Heat Transfer

Developed by Clark Planetarium

With support from Utah NASA Space Grant's K-12 Educational Funding Award

Contents

Heat Transfer

Estimated setup time: 20 minutes

Estimated activity time: 45-60 minutes

Description:

This hands-on activity will encourage investigation of the surrounding environment by using observation, data collection, analysis, and comparison to allow the students to understand the differences in how materials gain and lose heat. Students will work together in small scientific groups to research and collect data and convene with the greater scientific community (classroom) to share data and draw conclusions. Students will:

- Measure the temperature of different materials.
- Evaluate and compare the rate of change in temperature between different materials.
- Communicate the potential impacts of different materials found locally.

Student Performance Outline:

- Phenomenon – The measured temperature of materials varies when observed under identical conditions.
- Individual Student Performance
    - Complete the Heat Transfer worksheet and make a graph showing the rate of heat gained and lost by a specific material.
- Group Performance
    - Make predictions of the rate of heat gained and lost by a specific material.
    - Investigate the temperature response of a material over time to a heat source through measurement and recording of data.
- Individual Performance
    - Write in your journal your argument for why your evidence supports your group's explanation for the cause of temperature variations experienced in the environment.

Alignment to Utah 6th Grade SEEd Standards

Strand 6.2: Energy Affects Matter

Matter and energy are fundamental components of the universe. Matter is anything that has mass and takes up space. Transfer of energy creates change in matter. Changes between general states of matter can occur through the transfer of energy. Density describes how closely matter is packed together. Substances with a higher density have more matter in a given space than substances with a lower density. Changes in heat energy can alter the density of a material. Insulators resist the transfer of heat energy, while conductors easily transfer heat energy. These differences in energy flow can be used to design products to meet the needs of society.

Standard 6.2.3

Plan and carry out an investigation to determine the relationship between temperature, the amount of heat transferred, and the change of average particle motion in various types or amounts of matter. Emphasize recording and evaluating data and communicating the results of the investigation.

Scientific and Engineering Practices Utilized:

- Asking questions or defining problems
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Obtaining, evaluating, and communicating information
- Engaging in argument from evidence

Crosscutting Concepts:

- Patterns
- Cause and effect: mechanism and explanation

Key Terms:

- Absorption – The process of acquiring and retaining energy or matter.
- Air pressure – The force per unit area exerted on objects immersed in the air. This force results from the collective weight of molecules in the air being pulled down by gravity.
- Air Density – The amount of air molecules in a given volume of space. In warmer air, the molecules spread out more (and are less dense) than in cooler air.
- Albedo – The proportion of incident light that is reflected by a surface.
- Climate – The average weather conditions (temperature, humidity, air pressure) expected in a given location or region.
- Conduction – The transfer of energy from a hotter object to a colder one when they come into direct contact with each other.
- Convection – the transfer of heat by the movement of a fluid such as air.
- Cool – To lose energy.
- Energy – The ability to do work.
- Heat – Energy that is transferred from one object to another because of a difference in temperature.
- Radiation – The transfer of energy in the form of electromagnetic waves. These waves consist of visible light and other wavelengths that human eyes cannot see, such as infrared radiation (also called radiant heat).
- Reflection – The redirection or "bouncing" of light or other forms of electromagnetic radiation from a surface, such as when sunlight bounces off the ground or water.
- Temperature – A measure of internal (or thermal) energy in matter. It is proportional to how fast the atoms and molecules in a substance are moving (or vibrating in place).
- Thermal Inertia – Used to describe the resistance of an object to gain or lose heat. Generally measured by the rate at which an object gains or loses heat. The longer it takes for an object to heat up, the greater thermal inertia it has.
- Thermometer – A device that can measure the temperature of an object.
- Weather – The general state of the atmosphere in terms of temperature, humidity, and air pressure.

The Key Components of the 5E Model

<table>
<tr><th rowspan="2">PHASE</th><th colspan="2">WHAT THE TEACHER DOES THAT IS:</th></tr>
<tr><th>Consistent with the 5E Model</th><th>Inconsistent with the 5E Model</th></tr>
<tr><td>ENGAGE</td><td>• Creates interest
• Generates curiosity
• Raises questions
• Elicits responses that uncover what students know or think about the concept/subject</td><td>• Explains concepts
• Provides definitions and answers
• States conclusions
• Provides premature answers to students' questions
• Lectures</td></tr>
<tr><td>EXPLORE</td><td>• Encourages students to work together without direct instruction from teacher
• Observes and listens to students as they interact
• Asks probing questions to redirect students' investigations when necessary
• Provides time for students to puzzle through problems
• Acts as a consultant for students</td><td>• Provides answers
• Tells or explains how to work through the problem
• Tells students they are wrong
• Gives information or facts that solve the problem
• Leads students step-by-step to a solution</td></tr>
<tr><td>EXPLAIN</td><td>• Encourages students to explain concepts and definitions in their own words
• Asks for justification (evidence) and clarification from students
• Formally provides definitions, explanations, and new labels
• Uses students' previous experiences as the basis for explaining concepts</td><td>• Accepts explanations that have no justification
• Neglects to solicit students' explanations
• Introduces unrelated concepts or skills</td></tr>
<tr><td>ELABORATE</td><td>• Expects students to use formal labels, definitions and explanations provided previously
• Encourages students to apply or extend concepts and skills in new situations
• Reminds students of alternative explanations
• Refers students to existing data and evidence and asks "What do you already know?" "Why do you think…?"</td><td>• Provides definitive answers
• Tells students they are wrong
• Lectures
• Leads students step-by-step to a solution
• Explains how to work through the problem</td></tr>
<tr><td>EVALUATE</td><td>• Observes students as they apply new concepts and skills
• Assesses students' knowledge and/or skills
• Looks for evidence that students have changed their thinking or behaviors
• Allows students to assess their own learning and group process skills
• Asks open-ended questions, such as "Why do you think?" "What evidence do you have?" "What do you know about x?" "How would you explain x?"</td><td>• Tests vocabulary words, terms and isolated facts
• Introduces new ideas or concepts
• Creates ambiguity
• Promotes open-ended discussion unrelated to concept or skill</td></tr>
</table>

<table>
<tr><th colspan="4">Heat Transfer Activity Overview</th></tr>
<tr><th>Activity</th><th>Estimated Time</th><th>Materials/Equipment</th><th>Purpose/Objectives/Essential Question</th></tr>
<tr><td>Engagement
Stations will be set up for students that contain a variety of materials, a bulb thermometer and an infrared thermometer. Each group will be challenged to use the thermometers to see if the temperature of the materials matches the temperature of the room.</td><td>5 minutes</td><td rowspan="5">Materials for each group:

Heat lamp
Material sample
Bulb thermometer
Laser Infrared thermometer
Worksheet
Pen/pencil

Teacher Preparation
Assemble experiment stations

Place materials in locations students can interact with them

Place or indicate appropriate cautions regarding the use of equipment at the stations.</td><td>Purpose:

To allow students to carry out an investigation to determine the relationship between temperature and the amount of heat transferred over time.</td></tr>
<tr><td>Exploration
Students will use the thermometers to make predictions and explore the environment of their classroom to determine the consistency of temperatures.</td><td>10 minutes</td><td rowspan="3">Objectives:

To use a model to test phenomena, collect data and communicate information based on evidence.

To understand the relationships between cause and effect in both natural and designed systems.

To use evidence to describe differences between objects in relation to how they respond to change.

To understand the relationship between the temperature and total energy.</td></tr>
<tr><td>Explanation
Teacher discusses different ways to observe temperature. Showing various images taken with an infrared camera, students will be asked to identify each and explain their reasoning. Teacher uses student responses to continue discussion on how any given environment will have specific and overall responses to heat energy.</td><td>30 minutes</td></tr>
<tr><td>Elaboration
Students will conduct an investigation of a specific heat source and material.</td><td>20 minutes</td></tr>
<tr><td>Evaluation Using the data collected, they will graph their information to analyze if there are differences between the materials they tested. Students will then write a brief statement about where the materials they measured are found in every-day life and what affect their presence might have on their surroundings.</td><td>10 minutes</td><td>Essential Questions:

How quickly do different materials absorb heat?

How slowly do different materials radiate heat?</td></tr>
</table>

Background: Electromagnetic Radiation

All objects continuously radiate energy in the form of electromagnetic waves. Electromagnetic waves (also called electromagnetic radiation) are divided into different categories depending on their wavelength. These include radio waves, microwaves, infrared, visible light, ultraviolet, x-rays, and gamma rays.

The type of electromagnetic radiation given off by an object depends on the object's temperature. When an object is hot enough (like an electric stovetop coil), you can see some of the radiation it emits as visible light. Cooler objects emit mainly infrared radiation.

So, how do we see these cooler objects? We cannot see them in a dark environment. However, we can see them if visible light from some light source reflects off them. An important light source is the Sun.

The Sun gives off ultraviolet and infrared radiation in addition to visible light. About five percent of solar radiation that reaches Earth's surface is ultraviolet (responsible for sunburns); 42 percent is visible light (in colors ranging from violet to red); and 53 percent is infrared (sometimes called radiant heat).

