**Urban Heat- Final Lesson**
Teacherstryscience.org

## Summary Information

## Keywords:

Surface temperature, human activity/development, design constraints

## Performance Expectation:

PE MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

PE MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

## Estimated Time Required:

3-5 hours

## Lesson Overview:

They will be addressing the driving question: How can human activities affect the environment's surface temperature?

## NGSS Alignment

## Building Towards:

- PE MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- PE MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

## Science and Engineering Practice:

- Constructing Explanations and Designing Solutions: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
- Analyzing and Interpreting Data: Analyze and interpret data to provide evidence for phenomena.

Disciplinary Core Idea:

- ESS3.C Human Impacts on Earth Systems: Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)
- PS4.B: Electromagnetic Radiation: When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)

Crosscutting Concept:

- Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS3-4)

Common Core State Standards

- CCSS.ELA-LITERACY.RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.
- CCSS.ELA-LITERACY.SL.6.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
- CCSS.ELA-LITERACY.SL.6.4 Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.
- CCSS.ELA-LITERACY.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
- CCSS.ELA-LITERACY.WHST.6-8.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

# Lesson Level Learning Goal

- Students will be able to collect and analyze data on the relationship between surface variance and temperature.
- Students will be able to design a roof model to minimize the effect of human development on surface temperature.
- Students will be able to present their claims and findings from their roof design, and explain how it mitigates humans' effect on surface temperature.

# Instructional Resources

*Note: This lesson focuses on the effect of human development in urban areas. As such, this is particularly well suited for students in an urban environment, as they can more readily connect the learning with their lives and communities.*

*Students are expected to have previous knowledge of the practice of planning and carrying out investigations.*

**Investigation 1: Surface Temperature Part 1**
*Note: This investigation takes place outside with access to grass and pavement. If this is not accessible to your students, you may supplement this investigation with exploring the surface temperature of different materials within a lab setting.*

Instructional Sequence:

Show students the Landsat Satellite Image
from http://www.epa.gov/heatisland/about/measuring.htm and the satellite image
from http://science.nasa.gov/science-news/science-at-nasa/1998/essd21jul98_1/

Do not show students the rest of the articles. Tell students that the first image is a satellite image that shows temperatures in the Atlanta, GA region. The darker tones (oranges and reds) represent higher temperatures. The second satellite image shows temperatures in the Salt Lake City area. The red/orange tones represent higher temperatures and the green and blue tones represent lower temperatures.

Have students look at the images and answer the following questions.

- What do you notice about the temperatures in the same region in the first image? In the second image?
- What are the similarities? What are the differences?
- Why do these temperature differences exist? What could be the causes behind the temperature differences?
- What effects can the temperature differences have?

Have students discuss their thoughts with a partner first and then have a class discussion. Encourage students to come up with any questions they have at this point.

Write their questions up on the board. Tell students that they will be investigating and learning about some of the causes for the temperature differences and how human activities can affect the environment's surface temperature.

Ask students - If it were a hot summer day, where would you go outside to cool off? What areas outside would you stay away from? Why?

Have students write down their answers to the questions and then share with a partner. After students have shared with a partner, lead a class discussion. Ask students to share the places they would prefer to go to outside to cool off and the places they would stay away from. Ask students to share with the class why they chose those places. Ask students why do they feel cooler in certain places over others? Write their ideas up on the board. *Students may have shared that they feel cooler in the shade than in sunny areas. If those are the only types of answers shared, ask students if the entire area had no shade, what spots would they choose and why? Guide them to think about different surfaces within an area.* Ask students what warms up the different ground surfaces outside? *Heat from the sun.*

Do they think different surface materials have different temperatures during the same time of the day? Why or why not? Ask students if they can think of ways they can go about finding evidence for answers to this question. Write their ideas on the board. *If students need some guidance, ask the different methods through which they can generally gather evidence – i.e. conducting investigations, research, etc.*

