again of your home and the containers you use for cooking food. Are they often made of metal?

How does heat transfer impact the Earth?

One example of how heat transfer impacts the Earth is related to its atmosphere, which is the blanket of gases surrounding the Earth. Gas is another material that can transfer heat. There are certain types of gases called greenhouse gases that trap energy from the Sun and lead to the greenhouse gas effect, which is the warming of the Earth's surface and the air above it. Have you ever heard of a greenhouse? This is a building made of glass which allows sunlight to pass through to heat the environment inside. A greenhouse stays warm enough to grow plants even in cool weather. Common greenhouse gases in our atmosphere are water vapor (the most abundant), ozone, carbon dioxide, methane, and nitrous oxide, all of which are naturally present. Some greenhouse gases, however, are not natural. Some are chemicals made by people and others result from burning fuel.

So, what exactly is the greenhouse gas effect?

When the Sun shines down on the Earth, the light passes through the layer of greenhouse gases on the way down to us at the Earth's surface. The Earth's surface heats up from the Sun's light, but at night the surface cools, and the heat is released back into the atmosphere. Some part of this energy passes back into space, but some stays trapped in the atmosphere by the greenhouse gases. This trapping of heat by the greenhouse gases in our atmosphere gives our world the heat we need to survive (see Figure 2)! The natural greenhouse effect has made the planet we call home good for growing food and housing all animals and plants. Without the natural greenhouse effect, Earth would be too cold for life to exist. It would be a solid ball of rock and ice—dropping from 14 °C (57 °F) to as low as -18 °C (-0.4 °F).

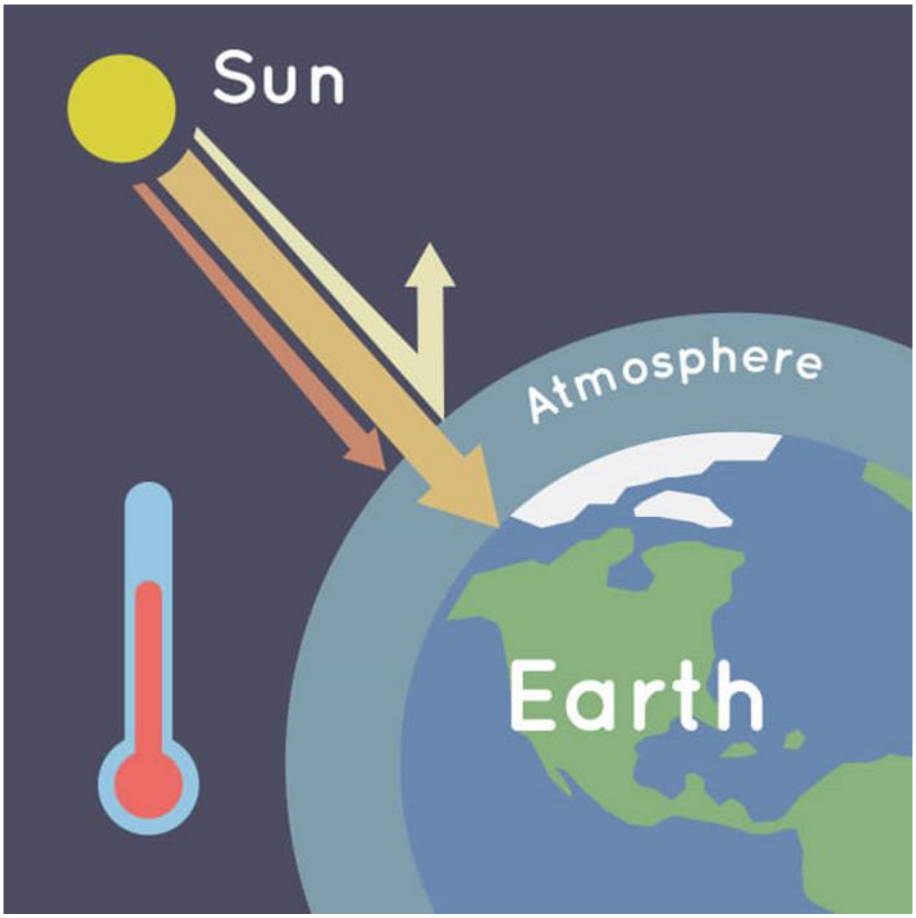

Figure 2. Sunlight hits the Earth, and these light rays can be absorbed into the atmosphere or reflected into space. The atmosphere traps some of the Sun's rays, which heats the Earth. Credit: NASA/JPL-Caltech.