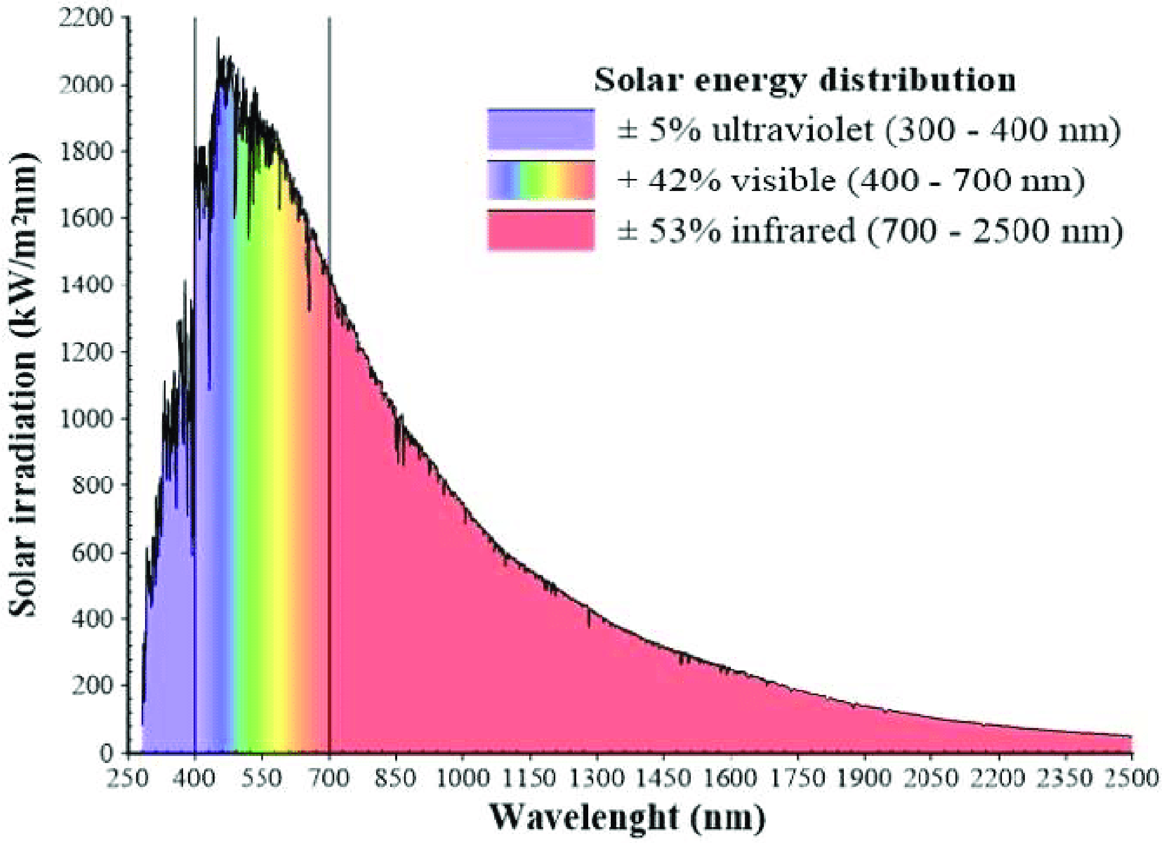


Image Credit Solar reflectance of ETICS finishing coatings – a comparison of experimental techniques, Ramos, et. al., 2020

Heat Transfer by Radiation

Electromagnetic waves transfer energy from one object to another unless the objects are at the same temperature. If two objects are at different temperatures, there will be a net transfer of energy from the hotter to the colder object. The Sun's surface has a temperature of about 10,000 °F (6000 °C). So, there is a transfer of energy from the Sun to Earth. All the wavelengths in solar radiation transfer energy. Infrared radiation plays a large role in heating our planet.

When solar radiation hits a surface, portions of it are absorbed, reflected, or transmitted (in the case of a transparent surface like glass). The fraction of radiation that is reflected or absorbed depends on the properties of the material. For example, dark colored surfaces absorb more visible light than light colored surfaces.

Absorbed solar energy can raise the temperature of an object. The object's properties determine how much the temperature changes as radiation is absorbed. For example, the temperature of asphalt will increase significantly as it absorbs solar radiation. In contrast, absorption of solar radiation will not result in as large a temperature increase for plants (which contain water) or moist soil. Instead, some of the absorbed energy will evaporate water (a process called evapotranspiration).

On a sunny day, the Sun can heat dry surfaces, like roofs and pavement, to temperatures much hotter than the air while shaded or moist surfaces remain close to air temperatures. Researchers are trying to develop specially engineered pigments that reflect well in infrared wavelengths to help keep surfaces cooler.

Once the Sun sets, an object with a temperature higher than its surroundings will radiate energy away until it has lowered its temperature to the same temperature as its surroundings.

In urban environments with many buildings and little vegetation, temperatures can be higher than surrounding regions. This is known as the urban heat island effect.

Background: What Causes Weather?

Weather is the state of the atmosphere with respect to being hot or cold, wet, or dry, calm or stormy, clear skies or cloudiness. These conditions describe what we are experiencing at the moment and can change within minutes or hours. The average weather over a long period of time defines **climate** – the overall expectation of conditions.

Differences in temperature, air pressure and humidity between locations drive the changes in weather that we experience. The primary source of heat and energy that Earth receives is from our Sun. As Earth rotates on its axis, and orbits around the Sun, the amount of solar energy reaching particular locations on Earth changes. Daily changes as Earth rotates are relatively small. Yearly changes as Earth orbits the Sun are much more intense which can be observed as Earth's seasons. Because Earth's motions cycle in a regular and ongoing basis, patterns emerge and can be predicted. Over longer periods of time (tens or hundreds of thousands of years), changes in Earth's orbit affect the amount of heat and energy Earth receives. This results in long-term changes to climate, both locally and globally.

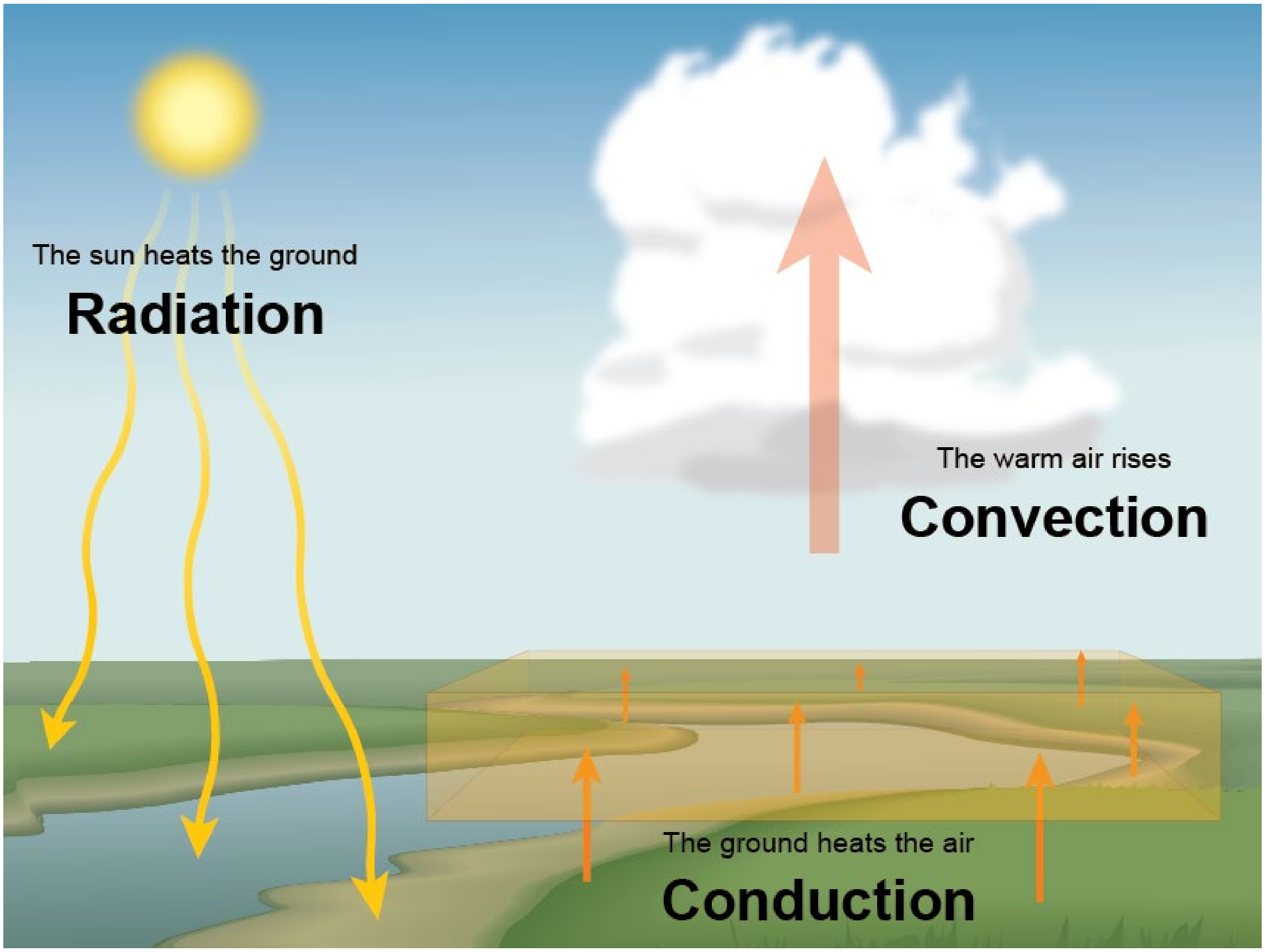


Image Credit NOAA NWS

The **heating** and **cooling** of Earth's surface is not uniform. Differences in surface temperatures can in turn affect air pressure. Altitude also has an effect on **temperature** and pressure as higher altitudes have fewer air molecules in a given volume. Fewer air molecules that come into contact with Earth's surface reduces the impact of surface heating. This uneven heating of Earth's surface drives the flow and transfer of matter and energy, creating the cycles and patterns we experience with weather and climate.