**Investigation 1 – Part 1 Lab Report Worksheet**

*Preparing for the Investigation:*
Materials
Infrared thermometers
Outdoor sites

Tell students they will be conducting an investigation to answer the question: Do different surface materials have different temperatures during the same time of the day? Provide students with the lab report handout that they can fill out for this experiment. Ask students to define what the independent and dependent variables will be for the experiment. Have students work with a lab partner to formulate the Title, Question, and Hypothesis and complete these sections on their lab report. Tell students the materials that they will have to carry out their investigation (i.e. infrared thermometer to collect temperature readings, outdoor sites that have asphalt, grass, etc.). Have them collaboratively come up with a procedure to answer their question keeping in the mind the materials they can use. Tell students that everyone will be testing the temperature of different ground materials such as asphalt and grass, and that this should be included in their procedure. When students are coming up with their procedure, remind them to consider what data they will be collecting, why they are collecting that data (how will it help them answer the question), and how much data will be adequate to answer the question (i.e. number of trials). Once students have finished, take a moment to review these sections as a class, and discuss the procedure they will all be using. *(Depending on how comfortable your students are in writing procedures, you may want to have each pair check in with you before you discuss as a class. The overall idea for the investigation is that students will use an infrared thermometer to find the temperature of different types of ground surfaces.)*

Ask students to share their thoughts about the data with the class – what are they collecting, how much are they collecting, and why are they collecting it. Have them work with their partner to create a data table in which they can record their data. The data table should have a section in which they can average the temperature from multiple trials. *(If your students need help creating a data table or if you have limited time, a data table example has been included in the student lab report handout.)*

*Carrying Out the Investigation:*

Ask students to note any observations they may have while they set-up and conduct their experiment.

Have students work with their lab partners to follow their procedures to carry out the investigation and record data.

Back in the classroom, have students calculate the average temperature of each type of ground covering. Compile class data (using the averages) for the different ground surfaces from each pair. Next, have students work with their lab partner to analyze their data, and write out their analysis on their lab report. Students should address the following questions:

- Are there any patterns in the data?
- What may be the cause of the patterns that you observed? Why?
- How can the similarities and differences in the data be explained?
- Based on your data, why do you think these temperature differences exist?

- Based on your data, do you think the color of the surface affects its temperature?
- Based on your data, do you think the type of surface affects its temperature?
- Did you collect adequate data to answer the question, "Do different surface materials have different temperatures during the same time of the day? Why or why not?" What additional information do you need to answer the question? Construct questions that you have and that still need to be answered to answer this question. *(At this point, students should understand that they collected evidence that different surface materials have different temperatures during the same time of the day. However, they do not know for sure why this difference exists. Based on their data, they can point toward the idea that the color of the surface may matter, but they need more information to be able to thoroughly answer why.)*
- How is the data collection limited?

Have students switch out one partner with a group near them so they have a new partner. Each new partner will then take a few moments to share their findings, and their conclusion. Afterwards, students can move back into their original partner pairings, and make any modifications to their conclusions that they feel are necessary. Have students share their analysis and conclusions with the class. Have students share the questions they constructed and write them up on the board.

During the discussion, students may have pointed out that they need more information to conclusively say why the temperature differences exist. Ask students what some of the reasons they came up with are. Tell students that they will be further investigating how the color of a surface can affect its temperature.

Accommodations: Having students work in teacher-selected partnerships allows the teacher to match students in a way that they are both being supported. The warm-up activities should be used to connect students' learning to their community. You can use graphic organizers to help scaffold student learning.

Assessment: Student understanding of temperature variance on different surfaces will be assessed by their answers to the data analysis questions and the class discussion.

**Investigation 1: Surface Temperature Part 2**

Preparation:
Each group of students (3-4) will need five jars with lids. The lids should have holes in them (you can drill them in, if necessary) large enough to fit a thermometer through. Each pair will also need colored construction paper (black, white, and then assorted colors such as yellow, green, brown, etc. – colors you can find readily in nature and on buildings) that can be wrapped around the jars. Each pair will need five thermometers, water (to fill the jars), and tape or a rubber band.

Instructional Sequence:

*Preparing for the Investigation*

Ask students if they have ever noticed if the color of their clothes affects how hot or cold they feel. Have they ever worn dark colored clothes in the summer and felt a difference from when they wear light colored clothes in the summer? Have students share their experiences.