Can the greenhouse gas effect be harmful?

Yes! If there is too much of the greenhouse gas effect, the Earth will heat up and the temperature could rise more than what is comfortable or tolerable for animals and plants. If the temperature of the Earth rises by just a few °C, this could make parts of the planet too hot for humans to survive.

Unfortunately, human activities like pollution, cutting trees, and burning fuels add or contribute to extra greenhouse gases in the atmosphere. As humans make more of these gases, the temperature of the Earth rises. We call this global warming.

2.2. Sources

https://www.bulbapp.com/u/conduction-convection-and-radiation~1

https://scied.ucar.edu/teaching-box: Center for Science Education (UCAR) - includes NGSS for middle and high school students.

Climate Change Live. https://climatechangelive.org/index.php?pid=180

Solar Influence & Climate Change. https://cleanet.org/resources/43776.html

https://www.earthsciweek.org/classroom-activities/your-own-greenhouse

https://climatekids.nasa.gov/greenhouse-cards/

https://climatekids.nasa.gov/greenhouse-effect/

https://www.steampoweredfamily.com/activities/the-greenhouse-effect-experiment/

https://sciencing.com/homemade-alternative-baking-soda-vinegar-8509768.html

3. Summary of Experiments

This lab consists of two experiments and one design challenge to understand the concepts of energy transfer. Students will explore how different materials transfer heat and that some materials transfer heat more quickly than others. They will also work to simulate the greenhouse gas effect using chemical reactions that create carbon dioxide and heat up a jar. By comparing the temperature of jars with different chemicals inside, students get a hands-on comparison of how the atmosphere heats up when we create greenhouse gases on Earth.

3.1. Supplies List

- 1 glass object, 1 metal object, 1 plastic object

    - Optional: Fabric, ceramics, rocks, plants, whatever materials you think may be fun to try!
- 5 glass or plastic jars
    - These can be used food or drink jars
- 1 marker for writing on the jars
- Plastic covering for the jars (can be plastic wrap, a plastic bag, or any other flexible plastic material)
- Elastic band or fabric strip to secure the plastic around the jar
- 1 measuring cup
- Two chemicals (one from Chemical 1 options and choose Chemical 2 based on Chemical 1) to make the greenhouse gas reaction occur
    - Chemical 1 options:
        - Vinegar
        - Ketchup
        - Soda (any carbonated beverage)
    - Chemical 2:
        - If Chemical 1 is vinegar or ketchup:
            - Baking soda
        - If Chemical 1 is soda:
            - Salt
- Thermometer (optional)

3.2. Safety Information

Before the students begin the laboratory, please take into consideration the following safety concerns:

- Students should be careful when heating objects in the Sun! Objects may become hot quickly.

3.3. Teacher Pre-Lab

Teachers can organize the supplies for the experiments ahead of time for each student or groups of 2-4 students (it is encouraged to have students work together):

Experiment 1:

- Each group should have: 1 metal object, 1 plastic object, and 1 glass object
- Optionally, you can provide other materials to the groups if you have them: fabric, ceramics, rocks, plants, etc.

Experiment 2:

- Each group should have: 5 glass or plastic jars (these can be recycled from food or drink jars), 1 marker, plastic covering for the jars (can be plastic wrap, plastic bag, or any thin plastic, air-impermeable material), elastic or fabric band to secure around the jars, 1 measuring cup, and a pair of chemicals to make the chemical reaction occur:
    - Choose one from Chemical 1 options and choose Chemical 2 based on Chemical 1)
        - Chemical 1 options:
            - Vinegar
            - Ketchup
            - Soda (any carbonated beverage)
        - Chemical 2:
            - If Chemical 1 is vinegar or ketchup:
                - Baking soda
            - If Chemical 1 is soda:
                - Salt

3.4. Troubleshooting

Depending on the time of year, it may take longer for materials to heat up in the sunlight. We suggest that you run these experiments on a bright, sunny day, if possible.