The intensity of sunlight in the Northern and Southern hemispheres changes in a repeating, yearly cycle. This is because Earth's axis is tilted with respect to the orbital path Earth follows as it travels around the Sun each year. The Northern Hemisphere experiences more intense sunlight when it leans towards the Sun. Light striking the surface at a more direct angle results in a higher concentration of **radiant energy**. Because the Southern Hemisphere is leaning away from the Sun during this time, it experiences less direct light and therefore less intense sunlight. Earth's axis remains generally unchanged as Earth orbits the Sun. As a result, the Northern Hemisphere does not remain tilted towards the Sun. By the time Earth is half-way through its orbit, it is the Southern Hemisphere, not the Northern, that is leaning towards the Sun. The intensity of sunlight at the surface is now reversed and each hemisphere experiences opposite seasons as a result. This cycle continues year after year.

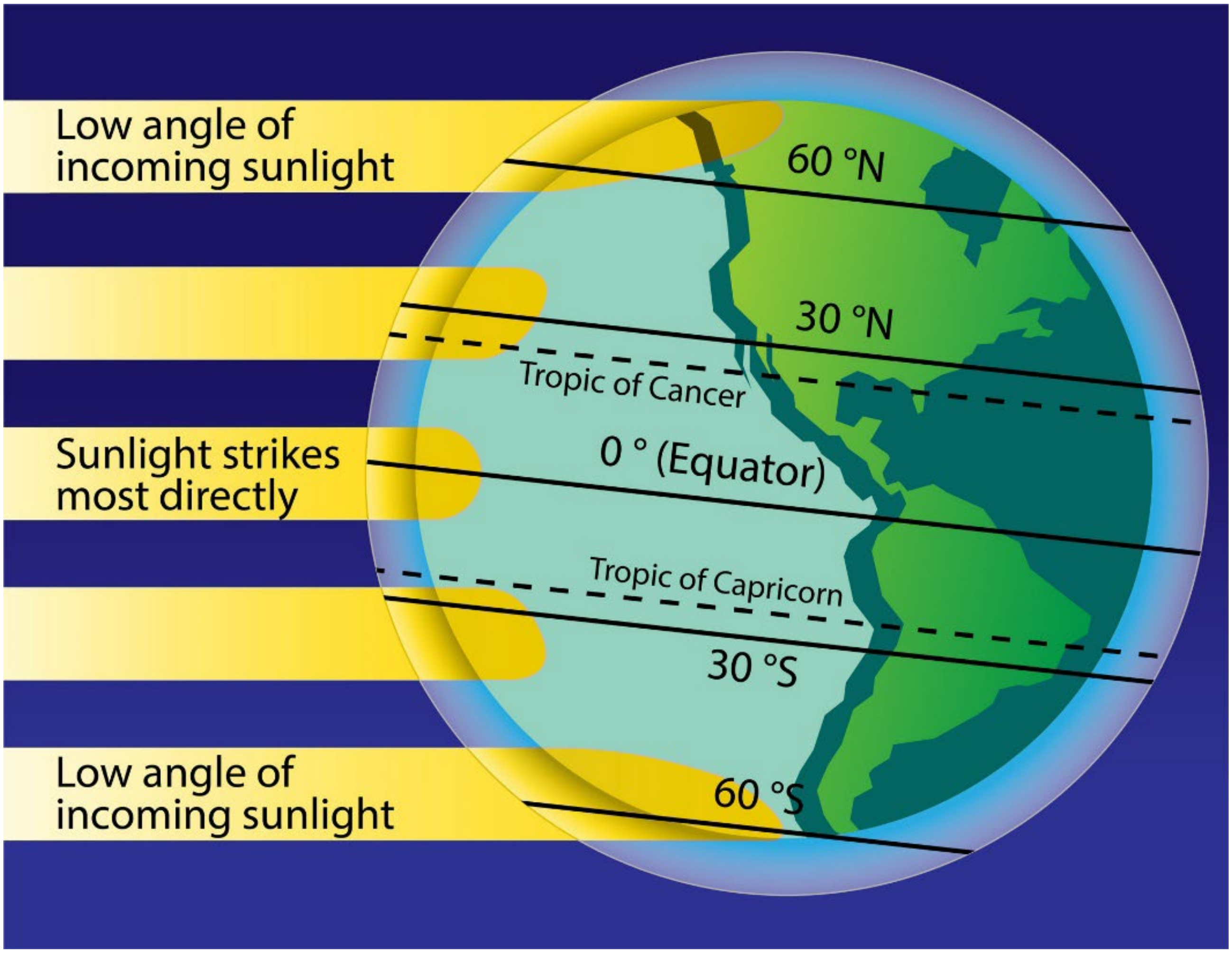


Image Credit UCAL Berkeley

On local scales, temperature differences can occur because different surfaces (such as oceans, forests, ice sheets, or man-made objects). This is due to differing physical characteristics such as reflectivity, roughness, or moisture content. Temperature also affects **density**. Higher temperatures cause air to expand, creating a change in air pressure. As surface temperatures heat up, the air mass in contact with the surface **absorbs** that energy, resulting in a lower density. As the less dense air rises, the surrounding, cooler, more-dense air moves in to take its place.

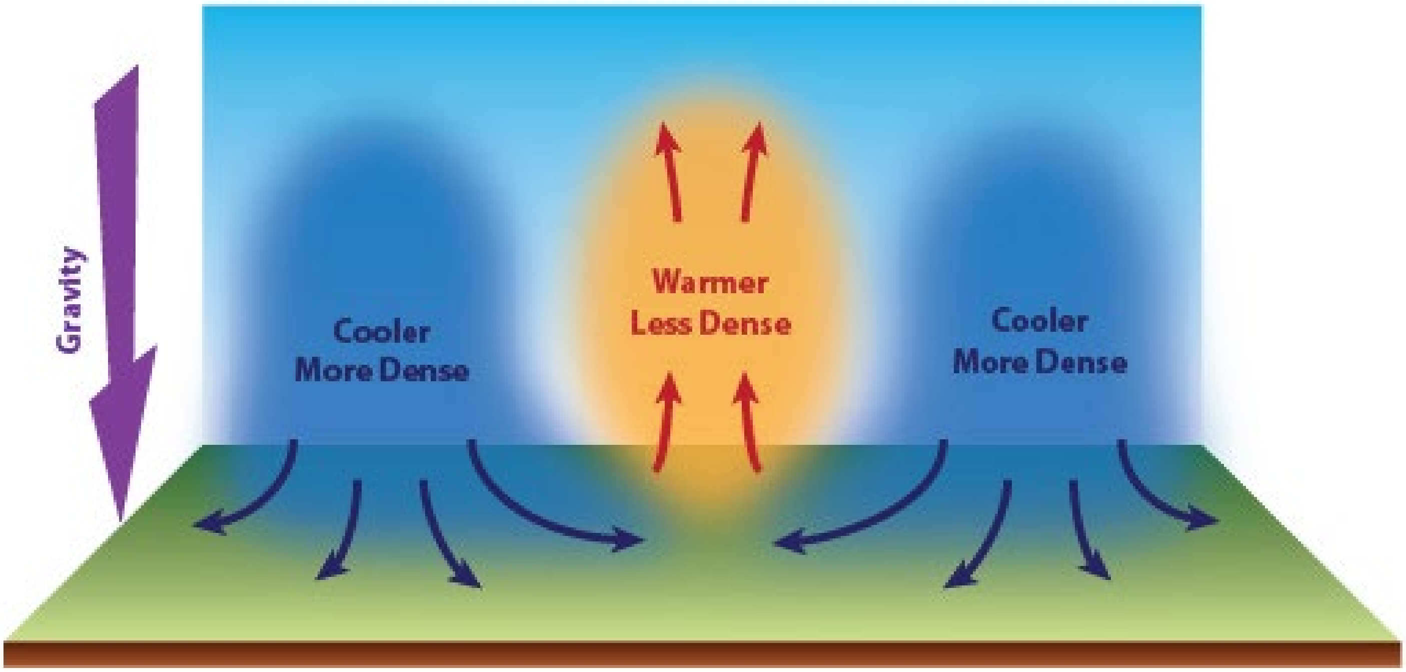


Image Credit NOAA NWS

The changes and interactions between each of these systems have impacts on both local and global scales. Locally, these are experienced as the familiar aspects of weather. Wind results from changes in air pressure, clouds form when water in the air condenses, rain or snow occur when water in the air precipitates. Over the course of a year, these changes provide the basis for weather expectations on an annual scale for any given region on Earth. Regions with defined averages of these conditions are also called climate regions.

Background: What is Climate

Climate is the average weather conditions at a place over time, primarily relating to temperature and precipitation. These climate conditions can be viewed at a local, regional, or global scale. There are several factors that can affect climate, such as latitude and overall geography. In addition, Earth has its own large-scale systems that are divided into basic major components: land, air, and water. Changes in interactions between each of these normally occur from seasonal and solar cycles on a short-term scale. As a result, scientists generally use 30 years as the range of time to establish a climate average. Over the long-term, some patterns and cycles found on Earth can take thousands or millions of years and produce major changes in Earth's major components.