Ask students to make a prediction based on their prior knowledge and experiences about whether the color of a material affects its temperature and why. Have students share their predictions with their partners. Tell students they will carry out an investigation, working collaboratively with their group, to answer the question and collect evidence. Ask students to identify what the independent and dependent variables are for this investigation. Give them the procedure for the lab, and have students identify what data they are collecting, why they are collecting that data, and how it will help them answer their original question. They should create a data table to record the data. Make sure they understand all the components in their set-ups and why each component is necessary for the investigation to take place. For example, students should understand that they are placing water in the jars because they will measure the temperature of the water to see how much heat was absorbed and transferred by the colored jar. *(If students are struggling to understand the different components of the set-up and the role they play in the experiment, have students create a diagram of the set-up and label and describe in writing what they know. Then, have the students brainstorm with a partner or a group. You can check in on each group individually or have a class discussion.)*

*Carrying Out the Investigation*

- Have students work in groups (3-4 students) for the investigation. Each group should gather the following materials:
    - five jars with lids (the lids should have holes big enough to fit a thermometer)
    - five thermometers
    - five different colored pieces of paper *(Note: each group needs a black sheet and a white sheet, but you can choose the other colors. Keep colors consistent for each group, because each group will be a trial for the investigation.)*
    - graduated cylinders
    - tape
    - scissors
    - water (to fill the jars)
    - timer
- Students should wrap the outside of the jars with the different colored paper, cutting the paper if necessary to ensure a good fit. Each jar should be wrapped in a different color. They can use tape to hold the paper in place.
- Students should use graduated cylinders to fill each jar with the same amount of water. The water should also be at the same temperature.
- After filling the jars, students need to cover the jars with their lids and insert the thermometers into the lid holes.
- Have students take their jars and place them outside in the sun (where they get the same amount of sunlight) or on a window sill. Inform students that each group will represent one trial for the investigation. (*Note: If you are unable to take the set-up outside, then you will need table lamps for each group to replace the sunlight. Make sure each group has the same watt bulb for the lamp.)*
- Have students wait three minutes and then record the initial temperature for each jar.
- Leave the jars for 30 minutes and start a timer.
- After 30 minutes have passed, have students check and record the temperature for each jar.

- Once you are back in the classroom, compile class data. *(Note: If you have computers and internet available, you can use google documents to easily compile and share the class data.)*

*Analyzing Data*

Once you have compiled class data, have students answer the following questions. They should initially work with their group members to discuss and write down their answers to the questions. Then, you can have them share with the class.

- Calculate the initial and final temperature averages for each color.
- Using the averages, find the increase in temperature for each color.
- Are there any patterns in the data?
- What may be the cause of the patterns that you observed? Why?
- Based on your data, do you think the color of the surface affects its temperature?
- Did you collect adequate data to answer the question?
- How is the data collection limited?
- Why does color affect the temperature of the water?

Accommodations: Having students work in teacher-selected partnerships allows the teacher to match students in a way that they are both being supported.

Assessment: Student understanding of temperature variance for different colors will be assessed by their answers to the data analysis questions and the class discussion.

**Investigation 2: Real World Connection**

Preparation
Each student needs a copy of the **Urban Heat Island Article** and the worksheet **Investigation 2: Urban Heat Island Graph Analysis**

Instructional Sequence:
Begin the lesson by reviewing the previous activity with students:

- What were your findings from the investigations that we did?
- What do you think this might tell you about temperature during the summers in different types of places? What patterns in temperature might be observed in a rural area with lots of fields? What about an urban area with lots of pavement? Why?
- Are these surfaces/environments naturally occurring? Where do they come from? How can human activity increase or decrease surface temperature?

Have students work with a partner to read through only the first page of "Urban Heat Islands" and complete the Urban Heat Island Graph Analysis. Have students answer the following questions:

- How does energy warm up materials on the Earth? Include the energy flow and transfer processes involved.
- How does the flow of energy change depending on the color of the material?
- How does the color of a material affects its temperature and why?

- Based on your data and the reading, draw diagrams that show how energy is either reflected or absorbed for one dark and one light colored material. Identify and describe the components in the system and explain the flow of energy. Describe the similarities and differences between energy flows in the two diagrams.
- What is an Urban Heat Island?
- What causes an Urban Heat Island?
- What do you think the effects of an urban heat island are on the area and on people specifically? Why?
- Are there any trends in the graph/data for the "Sketch of an Urban Heat-Island Profile?"
- How does the temperature downtown relate to the surrounding areas? What are the causes behind the higher temperature in the city center? Why? What are the causes behind the lower temperature around the park? Why?
- How can humans affect the temperature of different areas? Include ways that humans can both increase and decrease temperatures.

After students are done answering the questions, have a class discussion about the questions. Build off the discussion to bring students back to the very beginning of the lesson and the satellite images they saw. Ask them if they can now explain, with supporting evidence some reasons why the temperature differences existed in the images? Show students the images again and have them discuss their answers with their partners.