4. Experiments

4.1. Part I. Heat Transfer

4.1.1. *Summary*

In this experiment, we are going to test how heat from the Sun is transferred to objects and how the material the object is made of matters.

4.1.2. *Pre-Experiment Questions*

1. What objects in your life heat up quickly?
    a. Answer: There can be many answers. Some examples are cookware, the roads, rocks, cars, and anything made of metal.
2. Do you know what the objects are made of that heat up quickly?
    a. Answer: These objects are mostly made of metal.
3. What are some objects that you use that you want to heat up fast? What are these objects made of?
    a. Answer: There are many answers, but one example is cookware which we want to heat up quickly so that we can cook efficiently. Cookware is usually made of metal.
4. What are some objects that you don't want to heat up fast or at all? What are these objects made of?
    a. Answer: There are many answers, including our clothes, our furniture, or our shoes. These materials are typically not made of metal.

4.1.3. *Materials*

- 1 glass object
- 1 metal object
- 1 plastic object
- Fabric, ceramic, rocks, plants, etc. (optional to test)

4.1.4. *Procedure (work in groups of 2-4)*

1. For the materials you have collected, record in the table in Results which you think will heat up the fastest and the slowest when placed in the sunlight. If you want to rank all of the materials in order as your prediction, you can rank them starting with "1" being the object you think will heat up the fastest, "2" being the next object to heat up the fastest, and so on.
2. Compare the temperatures of the glass, plastic, and metal objects (plus other objects you want to test) in your classroom. Record your results in the table. You can list words like "warm", "cool", "room temperature", etc.
3. Place the objects in the sunlight. This can be outside in the sunlight or an area of the classroom with lots of sunlight coming through a window.
4. After 5-10 minutes, feel the temperature of the objects with your hand or a thermometer. Record your observations in the table in Results. If you don't have a thermometer, use words like "cold", "chilly", "cool", "warm", "hot", and "very hot".
    a. Note: depending on the time of year and sunlight, this step may take longer than 5-10 minutes. If needed, you can move to Part II and come back to this step later.
5. Now, place the objects in the shade. This can be outside in the shade or in a shaded part of the classroom.
6. After 5-10 minutes, feel the temperature of the objects with your hand or a thermometer. Record your observations in the table in Results. If you don't have a thermometer, use words like "cold", "chilly", "cool", "warm", "hot", and "very hot".

4.1.5. *Results*

Object	Which object will heat up the fastest? Slowest?	Temperature of object in the classroom (or before placing in sunlight/shade)	Temperature of object after sunlight	Temperature of object after shade
Glass				
Plastic/Styrofoam				
Metal				

4.1.6. *Post-Experiment Questions*

1. Which object heated up fastest in the sunlight? Which object was the slowest to heat up in the sunlight? How did these results compare with your predictions?
   a. Answer: The metal should heat up the fastest, then glass, then plastic. It may be difficult for students to tell the difference between the temperature of glass and plastic after only a few minutes. Other materials such as fabrics or paper will depend on the color (black will heat up the fastest and white the slowest). Students should be careful to make their judgement based on the change in temperature from room temperature to sunlight (i.e., which material changed temperature the most in 5-10 minutes) instead of the final temperature recorded in the sunlight.
   b. Extension question: Did the color of the object matter?
      i. Answer: Answers may vary depending on color of the objects. It is important to have the students make observations based on their objects and speculate as to the reason color may have mattered. As the teacher, you can assist by telling them that if the objects were dark or black in color, the material could absorb more sunlight and so it could heat more and faster than the object that was a lighter color, like white, and reflected some sunlight. You can spend some time getting students to recognize that this experiment may have multiple variables that impact the result, including the color and material of the object. If all objects were similar colors, then this variable would be fixed and only the material would matter.
   c. Extension question: Based on the types of heat transfer you learned about in the Introduction, which type heated the objects in this experiment?
      i. Answer: These objects were heated by radiative heat transfer. Sunlight passed through space to reach the objects and heat them.
2. Why did you record the temperatures of the objects before placing them in the Sun?
   a. Answer: The temperatures of the objects were recorded before placing them into the Sun in case any of the objects were at a different temperature prior to placement in the sunlight or shade. For example, if the metal object was already “hot” in the classroom, then its temperature may not change as much when placed in the sunlight as the metal object that was “cool” in the classroom. You were recording the initial conditions of the objects so that you could observe any changes afterward.