Different Climate at Different Latitudes

Latitude plays a role in global climate zones as the intensity of light received from the Sun depends on the angle at which sunlight hits Earth's surface. Locations close to the equator receive mostly direct sunlight throughout the year. The farther you are from the equator, the greater the change in the angle and intensity of sunlight during the year. Seasonal cycles result in a minimum and maximum range of average solar intensity experienced, giving rise to Earth's three described climate zones: Tropics, Temperate and Polar. The Tropics can be found 23.5 degrees north or south of the equator. Excepting high altitude areas, this zone is typically hot for most of the year. The temperate zone is found between 23.5 degrees and 66.5 degrees from the equator. This zone experiences temperate or moderate weather on average. Finally, there is the polar zone, found between 66.5 degrees and the poles themselves. These areas get little radiative heat from the Sun and remain much colder throughout the year.

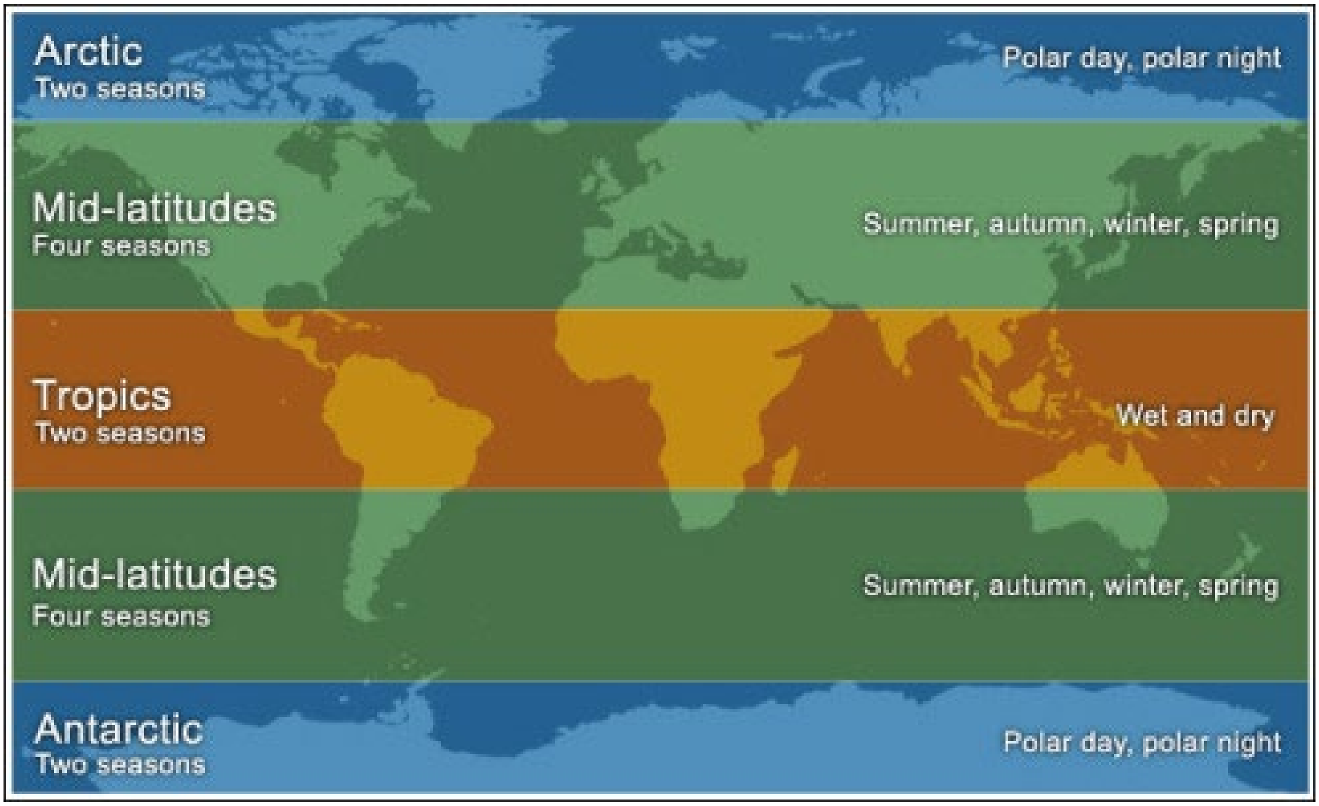


Image Credit Otway et al., 2011

Climate Types

When looking at climate, the three main zones can also be divided in to six primary different climate types. Tropical climates have hot weather that can be either wet or wet and dry. Dry climates are typically dry and desert-like. Polar climates experience freezing cold conditions. Mild climate types enjoy moderate temperatures. Continental climates experience large shifts in temperatures from summer to wintertime. Lastly, High Elevation climates exist where high altitudes also play a role on temperatures and precipitation experienced.

The Role of Geography in Climate

Unlike latitude, geography has many aspects that can change over short and long periods of time. Elevation, water, mountains, and human-made structures (such as cities) also play a role in climate.

Elevation impacts the amount of air that surrounds you. At a higher altitude, air has a lower pressure due to fewer air molecules in a given volume. Air warms by conduction when it is in contact with the ground. At higher elevation, fewer air molecules are in contact with the ground at any point in time. So, heat transfer by conduction is less effective. The large-scale system that deals with the air is called the atmosphere.

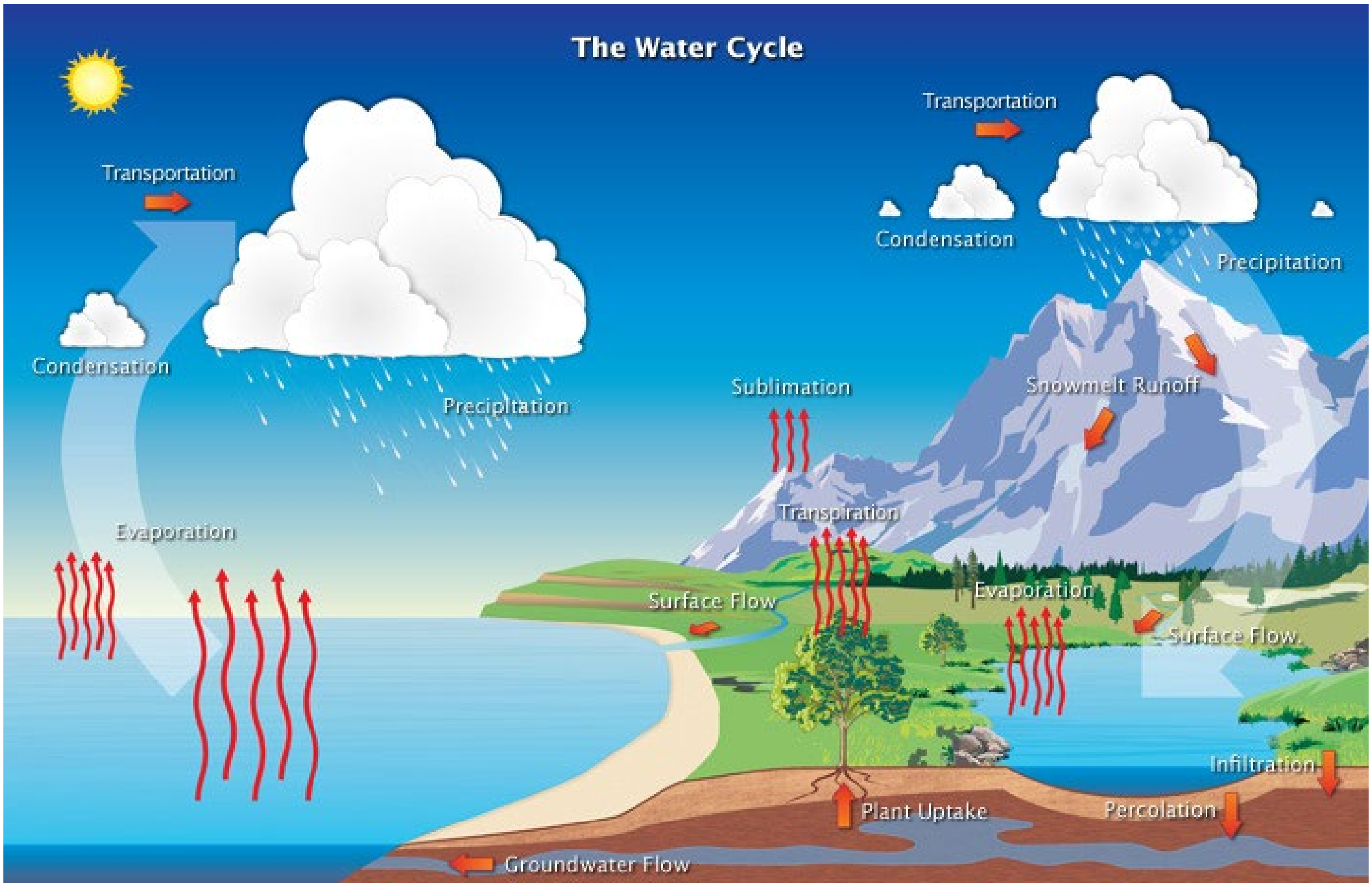


Image Credit NOAA NWS

Geographically, water can range in scale from a small stream or lake to an entire ocean. Temperature changes that result from the transfer of heat to or from water take longer than in many other substances. Large bodies of water have the effect of stabilizing temperatures near coastlines, producing fewer overall fluctuations in temperature. In the ocean, currents form as warm water near the equator moves toward the cooler waters of the northern region. This movement creates a pattern that continuously cycles water between regions. The large-scale system that deals with water is divided into the hydrosphere and cryosphere (snow and ice).