Tell students to read the rest of the Urban Heat Island Article. Ask students what new information did they learn about how humans can increase or decrease surface temperatures? How does this new information help them explain the temperature differences in the satellite images?

Have students complete the "Claim, Evidence, Reasoning" organizer where they are asked to use their data from the previous experiments to state a claim while providing evidence, and using information from the article. Provide each pair of students with a piece of chart paper and a marker.

Next, students will create a poster explaining their Claim using Evidence and Reasoning from their experiment and the article. Students will then circulate around the room in a Gallery Walk, looking at one another's posters, and leaving feedback or questions for their peers using Post-It notes. Afterwards, give students a few minutes to debrief with their partner, and see if they would like to incorporate more into their explanation to make it stronger.

Accommodations: Having students work in teacher-selected partnerships allows the teacher to match students in a way that they are both being supported. Graphic organizers help to scaffold student learning.

Assessment: Students will be assessed on their understanding of the urban heat island effect using their Claims, Evidence, and Reasoning worksheet and Gallery Walk poster.

**Investigation 3: Designing a Roof**

Preparation:
Materials for the design challenge:

- (items such as black/white/colored paint, plastic wrap, foil, wax paper, pebbles, fish tank gravel, cotton balls, soil, grass, live plants, newspaper, marbles, filter material, fabric, stockings, etc.)
- Shoebox with lid for each group
- **Urban Heat Island Effect Rubric**
- Worksheet **Reducing the Urban Heat Island - Roof Design Challenge**

Instructional Sequence:

Review the previous two investigations with students, and ask them: "If we are forecasted to have more heat waves, how might this impact residents of cities? Would the effects be similar for the residents of rural areas outside of the city (*encourage students to think back to the satellite images)*? Why or why not? What might be some possible issues of the heat waves in cities? What might be some potential solutions?"

Tell students that they will design, build and test a model roof design with the goal of minimizing the urban heat island effect. Guide the class towards defining the problem behind the Urban Heat Island effect, why it's important to people, and potential solutions.

Tell students that they will be given a cardboard shoebox that represents a building, the lid acting as the roof. Inform them of the materials that will be available for them use. *(Possible materials for their design challenge may include: black/white paint, plastic wrap, foil, wax paper, pebbles, fish tank gravel, cotton balls, soil, live plants, newspaper, marbles, filter material, fabric, stockings, etc.)* Ask students to define the word "constraints," and have them think-pair-share some of the constraints for their roof design *(i.e. time, materials, etc.)*. Ask students to define the word "criteria," and have them think-pair-share some of the criteria for the design. Have all groups share their criteria and constraints with the class. Finalize a list that will apply to all groups and post it where it is visible.

Ask students how they think they can test all the designs to see which decreases the urban heat island effect the most. What should the testing protocol include? What data should be collected? Why? How will that data measure the effectiveness of their design? Have the class agree upon a testing protocol that will be applied for all designs.

Students should work with their partner/small group to begin planning their design using the planning sheet. Students will define the problem they are trying to solve, the constraints involved, their design idea, and how they will measure the effectiveness of their design. When students are creating their designs, tell them to keep in mind the energy flow/absorption that will take place with the components of their design. They should use the data they collected from the investigations and the information from the reading to help guide their design.

After students are done designing their roofs, they should check in. Before testing, each group should be able to explain the components of their design, why they chose those components (how do the components minimize the urban heat island effect), and how those components

affect heat absorption (based on their data and reading). Students should be clear about how the science informs the engineering design.

Have students test their designs. Each group should test and modify their designs at least once. When carrying out their modifications, tell students to explain why they chose each modification, how the modification will affect their design (how it will affect heat absorption) and ultimately the data. Afterwards, students should complete the reflection portion on their roof design handout. Students will then use their reflections on the roof design to complete a write up that includes details about their design, observations from their testing and how this connects back to the observation and data from previous investigations, claims about how their design helps to minimize the effects of an urban heat island, and a reflection about the design process. Students' writing will be evaluated using the Urban Heat Island Effect rubric. This rubric should be provided to students ahead of time so that they can build their writing piece around the specified criteria.

Assessment: The group check-ins before the designs are tested can be used as formative assessment to make sure students understand the components of their design and how those components will help minimize the effects of the urban heat island. Evaluate students' writing for understanding of content.

Accommodations: Having students work in teacher-selected partnerships allows the teacher to match students in a way that they are both being supported. Graphic organizers help to scaffold student learning.