3. Which object cooled fastest in the shade? Which object cooled slowest in the shade?
    a. Answer: The metal object cooled the fastest in the shade, followed by the glass and the plastic objects. The metal, being a good conductor of heat, can also cool quickly. Students should be careful to make their judgement based on the change in temperature from sunlight to shade (i.e., which material changed temperature the most in 5-10 minutes) instead of the final temperature recorded in the shade.
4. Consider a future experiment that tests how quickly other objects you don't currently have with you heat up in the sunlight. Predict how well these objects will transfer heat based on what they are made of. Be creative!
    a. Answer: Answers will vary. The point is to get students to connect materials with how well they transfer heat based on this experiment and their lived experiences.

4.2. Part II. Make Your Own Atmosphere

4.2.1. *Summary*

In this experiment, we will simulate the greenhouse gas effect. Inside jars, we will see if we can create an environment that is like what happens on Earth when we burn wood or fuel for cars that generate greenhouse gases that cause the atmosphere to heat up. The air inside the jars represents the atmosphere of the Earth and the chemicals inside them represent things on Earth that, when mixed together, give off greenhouse gases. When two things (sometimes called "chemicals") are added together and give off gases and/or heat and produce a new thing (or new chemical), we call this a "chemical reaction".

4.2.2. *Pre-Experiment Questions*

1. What is the greenhouse gas effect?
    a. Answer: The greenhouse gas effect is the warming of the Earth's surface and the air above it. Students can go into more detail based on the information they were provided in the Introduction.
2. What are examples of greenhouse gases?
    a. Answer: Examples include water vapor, carbon dioxide, methane, ozone.

4.2.3. *Materials*

- 5 glass or plastic jars
- 1 marker for writing on the jars
- Plastic covering for the jars (can be plastic wrap, a plastic bag, or any other flexible plastic material)
- Elastic bands or fabric strips to secure the plastic around the jar
- 1 measuring cup
- Two chemicals (one from Chemical 1 options and choose Chemical 2 based on Chemical 1) to make the greenhouse gas reaction occur
    - Chemical 1 options:
        - Vinegar
        - Ketchup
        - Soda (any carbonated beverage)
    - Chemical 2:
        - If Chemical 1 is vinegar or ketchup:
            - Baking soda
        - If Chemical 1 is soda:
            - Salt
- Thermometer (optional)

4.2.4. *Procedure (work in groups of 4)*

Note: A schematic of the jars you will prepare and measure in the following steps is shown in Figure 3.

1. Label the glass or plastic jars: "air", "1st chemical", "2nd chemical", "closed greenhouse effect", and "open greenhouse effect".
2. Cover the jar labeled "air" with plastic and secure it to the lid of the jar with an elastic band or a tied piece of fabric.
3. Record the temperature of the jar in "Temperature before sunlight" in the table in Results. Use your hands to describe the feeling or the thermometer to measure the temperature inside the jar.
4. Pour 60 mL (1/4 cup) of chemical 1 into the jar labeled "1st chemical". Cover the jar labeled "1st chemical" with plastic and secure it to the lid of the jar with an elastic band or a tied piece of fabric.

5. Record the temperature of the jar in "Temperature before sunlight" in the table in Results. Use your hands to describe the feeling or the thermometer to measure the temperature inside the jar.
6. Add 15 mL (1 tablespoon, or 1 spoonful) of chemical 2 to the jar labeled "2nd chemical". Cover the jar labeled "2nd chemical" with plastic and secure it to the lid of the jar with an elastic or a tied piece of fabric.
7. Record the temperature of the jar in "Temperature before sunlight" in the table in Results. Use your hands to describe the feeling or the thermometer to measure the temperature inside the jar.
    a. Note: The "air", "1st chemical", and "2nd chemical" jars act as "controls" in the experiment. A control is a part of an experiment that we can compare our results to that helps us learn.