Mountains also affect how water is cycled on Earth and influence rain patterns. When warm air with water vapor hits a mountain, it rises and begins to cool. As it does so, the water vapor begins to condense and precipitate. The side of the mountain that is hit by this warm, moist air experiences more rain than the other side where water vapor has been stripped from the atmosphere. This phenomenon is known as a rain shadow. Mountains belong to the large-scale system called the lithosphere – essentially the land.

Human Activities and Effects on Climate

Human activity can also effect climate. This impact has grown dramatically over time, primarily due to an increase of greenhouse gases in the atmosphere. On smaller scales, structures such as buildings and roads can have an impact on heat that is absorbed. Loss of vegetation that is cleared or altered to build structures can cause reductions in evapotranspiration, a process by which plants can lower an area's temperature. As a result of these impacts, cities can experience temperatures up to 5 degrees Celsius higher than a surrounding area. This is known as the "heat-island effect". Humans and all other life forms form a large-scale system unique to Earth – the biosphere.

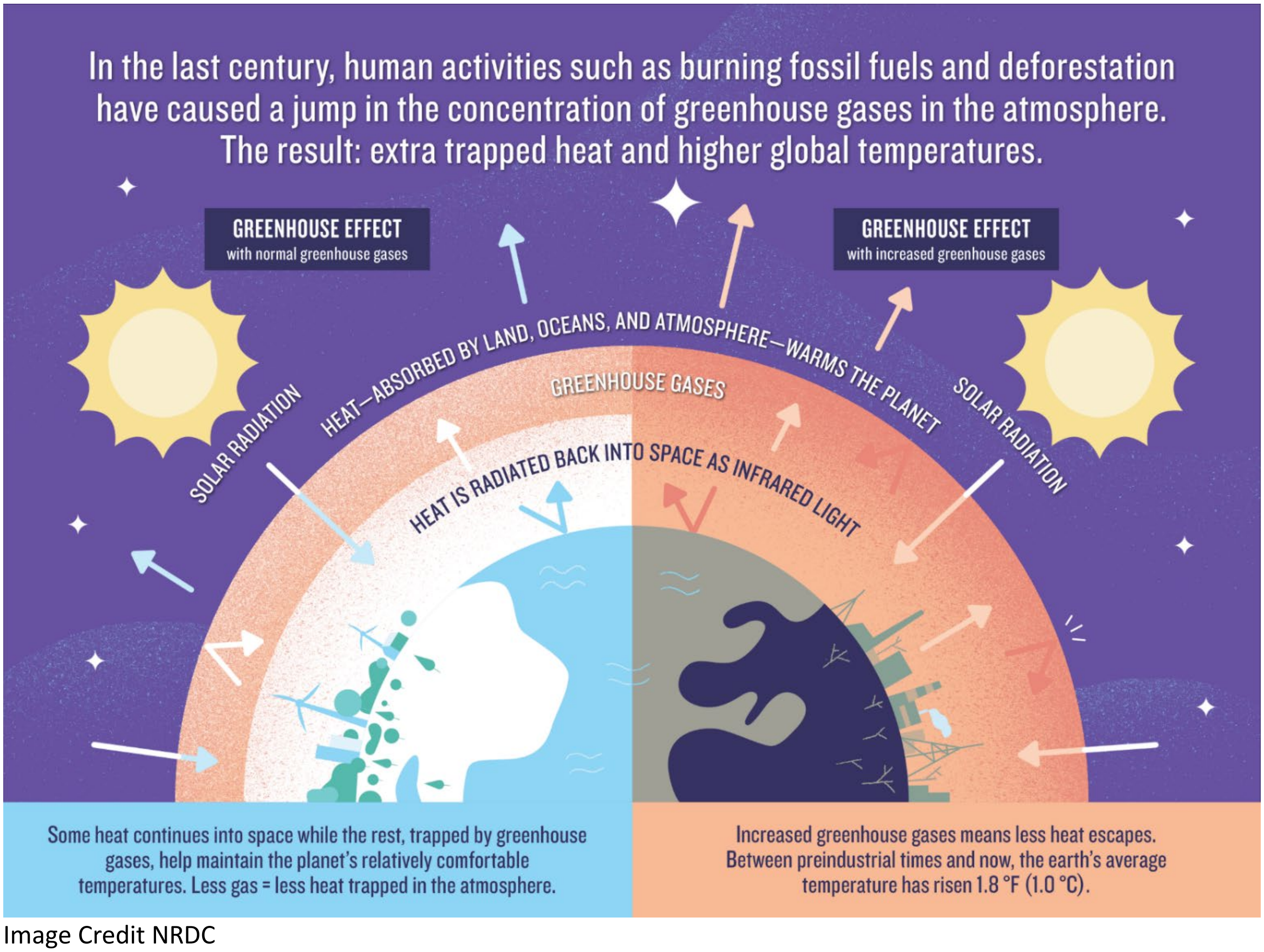


Image Credit NRDC

Weather Cycles That Impact Climate

In addition to these factors and components of Earth's climate, another pattern also plays a major role in the cycling of energy around the planet, El Niño and La Niña. These describe changes in ocean temperatures across the Pacific Ocean. Normally, trade winds blow west along the equator. This pattern helps drive warm water across the Pacific from South America to Asia. As this happens, colder water rises from deep within the ocean through a process called upwelling. El Niño and La Niña are climate patterns that break with the normal conditions. Combined, these events are called the El Niño-Southern Oscillation (ENSO) cycle. This cycle generally occurs every two to seven years, though not on a regular schedule.

During an El Niño event, the trade winds soften and don't move the warm waters of the Pacific as much. As a result, colder waters don't rise up as much, leaving the warmer waters to contribute to heavier rainfall and storms than normal.

La Niña has the opposite effect of El Nino. During this event, trade winds are stronger, pushing the warmer waters farther than normal. With more cold water upwelling from below, storms aren't able to form as normal and can cause drought conditions.

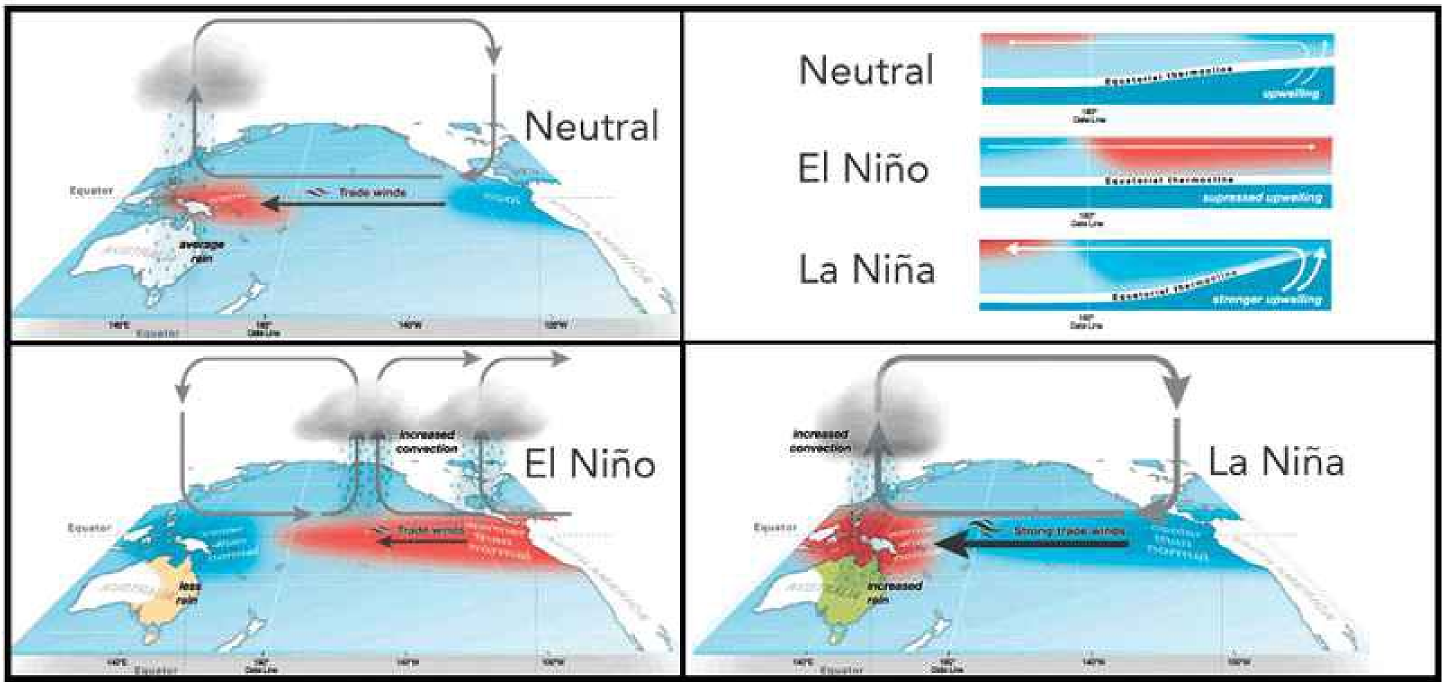


Image Credit NOAA NWS

The patterns and cycles that each local and large-scale system go through affect each other. Impacts on one shift the effects of another. Studying Earth and how each of these factors interact can help us make more informed decisions on the components we have control over.

Activity Outline:

Engagement:

Have students touch the top of their desk and then something else around them, such as the metal legs of their chair or other object. Have them make observations about what they noticed or if there were any differences they felt in comparison. Ask them how they would measure the temperature of something in the room, and if they think everything in the room is the same temperature.

Exploration:

With the stations set up, have the students take the temperatures of the samples presented and compare them. As students make comparisons, have them make predictions about what they think the result would be if they measured various items around the classroom. Have them communicate with each other regarding why they made the predictions they did and what evidence they could use to support them.

Explanation:

Have the students return to their seats and use the Heat Transfer and Thermal Inertia PowerPoint to discuss how heat is absorbed and re-emitted differently by objects in the environment. Use the following to help guide the conversation:

- Have students observe various infrared views of objects in the PowerPoint.
- Ask them what they think they are observing and why.
- Explain to students that scientists can use heat images to study the effects of various structures we construct to support our cities and communities.
- Ask students why they think there are differences in temperature observed in the examples given.
- Ask students how they could test their ideas.

Elaboration:

- Divide students into appropriate groups and use the procedure listed to give them instructions on how to use the equipment at the workstations.
- Students will conduct an investigation on the relationships between various samples and how they respond to change when heated.
- Using the data sheet provided, have students complete the activity and record their data for analysis.

Evaluation:

Have students return to their seats once they have completed their data collection. Using the Excel Data Graphing file, have students from each team report on the material they tested. Once all the data has been input into the Excel sheet, have students from each team report on what the graph shows about the material they tested.

Have students write 2-3 sentences about where materials they tested can be found in every-day life and what affect their presence might have on their surroundings.

Materials Needed:

- Provided in kit:
    - 6 250-Watt Work Lamps
    - 6 8ft Light Duty Extension Cords
    - 2 2.5ft Power Strips
    - 2 25ft Light Duty Extension Cords
    - 6 Base Stands
    - 12 Wooden Dowels
    - 12 Infrared Thermometers
    - 6 Sample Containers

- Additional resources needed:
    - 1 (or more) electrical outlet(s)
    - 6 desks or small tables (must be level, the same height, and large enough to hold all of the station materials.)
    - pencil/pen (one for each student)
    - copies of student worksheets (one for each student)
    - 1 projection screen - *optional*
    - 1 overhead projector – *optional*
    - 1 overhead copy of the Worksheet (for the overhead projector: classroom analysis and comparison) – *optional*

- *Extras provided in the kit for replacement or additional options*
    - Replacement rubber ends for work lamps
    - Replacement pack of Halogen bulbs for work lamps
    - 2 Sample containers (1 empty, one with extra sample provided)
    - 12 Bulb Thermometers (for adaptations and future supplemental activities)

Setup and Preparation:

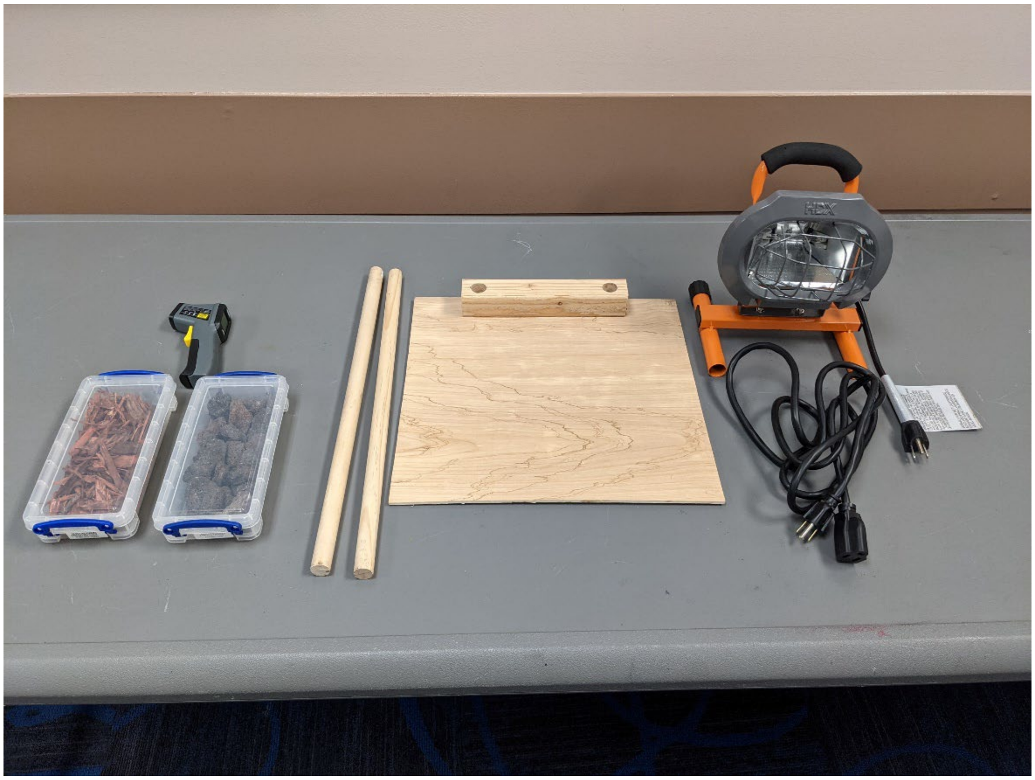
The experiment stands are designed to provide a controlled environment with a directed light and heat source. By exposing different sample materials to the same heat source, the intensity of light is the same for all objects. This will allow for qualitative testing of each of the materials. As a result, measuring the rate at which each sample gains or loses heat will have a standardized procedure and allow for valid comparison.

The activity can be set up in a variety of ways and places, ideally where the stations are separated enough for students to work at each station with enough room for the others. The extension cords provided allow for a decent amount of space between desks or tables. Caution and attention will need to be made to keep the extension cords from being tripped on. Mindful placement of the cords and desks can help reduce this issue, but additional duct tape or similar will provide extra safety. When students are ready to work with the laser infrared thermometers, make sure that the safety guidelines have been communicated and understood by the students.

- Arrange for 6 desks or tables to be designated as the research workstations.
- Make sure that the desks or tables are within close enough distance from each other that the 8ft extension cords can be plugged into one of the power strips without causing a hazard.
- Make sure the power strip can be safely plugged into the 25ft extension cord without causing a hazard.
- Assemble the workstations by placing each of the following at their designated locations:
    a. 1 250-Watt work lamp
    b. 1 8ft Light Duty Work Cord
    c. 1 Base Stand
    d. 2 Wooden Dowels
- Place each of the wooden dowels into the drilled holes on the base stand.
- With the work lamp facing downward, line up and place the wooden dowels into the open ends of the work lamp stand.
- Plug the power cord of the work lamp into an 8ft extension cord.
- Once all stations are set up, plug three of the 8ft extension cords into one power strip, and the other three into the other power strip.
- Plug one of the 25ft extension cords into an outlet, and the other cord into another outlet. (note: they can share the same outlet, but it is recommended that only three workstations are plugged into a single power strip.)
- Plug each of the power strips into the other end of a respective 25ft extension cord. (the power strips have an off-on switch to allow you to control multiple workstations turning on or off at the same time when ready to start.)
- From the sample containers provided, choose one to place at each of the stations. (there is an additional sample provided for options, as well as a spare container if you would like to test a material of your choice.)
- Place an infrared laser thermometer and a bulb thermometer at each of the workstations.

This completes the setup for the activity. In this model, the work lamps represent the Sun. With workstations in this configuration, you are able to test the thermal inertia, or responsiveness to being heated, and make a comparison to not only the materials provided, but optionally choose items or materials found in your classroom, school, or other areas of everyday life and make direct comparisons to materials found in nature or used in constructing buildings and more.

NOTE: The pictures below show a single station before assembly and after. Remember when setting up multiple stations to space them apart from each other. The picture in the safety section shows six workstations set up on two tables for reference.



Helpful Tips:

- If students provide incorrect or inconsistent answers to questions during the discussion, it may be tempting to correct them immediately. A better approach is to ask additional questions that will help students clarify their thinking. Asking them to cite evidence in their arguments may also help.
- Teachers and students are encouraged to use a questioning approach throughout. There are many opportunities for students to make observations that are not necessarily listed below.

Setup checklist:

- ☐ Check power and light source.
- ☐ Check distance between workstations.
- ☐ Check power cords for their placement to avoid tripping hazards.
- ☐ Check stations for pens/pencils.
- ☐ Check stations for activity sheets.
- ☐ Check stations laser infrared thermometers to make sure batteries are working.

Procedure:

Student Roles as Scientific Research Groups:

Before beginning the activity separate the class into 6 equal size groups, 2 to 4 students per group depending on class size. (The students can form into their standard work groups or can be randomly organized by the teacher. The teacher should also reserve the right to reorganize groups that will work together more productively). Each student in the scientific group will have a role or responsibility: Temperature Taker (**TT**), Data Recorder (**DR**), Timekeeper (**TK**). Each workstation has enough equipment to support 2 groups.