Now, we will prepare the "closed greenhouse effect" jar. Each student will have a job:

8. Student 1: Measure 60 mL (1/4 cup) of chemical 1 and have it ready to add to the "closed greenhouse effect" jar. Don't add it yet!
9. Student 2: Measure 5 mL (1 tablespoon, or 1 spoonful) of chemical 2 and have it ready to add to the "closed greenhouse effect" jar. Don't add it yet!
10. Student 3: Have a piece of plastic and elastic band or piece of fabric ready to seal the jar.
11. Student 4: Feel the outside of the jar before we add any chemicals. Write down if it feels cold, cool, warm, or hot in "Temperature before reaction" in the table in Results.
12. Student 2: Add chemical 2 to the jar.
13. Student 1: Add chemical 1 to the jar on top of chemical 2.
14. Student 3: Quickly seal the jar with plastic! We want to keep the reaction (meaning the gases that are produced) inside the jar, so try to move quickly!!
15. Student 4: Feel the outside of the jar and record how it feels in the table in Results in "Temperature after reaction".

Finally, we will prepare the "open greenhouse effect" jar. Each student will have a job:

16. Student 1: Measure 60 mL (1/4 cup) of chemical 1 and have it ready to add to the "open greenhouse effect" jar. Don't add it yet!
17. Student 2: Measure 5 mL (1 tablespoon, or 1 spoonful) of chemical 2 and have it ready to add to the "open greenhouse effect" jar. Don't add it yet!

18. Student 3: Feel the outside of the jar before we add any chemicals. Write down if it feels cold, cool, warm, or hot in “Temperature before reaction” in the table in Results.
19. Student 3: Add chemical 2 to the jar.
20. Student 4: Add chemical 1 to the jar on top of chemical 2.
21. Student 4: Feel the outside of the jar and record how it feels in the table in Results in “Temperature after reaction”.

Now, we will test if any gases we created in our jars (Earth’s atmosphere) will be trapped and heated by the sunlight, similar to how greenhouse gases created on Earth are heated by the sunlight in our atmosphere.

22. Place all jars in the direct sunlight.
23. Wait 5-10 minutes after your jars have been left in the sunlight. If you have a thermometer, insert the thermometer carefully into the jar by poking a hole in the plastic covering of those jars covered in plastic. Record the temperature or the feeling of the jars in “Temperature after sunlight” in the table in Results.