- **Temperature Taker (TT):** One student will use the laser infrared thermometer to take a temperature reading of their sample material and read the display output to the Data Recorder.
- **Data Recorder (DR):** One student will record the collected data on the activity sheet.
- Additional students in each group could contribute to the study by acting as **Timekeepers (TK).**

It is important that these activity procedures are demonstrated by the instructor before allowing the students to proceed with the activity. Students will take turns taking the temperature and recording the data. During the first half of the activity while the lamp is on, students will fulfil their initial assigned role. Half-way through the activity when the lamp is turned off, students will switch roles and continue to take and record their measurements.

Rules:

1. **The lamps should not be turned on until ready to start the exploration activity.** Because it takes time for the materials to cool back down to room temperature, it is important to avoid adding heat that may interfere with collecting data that can be compared.
2. When using the laser infrared thermometers, it is important to take reading from the same spot each time. The laser that is integrated with the thermometer is for this purpose.
3. To ensure collected data is consistent, take measurement from the same angle and same distance as close as possible each time.

Safety:

The following precautions should be followed.

1. These lamps put out 250 watts of energy. They are very bright and very hot. Avoid looking directly at the lights. Avoid touching the lamps. Parts of the lamps do get hot enough to cause serious burns.
2. The lamps are plugged into a power strip with an extension cord. There is a risk of tripping on either of these power cords. The power cords can be taped down to present less of a hazard.
3. If room permits, the stations should be positioned in such a way that the power cords are not an obstacle for students. If setup makes this not feasible you can use duct tape to tape down the extension cords. This will minimize impact and keep the cords from coming up and being tripped on.

Data Collection:

Send the students to their assigned workstation. Each student should have their own data recording sheet. On the sheet, have students write down which material they are investigating. Prior to starting, have each group consider the material and make a prediction about how fast it might heat up and why. Students may want to consider using a comparison of another material to guide their answer. Before using the laser infrared thermometers, remind them of the safety and use of their device as a tool, not a toy.

Before turning on the lamps, have the students at each workstation assigned to a specific role. Regardless of the number of students at a workstation, make sure everyone understands that roles will change places during the experiment. If there are only two students, have one be the Temperature Taker and the other be the Data Recorder. During the activity, half of the time is used with the work lamp on, and the other with it off. Have students switch roles once the lamp is turned off. If more than two students are present at a workstation, the roles will need to be changed more than once (every two-three minutes, as an example).

As information is collected it will be important for students to focus on working together as a team. This will include making measurements at the appropriate times, making sure the lamp is only on when it is supposed to be, making sure the lamp is turned off when it is supposed to be, and sharing the data collected between everyone on the team when the experiment is done. Once the experiment is complete and the data recorded on each team member's data sheet, the team will need to choose who will be the voice to announce their data when the class is ready to go through the data graphing exercise. (An example of this could be one student reading aloud the temperatures taken with the lamp on, and another student reading out the temperatures with the lamp off.)

Teacher Background:

The heating of Earth's surfaces occurs when light and energy from the Sun is absorbed and re-emitted. Differences in physical properties affect how much energy is absorbed and how much is reflected. As a result, materials on Earth's surface heat at different rates. These differences can be large or small and are affected by local and regional geography.

Natural geography includes the surrounding land, rivers and lakes, and elevation. Human-made structures that impact these are the buildings, roads and other forms of infrastructure that supports communities and cities. Comparing how each of these materials absorb and give off heat allows us to understand potential impacts and design solutions that can help minimize those impacts.

The overall interactions between the energy we receive from the Sun, the atmosphere, land, and oceans exist in a balance that regulates the patterns and cycles Earth experiences – weather and climate. This is known as Earth's "Energy Balance". These patterns arise from the uneven heating of Earth's surface, which affects in turn how energy is transported around each of Earth's systems to maintain this balance.

Students will investigate the environment in their own surroundings using two different kinds of thermometers. Through initial exploration and additional controlled experiments, students will gather and collect information that they can use to communicate concepts and design solutions to reduce the impact of human activities on the environment.

Student Background:

Question:

How quickly do different materials absorb heat? How slowly do different materials radiate heat?

Background:

Heat is the transfer of thermal energy between substances. Different materials absorb and give off thermal energy at different rates. The rate at which a material absorbs or radiates heat can be measured using a thermometer and a stopwatch.

Instructions:

1. Choose a station and material to test. Record the material below.
2. Measure your material's starting temperature:
    a. Choose a spot on the sample. NOTE: Take the temperature at the same place each time for the experiment.
    b. Point the thermometer at the spot, pull the trigger, and wait two seconds.
    c. Record the temperature on your data sheet on the [0 mins] line.
3. Start heating your sample:
    a. Plug in the heat lamp. Immediately start the timer on the stopwatch.
4. Record the temperature of your material every 60 seconds (1 minute).
    a. Choose a spot on the sample. NOTE: Take the temperature at the same place each time for the experiment.
    b. Point the thermometer at the spot, pull the trigger, and wait two seconds.
    c. Record the temperature on your data sheet.
5. After taking a final measurement at 10 minutes, turn off the heat lamp.
6. Start cooling your sample:
    a. Move the sample out from under the heat lamp. Reset the stopwatch and start it.
7. Record the temperature of your material every 60 seconds (1 minute).
    a. Choose a spot on the sample. NOTE: Take the temperature at the same place each time for the experiment.
    b. Point the thermometer at the spot, pull the trigger, and wait two seconds.
    c. Record the temperature on your data sheet.

Data Sheet:

Name: ______________________________________

Material: _________________________

NEVER aim lasers at a person's eyes or face.

Always hold the laser at least one foot away from the sample.

Make a prediction

Write one or two sentences below about whether you think your sample will heat at the same rate, slower, or faster than one being tested at another station and why:

Heating (Lamp On)

Time	0 min	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Temperature (degrees F)											

Cooling (Lamp Off)

Time	0 min	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Temperature (degrees F)											

Observation

Write one or two sentences about the difference between your prediction and observation (if any). Explain why it was the same or different:

Impact

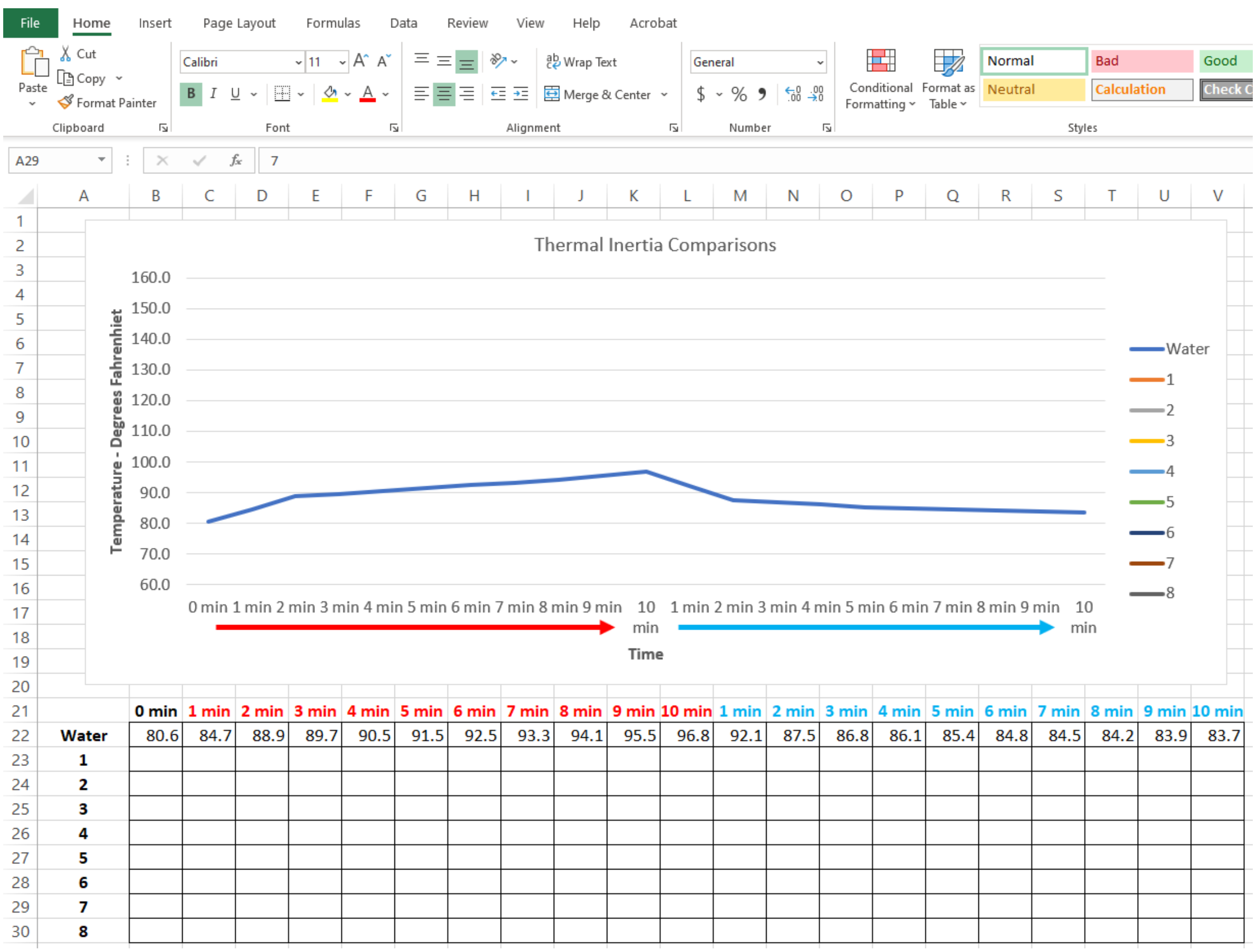
Write one or two sentences about where the material you observed can be found in every-day life and what impact it might have on the surrounding environment:

Using Excel to Graph Your Data

1) Go to the Activity Resources folder on the provided USB drive

2) Open the Excel file titled: Thermal Inertia Data Chart

   a) Note that water has been added in for comparison.
   b) While the starting temperature of student samples may start at a different one than samples, the curve that shows the rate of change is still applicable for comparison.



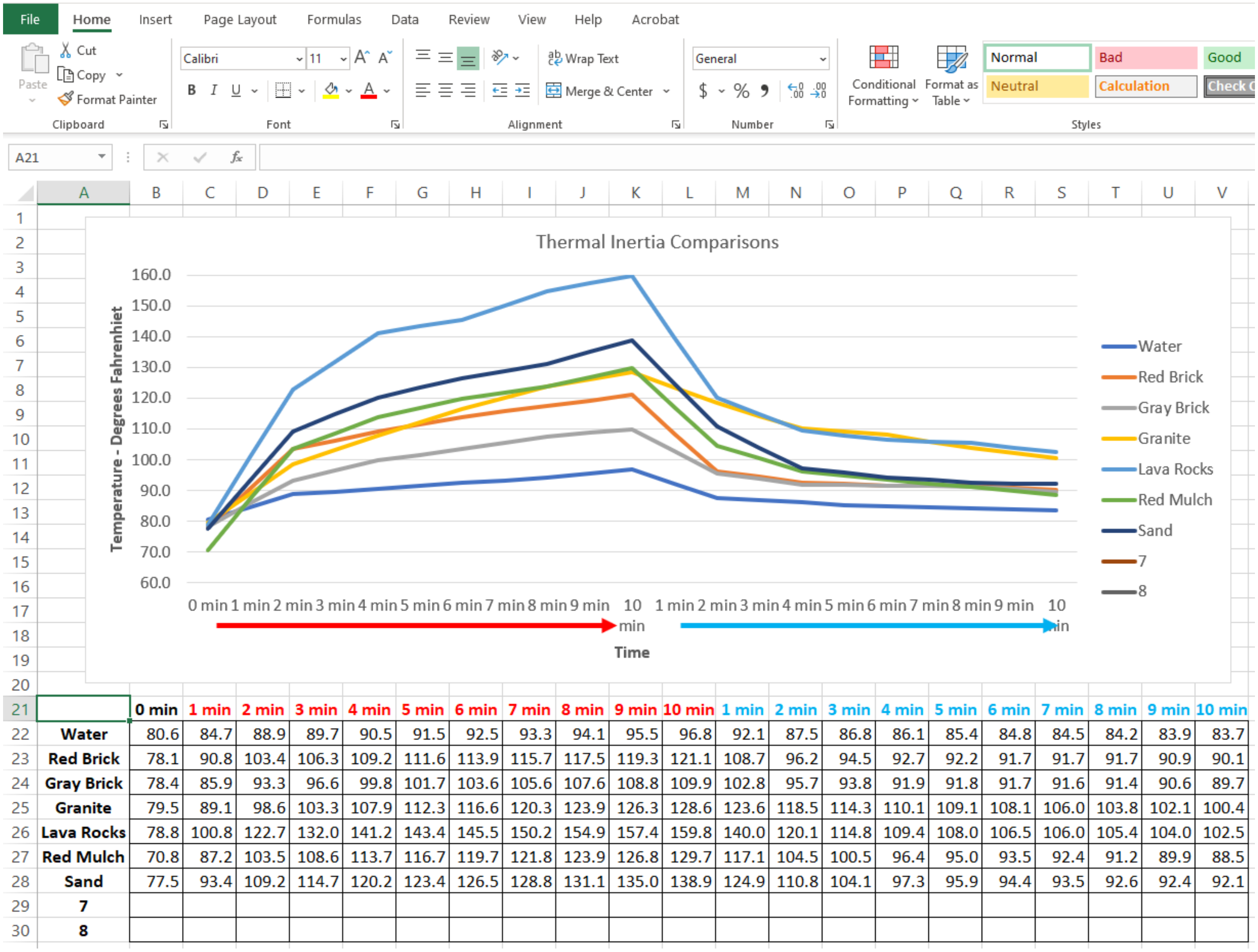
	0 min	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Water	80.6	84.7	88.9	89.7	90.5	91.5	92.5	93.3	94.1	95.5	96.8	92.1	87.5	86.8	86.1	85.4	84.8	84.5	84.2	83.9	83.7
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					

3) In the cells labeled (1, 2, etc..) have students relay the material that they measured and enter it into the field.

4) Have students report the temperature data for each interval for that sample.

5) Continue the process for each of the samples.

A sample chart is included below to show sample testing during material tests during development of the activity.



	0 min	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Water	80.6	84.7	88.9	89.7	90.5	91.5	92.5	93.3	94.1	95.5	96.8	92.1	87.5	86.8	86.1	85.4	84.8	84.5	84.2	83.9	83.7
Red Brick	78.1	90.8	103.4	106.3	109.2	111.6	113.9	115.7	117.5	119.3	121.1	108.7	96.2	94.5	92.7	92.2	91.7	91.7	91.7	90.9	90.1
Gray Brick	78.4	85.9	93.3	96.6	99.8	101.7	103.6	105.6	107.6	108.8	109.9	102.8	95.7	93.8	91.9	91.8	91.7	91.6	91.4	90.6	89.7
Granite	79.5	89.1	98.6	103.3	107.9	112.3	116.6	120.3	123.9	126.3	128.6	123.6	118.5	114.3	110.1	109.1	108.1	106.0	103.8	102.1	100.4
Lava Rocks	78.8	100.8	122.7	132.0	141.2	143.4	145.5	150.2	154.9	157.4	159.8	140.0	120.1	114.8	109.4	108.0	106.5	106.0	105.4	104.0	102.5
Red Mulch	70.8	87.2	103.5	108.6	113.7	116.7	119.7	121.8	123.9	126.8	129.7	117.1	104.5	100.5	96.4	95.0	93.5	92.4	91.2	89.9	88.5
Sand	77.5	93.4	109.2	114.7	120.2	123.4	126.5	128.8	131.1	135.0	138.9	124.9	110.8	104.1	97.3	95.9	94.4	93.5	92.6	92.4	92.1
7																					
8																					

Data Analysis:

When the students are done with taking and recording temperatures for their sample, have them work as a team to make sure each of their data sheets have the same data filled out. Have the students ready to call out their recorded data once the class is all back together.

With the Excel data graph open and viewable to everyone, have each team (one team at a time) call out the material they used to make observations and enter it into the field below “Water”. Proceed to have the team call out the temperatures they recorded for each of the indicated intervals. Do this for each team and sample measured until the data portion of the graph is filled out. The graph is set to automatically show the visual line connections as the data is entered.

With all of the data displayed, have the teams take a moment to look over the comparisons and see if it matched their predictions and have them write in the “Observations” portion of their data sheet. Once all teams have completed this step, open the discussion up to everyone to make observations and comparisons about the various materials. If needed, help guide the discussion with questions such as:

- “Are there similarities between certain materials?”
- “Which materials are closer to each other in temperature changes?”
- “Which materials differ the most in comparison to each other?”
- “What material showed the fastest change in temperature when heated?”
- “What material shows the slowest change in temperature when heated?”
- “What materials do we find most often in our every-day lives?”
- “Where do we find large amounts of these materials?”
- “What affect do you think any of these materials would have on the environment?”
- “What affect do you think your material would have on the environment if a lot more of it were present?”
- “What affect do you think your material would have on the environment if a lot less of it were present?”

Help the students make connections between their experiments and group discussion and the potential impacts on weather or climate as a whole. The ability to transfer heat and the rate at which factors in the environment can be small or great. Which of these factors are found in your own community? Which ones do we have control over (such as buildings, roads, etc.) and which ones are a part of the local geography (mountains, lakes, rivers, etc.)?

Through direct experimentation, observation and data analysis, students gain the ability to better understand their environment. The impacts of modifying our local environment can have serious implications. Understanding these enables both decisions and solutions that address those implications to be data driven.

Conclude by having students complete the final portion of their data sheet by writing in the “Impacts” portion. This can either be done individually or once again with the team.

Additional Resources:

There are a variety of additional resources available to add to or supplement both this activity and subject. We encourage you to sign up for our email list for a monthly publication we release called, “The Educator”. It has helpful information on ways we can support your class instructions, as well as periodic updates to kits and materials that have been produced by Clark Planetarium. We also have an area on our website dedicated to educational resources. Additional content can be found there as well.

Link to Clark Planetarium Education Resources: https://slco.org/clark-planetarium/education/for-educators/

NASA Climate Kids: https://climatekids.nasa.gov/

UCAR Center for Science Education – teaching Boxes: https://scied.ucar.edu/teaching-box

Urban Heat Island Basics: https://www.epa.gov/sites/production/files/2014-06/documents/basicscompendium.pdf