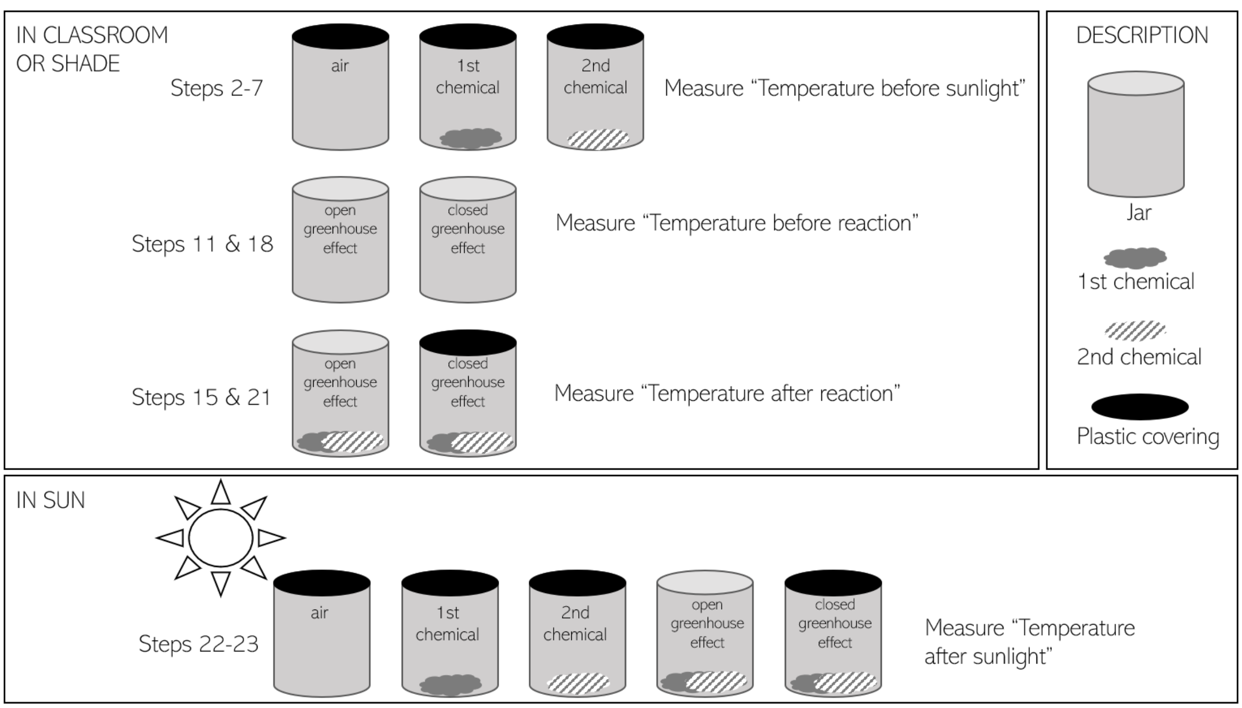

Figure 3. Schematic of the jars that the students will prepare with steps from Procedure. The upper left rectangle includes jar measurements taken in the classroom or shade. The bottom rectangle includes jar measurements taken in the sunlight. The upper right rectangle includes a description of the items in the Figure.

4.2.5. *Results*

Note: Those boxes with "X"s do not need to be filled in.

Jar	Temperature before reaction	Temperature after reaction	Temperature before sunlight	Temperature after sunlight
Air	X	X		
1st chemical	X	X		
2nd chemical	X	X		
Closed greenhouse effect			X	
Open greenhouse effect			X	

4.2.6. *Post-Experiment Questions*

1. Which jar warmed up the most after sitting in the sunlight? Why do you think this happened?
    a. Answer: The "closed greenhouse effect" jar warmed up the most because the gases produced from mixing the two chemicals were trapped in the jar and these gases were heated by sunlight.
2. Why do you think the "closed greenhouse effect" jar became hotter than the "open greenhouse effect" jar?

   a. Answer: We need to keep the gases inside the jar for them to heat up! If the jar is open, the gases go into the classroom and mix with the air instead of being heated in the jar.
3. Why do you think the “air”, “1st chemical”, and “2nd chemical” jars didn’t become as hot as the closed greenhouse gas effect jar?
   a. Answer: We need both chemicals to make the reaction happen! Alone, no additional gases are produced and so only the original air in the jar is heated by sunlight.
4. Which jar in this experiment represents the earth heating up due to the greenhouse effect?
   a. Answer: The closed greenhouse effect jar represents gases becoming trapped in the atmosphere above earth, causing it to heat up.
5. In the “closed greenhouse effect” jar, the release of gas (known as carbon dioxide) from the chemical reaction was trapped inside the jar as a greenhouse gas. Carbon dioxide is also formed when burning wood for fire, burning coal, driving cars (burning gasoline), and making new things in factories. What are some ways we can burn less carbon dioxide in our lives?
   a. Answers: Answers will vary, and you should encourage student creativity. Some include: we can walk instead of drive our car, we can reuse our belongings so factories make less items, and we can try to use power that is not generated by burning coal (these types of power are often called renewable energy sources).

5. Design Challenge

The Challenge: Now that we have learned about heat transfer from sunlight and the greenhouse gas effect, it’s time to use your knowledge to solve some hard problems! We know that if there is too much of the greenhouse gas effect, the Earth can heat up, and this temperature rise can lead to the changing of the Earth’s climate and cause more extreme weather events like extreme heat and drought and intensity of storms. Can you design a house that may keep you comfortable and safe both now and as the Earth’s climate changes?

5.1 Design Questions

Consider the following questions when designing your resilient home.

1. What weather events might you have to protect against?
2. What materials would you want your house to be made from? Are the materials different for the roof, walls, doors, and floor?
3. Do you want lots of windows and doors?
4. Do you want the Sun to shine into your house? Consider how this could be both a positive and a negative.
5. How could you make sure the stove does not heat up your house during cooking?

Possible answers to the questions above:

The possibilities are endless. Some options could be using sturdy but less heat absorbing materials than metal for the roof and walls of the house. Windows are important for allowing sunlight in to heat the house but ensuring there is a way to cover the windows in case it becomes too hot in the house is important. The heat from the stove could be piped out through an exhaust fan or the stove could be placed near a window. Encourage the students to think creatively about heat transfer in their home.

5.2 Design Sketch

Try out your design by sketching it on paper. You can also color it in with markers, pens, pencils, and crayons. Be creative!

My resilient home: