IS6

Earth and Space Sciences Instructional Segment 6: Urban Geoscience

To culminate the study of Earth's **systems [CCC-4]** and how humans interact with them, this instructional segment describes a range of possible project ideas that make the geologic history of a region relevant even in areas where the closest thing to a rock is a small patch of dirt among a sea of pavement. Equally important is an exploration of some of the ways that humans shape the landscape when they build cities. These impacts are perfect opportunities for using engineering and technology to reduce negative impacts while making cities more livable places. A teacher can guide students towards topics that are most appropriate for their local area.

EARTH AND SPACE SCIENCES INSTRUCTIONAL SEGMENT 6: URBAN GEOSCIENCE

Guiding Questions

- How do Earth's natural systems influence our cities?
- How do cities affect Earth's natural systems?

Performance Expectations

Students who demonstrate understanding can do the following:

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

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HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-5] Using Mathematics and Computational Thinking [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering)	ESS3.A: Natural Resources ESS3.B: Natural Hazards ESS3.C: Human Impacts on Earth Systems ETS1.B Developing Possible Solutions ETS1.C Optimizing Design Solutions	[CCC-2] Cause and Effect: Mechanism and Explanation [CCC-4] Systems and system models [CCC-7] Stability and Change

Highlighted California Environmental Principles and Concepts:

Principle I The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.

Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

Principle III Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

Principle IV The exchange of matter between natural systems and human societies affects the long-term functioning of both.

Principle V Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.

CA CCSS Math Connections: N-Q.1–3; MP.2, MP.4

CA CCSS for ELA/Literacy Connections: RST.11–12.1, 2, 7, 8, 9

CA ELD Connections: ELD.PI.11–12.1, 5, 6a–b, 9, 10, 11a

Since the beginning of civilization, the locations of human settlements have been shaped by the natural landscape. Cities tend to be located near water sources, placed on hilltops for visibility and protection from invaders or are built with access to a particular natural resource such as a mine or fertile soil for farming. The location of cities is, in essence, an example of the CCC of **structure and function [CCC-6]**. San Francisco was built along San Francisco Bay because of its protection from ocean waves. The bay exists because of movement along faults on opposite sides of the bay. Sacramento sits at the intersection between two major rivers, including the place where gold was first discovered in California. Both the water and the gold washed down from the Sierra Nevada which was formed by an ancient collision between two plates. Los Angeles was founded around the Los Angeles River, which once flowed year-round before European settlers diverted all its water for irrigation. The beautiful views and pleasant outdoor opportunities such as hiking and biking that make California an attractive place to live are all a direct and positive consequence of the geologic history of the local area. Students can **investigate [SEP-3]** the early history of their city and see how it relates to the topography and other natural features.

The geologic history of an area determines the stability of the ground beneath a city's buildings. San Francisco is founded on ancient sand dunes, a particularly unstable material in earthquake country. But many other cities share a similar fate because most of them were built near rivers. From IS3 on Mountains, Valleys, and Coastlines, students know that rivers break apart rock from upstream mountains and deposit it in flatter valley areas downstream. During rainy seasons, rivers naturally flood, adding a new layer of loose sediment to the ground before the existing sediment has a chance to solidify. Those loose deposits make unstable foundations, and the closer a building is to a river, the more likely it is to be built on loose sandy soil. During earthquake shaking, wet, sandy soil begins to flow like a liquid (a process called liquefaction) and can no longer support buildings perched on top of it. Because of this risk, the state publishes maps showing areas with known liquefaction hazard (California Department of Conservation 2015). Students can use these maps to identify areas around their school that are at risk for liquefaction.

The same state hazard maps that show liquefaction hazard also show landslide hazard zones. Landslides are an example of rapid erosion and are worse in areas with steep mountains. California's coastal region, housing most of the state's population, runs along a plate boundary where plate motion uplifts mountains causing slopes to get steep more quickly than erosion and landslides can flatten them. A wide range of engineering solutions exists for protecting homes built in landslide hazard zones. For schools in neighborhoods where there is abundant landslide risk, students could explore some of these **solutions [SEP-6]**.

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Performance Expectations

Students who demonstrate understanding can do the following:

HS-ESS2-4 Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate[Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [*Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.*]

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting, and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [*Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.*]

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a practice or disciplinary core idea.

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The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-4] Analyzing and Interpreting Data [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering)	ESS1.B: Earth and the Solar System ESS2.A: Earth Materials and Systems ESS2.D: Weather and Climate ESS3.A: Natural Resources ESS3.B: Natural Hazards ESS3.C: Human Impacts on Earth Systems ESS3.D: Global Climate Change ETS1.A: Defining and Delimiting Engineering Problems ETS1.B: Developing Possible Solutions	[CCC-2] Cause and Effect: Mechanism and Explanation [CCC-4] Systems and System Models [CCC-5] Energy and Matter: Flows, Cycles, and Conservation [CCC-7] Stability and Change Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World

Highlighted California Environmental Principles and Concepts:
Principle I The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.

Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

Principle V Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes..

CA CCSS Math Connections: S-ID.3, 5, 9; S-IC.6; MP.1, MP.2, MP.3, MP.4, MP.7

CA CCSS for ELA/Literacy Connections: W.9–10.1a–f, 6; SL.9–10.1a–d; RST.9–10.1, 3, 7, 9; WHST.9–10.1a–e, 6, 7, 9

CA ELD Connections: ELD.9–10.P1.1, 3, 6, 10

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Introduction

By discovering that certain urban areas are much hotter than their surroundings, students apply and refine their existing model about Earth's energy balance. They articulate the mechanisms by which human activities can alter the local climate system and ultimately design measures to reduce that impact.

Length and position in course: This vignette describes two to three weeks of instruction and could serve as the first lesson in an instructional segment on urban geoscience. It describes how different land uses result in changes to surface materials. Activities related to the water cycle will naturally follow from this vignette because these same changes to the surface also have a dramatic impact on the hydrosphere.

Prior knowledge: This vignette could support and extend students' existing **models [SEP-2]** of Earth's energy balance (as introduced in IS2 of this course), or the vignette could provide students initial exposure to the factors that affect a system's temperature (that could later be extended to the global **scale [CCC-3]** of Earth's climate).

Students will need basic skills in navigating digital maps (such as Google Earth). They will need to interpret aerial and satellite imagery, which is a unique skill (i.e., can they distinguish a small home from a commercial building in a satellite image?). While this vignette provides opportunities to develop those skills, they are not specifically addressed in this lesson outline.

Teacher background: Urban scientists use the term "built" environment to describe landscapes that have been constructed and altered by humans (i.e., "man-made"). Urban heat islands are well-known phenomena found where materials of the built environment absorb and retain energy more readily than surrounding natural landscapes. Urban areas that use these materials surrounded by more rural landscapes with more natural materials are like islands of warm temperatures. There are three main ways that urban land use alters the local energy balance: 1) natural materials tend to reflect more light than artificial materials; 2) natural landscapes retain water but most urban surfaces are designed to drain water very efficiently. Since water has a high heat capacity, natural landscapes that retain it heat up more slowly than built ones. The water that gets retained can also evaporate, which takes thermal energy with it and leaves the surface cooler; and 3) human activities generate excess heat locally. Heating and cooling buildings, combusting fuels in vehicles, using electrical appliances, and industrial processes are all examples that generate heat.

Urban settings: The urban geoscience unit is focused on issues facing the local community, and this vignette introduces a range of local data available freely on the Internet. Despite the use of the word "urban," heat islands can be found in most places where humans modify landscapes. Small towns, farmhouses, and even different species of crops have different thermal properties and affect local temperatures. As such, this vignette should have broad application in most California communities, urban and rural.

5E Learning: This sequence is based on an iterative 5E model where each activity has a role in the 5Es, but each activity also needs to include each of the 5Es along the way. The 5E model parallels the science and engineering practices of the CA NGSS in many ways, but are applied in the perspective of lesson design. While SEPs should be shared explicitly with students, the 5Es are only for the benefit of the teacher.

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Day 1: Built and Natural Environments

Students explore the differences between the natural and built environment and begin to consider the interactions between these environments and the Sun.

Days 2–3: Neighborhood Temperature from Satellite

Students use satellite images displayed in Google Earth to investigate temperature differences in their neighborhood.

Days 4–5: X-factor Temperature Investigation in the Schoolyard

Students use digital thermometers to investigate different factors that affect the local temperature in their school.

Day 6: Historical Land-Use Changes from Online Aerial Photos

Students analyze land-use changes in their neighborhood over the last several decades using online historical air photos.

Days 7–9: Urban Design Engineering Challenge

Students design and evaluate a city plan based on principles that will reduce the urban heat island effect.

Day 10: Systems Within Systems

Students consider implications for other Earth systems (most notably, the water cycle and relationships to global climate change).

Day 1: Interactions Between the Built and Natural Environment (Engage)

Everyday phenomenon: Some locations like parking lots are hotter than surrounding areas while parks can be cooler than their surroundings.

Dr. D had written a short skit that activated students' prior everyday experiences involving temperature variations at different locations in their own community. She assigned different students roles in the skit, and they acted out their parts, pretending to be hanging out after school and discussing the hot weather. In the skit, Andrea suggested that they all go to the beach, but Raul does not like to leave his car in the hot parking lot and his feet always get burned on the hot sand. Sara knew this one bench at the local park that always seemed much cooler than everywhere else. The skit finished with the students agreeing that wherever they go, they need to leave the hot concrete steps of the school. Dr. D told students that over the next two weeks, they would understand many details about the processes that affect temperatures in their community.

With these ideas in mind, Dr. D had an activity she hoped would motivate students to think about their community as a system with interacting components. She placed students in their standard groups of four and gave each student a different card with a picture of an object from their community on it. She asked students to identify their objects as either natural (like a plant, a rock, or an animal) or an object from the built environment (like a building, a

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parking lot, or a fountain). She had students brainstorm about how the four different objects in their group might interact. Casey was the class clown and comes up with a crazy story that related the fire engine, grass, apartment building, and butterfly in his group: a butterfly sitting on the grass narrowly escaped a lawnmower and flew up to land on the apartment balcony, distracting the resident from her cooking, which led to a disastrous fire that needed to be put out using the fire hydrant. Dr. D loved the story and invited Casey to relate the story to the whole class. She used the opportunity to emphasize that some interactions were simple and plausible and some were not. She asked students to tape their cards to the poster board and decide on plausible interactions between the objects that they thought were the most important to the functioning of the community. After a few minutes, she had each group pair up with a group that received a different set of objects. Students from one group **communicated [SEP-8]** their **models [SEP-2]** to the other group and then switched cards. Students needed to extend their model by adding the new objects. Dr. D then added the final and most important object. She handed each group a card showing the Sun and asked students to draw interactions between their object and the Sun (figure 8.62). The Sun is at the heart of Earth's energy balance and has an effect on every object in our community. She asked them to consider if there are differences between the way natural objects and built objects interact with the Sun.

Figure 8.62. Example System Model Linking Objects in the Built and Natural Environment

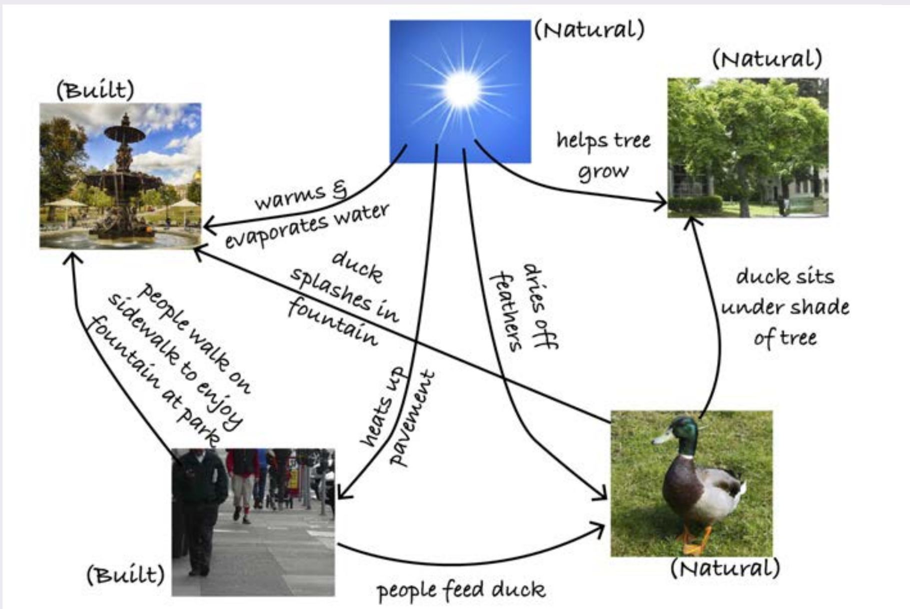

Figure by M. d'Alessio with images from Jordan 2012; Kilby 2013; radcliffe dacanay 2008; JGKlein 2010; nbcorp 2012
Long description of Figure 8.62.

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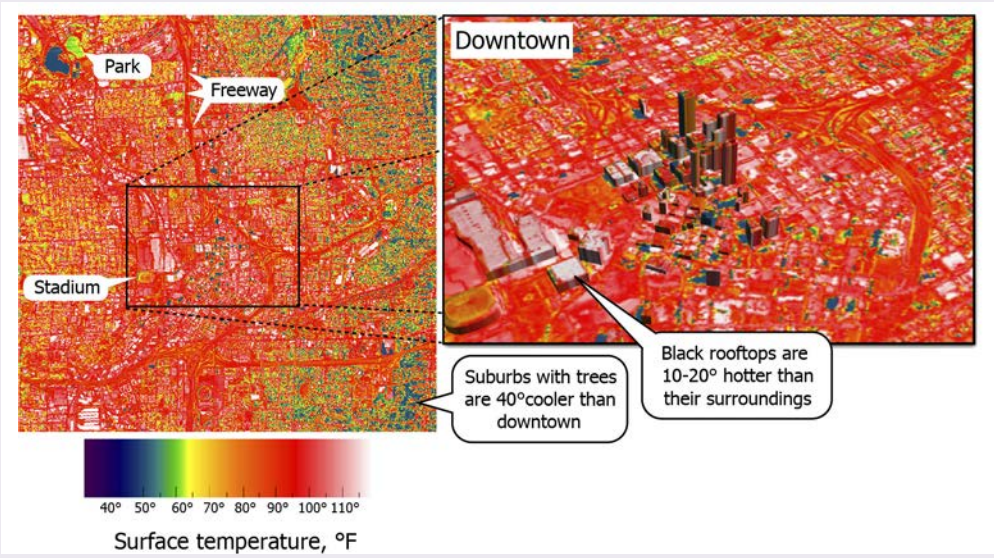
Days 2–3: Neighborhood Temperature from Satellite (Explore)

Anchoring phenomenon: An infrared camera can "see" the difference between a cup of hot water and a cup of cold water.

Earth scientists depend heavily on images collected by satellites to study what is happening on Earth. Dr. D's class next **analyzed [SEP-4]** two different types of satellite pictures, one that students were already familiar with and one that they were not. She began by engaging students with an Internet video clip of a building inspector demonstrating applications of thermal infrared cameras. The inspector held up a mug with cold water and one with hot coffee and showed how the camera distinguished between the two. Dr. D used this to motivate a brief introduction to the physics of black body radiation. She knew that the students would be using this idea again in the study of stars, so she gave a brief lecture about how objects at different temperatures emit energy at different wavelengths. She explained that some satellites have cameras that record the temperature of the land surface by the radiation the land emits in infrared. The students compared these thermal maps with the standard aerial photographs available in Google Earth, looking for **patterns [CCC-1]** in the relationship between the temperature and the type of landscape and land use (different types of natural and built environments) (figure 8.63).

Figure 8.63. Satellite Images Reveal Temperature Differences in Urban Areas



Satellite images in infrared reveal that different land uses cause dramatically different temperatures in urban areas. *Source*: NASA n.d.; NASA/Goddard Space Flight Center Scientific Visualization Studio 1997

Long description of Figure 8.63.

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Investigative phenomenon: The temperature of the ground surface at different locations in a city depends on the land use.

Before walking over to the computer lab, Dr. D used her classroom computer to demonstrate how students would obtain the data and how it could be viewed in Google Earth. She demonstrated map navigation and explained the color scale on the thermal map. She emphasized that there is a big range of temperatures and tests students' basic ability to identify the relative temperature of different regions from the color by asking a few clicker questions that the students answered using a smartphone app. She also showed students the data entry form on the course Web site where all student observations would be collected and analyzed together.

Once they walked over to the computer lab, she helped students log into the computers and download the satellite data file she had preloaded on her Web site under today's agenda and opened up the data collection online form. Knowing this is an exciting tool, she encouraged students to explore freely in Google Earth for about three minutes after everyone was logged in. She eventually called the students to attention and instructed them to begin their data collection. They worked diligently, exploring different locations on the map and recording map location, temperature, and land-use category. The class period ended and Dr. D ensured that students had all hit submit on their data collection forms.

When students arrived the next day, submissions from the whole class were combined in an online spreadsheet so that everyone could **analyze the large data set [SEP-4]**. The students all found that the airport runway was among the hottest places on the entire map, and that most of the large shopping centers were very hot as well. "That makes sense because you can feel the heat when you walk across the parking lot," offered Micah. Many people found that parks in the city were cooler than average, but there were a few discrepancies. Since each student had submitted the latitude and longitude of their observation, Dr. D zoomed in on one of these outliers. The location was much hotter than average, but it was clear that this location was a parking lot and not a park, so the submitter made an error. Casey admitted that the submission was his and apologized to the class, saying "It was big like a park."

Investigative phenomenon: Schools tend to be hotter than average, but there is variation between them.

The students were surprised to see that many of the schools in the city were hotter than average, but not all of them. The students were skeptical of the data and insisted that Dr. D zoom in to check the observations. They were satisfied after the data quality was confirmed for the first few submissions. They **asked questions [SEP-1]** about what made one school different from another.

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After the whole class discussion, Dr. D had students individually create a one-paragraph summary **communicating [SEP-8]** the overall class findings, with an emphasis on the **patterns [CCC-1]** in the data. She then randomly selected one student from each team to share their paragraph with the others. The team members offered improvements, additions, and edits, which were implemented in real time. At the end of class, Dr. D collected the one edited team submission and gave each team a group grade for the final product. She confirmed that students left class with the general understanding that many natural landscapes are cooler than average while the built environment is often warmer than average. Students had also come up with an appreciation that there are complexities and exceptions to this general pattern.

Days 4–5: X-Factor Temperature Investigation on the Schoolyard (Explain)

Investigative phenomenon: Two schools that look similar in an aerial photo have different temperatures in satellite data.

Dr. D started off class with aerial pictures of two schools from their city and asked the students to predict which one would be warmer. She intentionally selected two schools that appeared similar in the photos but that had fairly different temperature profiles in the satellite temperature data. This motivated students to think about the full range of possibilities that could **explain [SEP-6]** the difference. "The grass looks greener in one. Do you think that makes a difference?" "Maybe, but look at the parking lots. One is on the south side of the school and the other is smaller and is on the north side of the school." The students asked Dr. D for the answer, and she replied that she honestly did not know. The students had offered up many plausible ideas that would motivate further investigation, but in real science there is no answer key. They had already made some interesting claims about possible influences on the school's temperature, but today they would need to gather **evidence [SEP-7]** to see if they could support those claims.

Investigative phenomenon: Students investigate a single factor to see how much it affects the temperature around the schoolyard.

Each group had to **plan and carry out an investigation [SEP-3]** into a single factor that could have affected temperature (the "X-factor"). Each group got one digital stick thermometer that read temperatures with a precision of 0.1 degrees (they cost about $25 each and the chemistry teacher at Dr. D's school let her borrow a class set). Students all agreed on these general protocols: thermometers should always be shaded with a book; they should be held at arm's length about one meter above the ground; and they should not record the temperature until the thermometer has stabilized to within 0.1 degrees for at least 30 seconds. Beyond that, individual students had to decide their own procedure that would ensure sufficient data to show a repeatable signal.

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Some of the projects the students decided include measuring temperature as a function of

- distance away from a building;
- distance from the center of a grassy field out towards the edges;
- distance from an air conditioning unit attached to the classroom;
- position along the track for the 100 m dash;
- different sides of the building, as measured a fixed distance away;
- type of ground-surface material, as measured at several locations close to one another;
- elevation, as measured from the windows of different floors of the building;
- air speed, as measured while riding a bicycle at different speeds.

Dr. D knew that some of these factors should not affect the temperature.

After collecting their data, students presented their experiment and their findings and proposed an **explanation [SEP-6]** for the **data [SEP-4]**. Unlike a typical controlled laboratory experiment, students could not completely isolate a single variable. As they presented their project reports, they had to account for any unexpected variations and **construct an argument [SEP-7]** that 1) their X-factor was the most important determiner of temperature; 2) their X-factor turned out to be unimportant; or 3) an unintended variable interfered with the ability to conclude either way. Quite often, students discovered a factor that they did not anticipate had become more important than their original idea.

After the project presentations, Dr. D had students summarize all the findings in a two-column table: factors that **caused [CCC-2]** temperature to be warmer and those that caused temperatures to be cooler. She then gave a short lecture defining the framework for a **model [SEP-2]** of energy balances in **systems [CCC-4]**, including the energy input, output, and storage within the system. She referred back to a few examples from students' X-factor analyses during her lecture; then she asked students to sort all the items in their original table into three new rows corresponding to factors that had affected the amount of energy coming into a spot (e.g., shade from trees decreases the input), the energy output (e.g., shiny surfaces reflect light), or the energy retained (e.g., water has a high heat capacity and so a large amount of energy can be absorbed without causing the temperature to change much). Students applied this model to writing a scientific **explanation [SEP-6]** about why built environments appear hotter than natural ones.

Day 6: Historical Land-Use Changes from Online Aerial Photos (Elaborate)

Investigative phenomenon: Many cities look very different today than they did 50 or more years ago.

Cities are not static. Dr. D engaged students by asking them if anything in the city had changed since they were younger. How might those **changes [CCC-7]** have affected the temperature of the city? Students used online archives of aerial photographs to document some of these land-use changes (figure 8.64). Google Earth has archives going back one or

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two decades (see Google Earth Help at https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link66), and other Web sites include photos going back more than 50 years (such as Historic Aerials at https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link67). Students **communicated their information [SEP-8]** with a simple timeline in which they noted changes in land use and indicated whether or not they thought that the changes increased or decreased the local temperature and whether this change had affected the inputs, outputs, or energy retention properties of the system. Students loved seeing how their city had grown. Amara asked, "Didn't they know that they were heating up the city when they replaced that marshy area with the shopping mall?"

Figure 8.64. Aerial Photographs Around a Local High School Show Changes Over Time

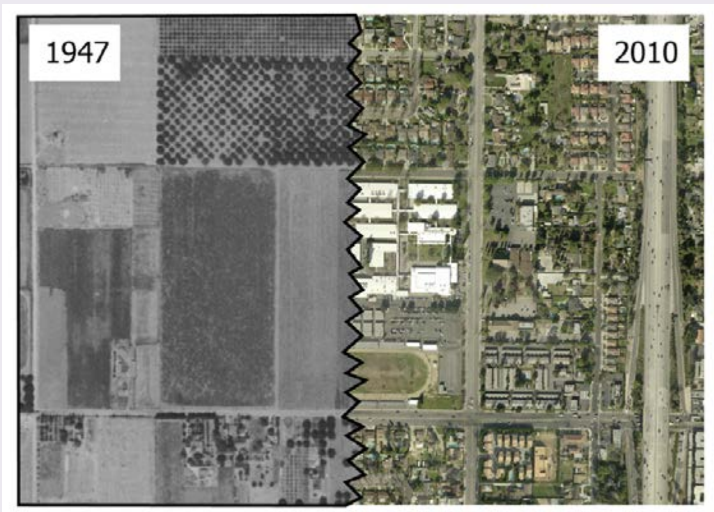

Figure by M. d'Alessio with images from USGS 2015
Long description of Figure 8.64.

Days 7–9: Urban design engineering challenge (Evaluate)

Investigative phenomenon: How can we design a city block so that it stays cool and is comfortable?

Dr. D began the day by showing two different designs by two different people for the same space (figure 8.65). She asked the students to think about the process the designers went through to create the plans. What did they consider? (HS-ETS1-1; EP&C V). She reviewed the engineering design process and explained that it can be applied to a wide range of different types of problems, including some that they may not have even thought of as "engineering" before. For this scenario, the city had recognized the urban heat island problem and was considering solutions. A developer planned to rebuild a large city block and the city council

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would evaluate a range of options. Students played the role of green urban planners presenting their proposal to a city council design review board (HS-ETS1-2). They discussed the constraints (i.e., what materials are available, how many people need to live on the block, the shape and size of the available land, etc.) and the criteria for measuring success (local temperature). They drew up a site plan, visualization sketches, and a bill of materials. As part of their **argument [SEP-7]** to the city council, they had to identify the specific components of the design that reduced urban heat island effects. Audience members evaluated the plan and helped iteratively improve the design by offering specific suggestions for reducing urban heating even further (HS-ETS1-3).

Figure 8.65. Two Competing Designs for a City Block by Professional Design Companies

Source: Cal Srigley Illustration, for Rafii Architects Inc. 2015; Cedeon Design 2015
Long description of Figure 8.65.

Day 10: Systems within Systems (Elaborate/Extend)

Investigative phenomenon: Simulations show that California will feel the effects of global warming, and the change will be more pronounced in urban areas.

Dr. D used this day to explicitly relate urban heating to global climate change. She engaged students by asking them to describe how their behavior changed on really hot days. She then provided students with the results of simulations that indicated that the number of extreme heat days in their city would likely go up significantly as a result of global warming (California Energy Commission 2015), and that this **change [CCC-7]** would be more pronounced in urban areas because of the urban heat island effect (figure 8.66). This **data analysis [SEP-4]** activity could support HS-ESS3-5.

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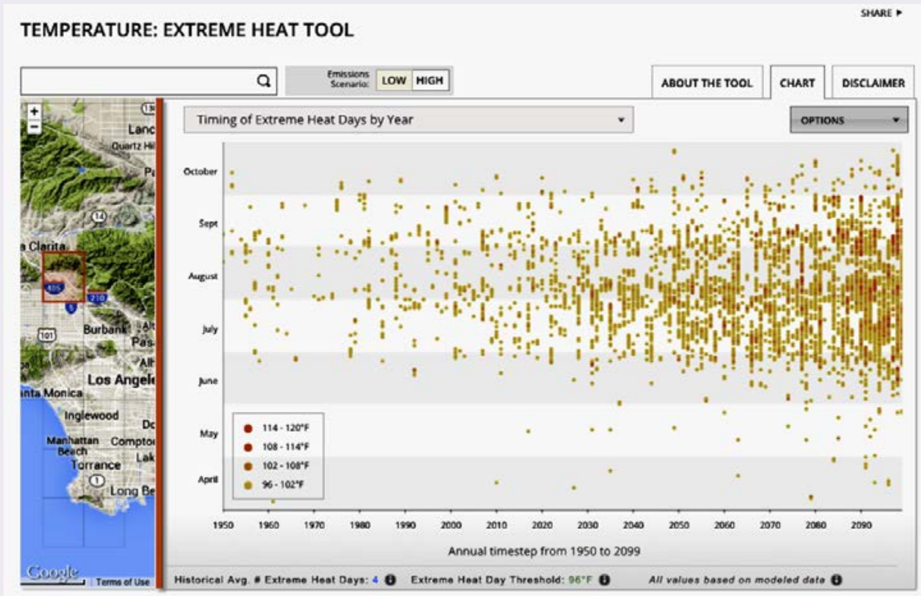
Figure 8.66. Forecasts of Extreme Heat Days for Northridge, CA



Available for all of California on the Cal-Adapt Web site. *Source*: California Energy Commission 2015.
Long description of Figure 8.66.

The class used the article "Climate Change in the Golden State" (https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link68) to gather evidence about the scale and scope of the effects of climate changes in California. The class discussed three key questions: Can the recent changes in California's climate be explained by natural causes? If natural causes cannot explain the rising temperatures, what anthropogenic factors have produced these changes? If temperatures in California's climate continue to rise, what effects will this have on humans and the state's natural systems? Dr. D prompted students to articulate the connections between human society and natural systems (EP&Cs I, II).

The urban heat island effect is very similar to what is going on at a global **scale [CCC-3]** with the greenhouse effect. Students compared the **models [SEP-2]** of the energy balance of the Earth as a whole and the energy balance of a city. So far, students had primarily focused on the interactions between the anthrosphere and the geosphere, but now Dr. D asked students to draw a concept map relating urban heat island effects to other Earth **systems [CCC-4]**. Their maps include the biosphere (that **causes [CCC-2]** cooling by evapotranspiration but is also stressed by increased evaporation from elevated urban temperatures stress plants and animals), the atmosphere (increased temperatures cause increased evaporation), and the hydrosphere (water runs off artificial materials instead of infiltrating into the ground). The connections to the hydrosphere offered an excellent transition into the next topic of study, urban hydrology and water resources.

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Vignette Debrief

Most students had personally experienced the phenomenon of heat islands in the built environment, but few had thought about it as deeply as in this vignette. Having data to measure and being able to visualize the effect (both using satellite imagery and temperature probes) allowed students to dive into understanding the situation using all three CA NGSS dimensions.

SEPs. After students performed two **investigations [SEP-3]** of temperature variations at a range of **scales [CCC-3]**, they **ask questions [SEP-1]** about what was causing the dramatic heat island effects. They **analyzed their data [SEP-4]** to help figure out the relationship between different components in the **system [CCC-4]** they studied. They used these relationships to **develop a model [SEP-2]** of the system. They used the data from their investigations along with the reasoning of their model to **construct an explanation [SEP-6]** about what **caused [CCC-2]** urban heat islands. In the engineering design challenge, they employed engineering practice by **defining the parameters of the problem [SEP-1]** and **designing solutions [SEP-6]**. They then created a compelling **argument [SEP-7]** that their design was an effective way to mitigate human impacts on local temperature. On day 10, students briefly explored the results of **computational [SEP-5]** simulations that forecast how urban heat islands will cause an even greater impact in the future.

DCIs. Urban heat islands are a tangible example of human impacts on Earth systems (ESS3.C) and a microcosm of the entire energy balance in the global climate system (ESS2.D). Students began to characterize variations in Earth materials and the impact of these variations (ESS2.A), acknowledging that the built environment is a key part of Earth's systems.

CCCs. Students applied the crosscutting concept of **systems and systems models [CCC-4]** to represent the **flow of energy [CCC-5]** and the interactions between energy and matter. Students looked for **patterns [CCC-1]** in temperature **data [SEP-4]** to test for **cause and effect [CCC-2]** relationships between land use and heat islands. The **model [SEP-2]** that they developed was valid at a range of **scales [CCC-3]** from a single city block to a whole city or the entire planet.

EP&Cs. Urban heat islands affect the welfare of humans in their everyday lives, and students discovered that many of the best solutions to the problem involved the successful integration of natural ecosystems within the urban core (EP&C I). At the same time, the effect of urban heat islands extended to natural **systems [CCC-4]** within and beyond the urban core. For example, excess heat from urban areas can drive evaporation that stresses ecosystems (EP&C II). Day 10 emphasized these relationships. The engineering design challenge was a realistic scenario in which students had to support the needs of the people living in an urban city block while reducing urban heat island effects. Their design had to consider a range of factors (EP&C V).

CA CCSS Connections to English Language Arts and Mathematics. Throughout the vignette students were asked to participate in small group and whole class discussions (SL.9–10.1a–d). They analyzed data sets online and also created their own data sets by measuring temperatures around their school looking for patterns (S-ID 3, 5, 9). Students were asked

PHYSICS IN THE UNIVERSE VIGNETTE 7.3: SEISMIC WAVES

to summarize their findings and also write scientific explanations (W.9–10.a–f; WHST.9–10.1a–e, 6, 7, 9). Finally, students participated in a mock city council where they presented proposals to reduce the effects of heat islands (SL.9-12.6).

Resources

Several of the activities described in this vignette were adapted from other sources and are cited within. Please refer to them for more detail.

The introductory lesson on the built environment and the historical aerial photo analysis are two lessons in a much broader series of activities by Arizona State University's Ecology Explorers. They offer additional activities that could extend ideas in day 10 of this vignette to investigate impacts on human heat illness, an investigation into evapotranspiration, and more. https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link69

The X-factor urban temperature analysis is a published activity: https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link70

Temperature data from day 2 come from the ASTER GED 100 m data set, which can be downloaded at https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link71. At this point, viewing images downloaded at that site requires specialized tools, but a service by Google called "Earth Engine" provides convenient and user-friendly access to the ASTER GED surface temperature data (https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link72). There are plans to create a simple educational interface for the entire state of California specifically for this activity.

Cal Srigley Illustration, for Rafii Architects Inc. 2015. 2010 Marine Drive / 1633 Capilano Road (Grouse Inn), Plaza Artist Rendering. https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link73 California Energy Commission. 2015. Cal-Adapt, Temperature: Extreme Heat Tool. https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link74

Cedeon Design. 2015. Proposed Commercial Square in Cambridge, UK. https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link75

JGKlein. 2010. "West Valley Regional Branch Library, Reseda, CA." Posted at *Wikimedia Commons*, https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link76

Jordan, Jonathan. 2012. "Mallard Duck on Grass." Posted at *Flickr*, https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link77

Kilby, Eric. 2013. "Boston Common Fountain (HDR)." Posted at *Flickr*, https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link78

NASA. N.d. https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link79

NASA/Goddard Space Flight Center Scientific Visualization Studio. 1997. "Beating the Heat in the World's Big Cities." https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link80

nbcorp. 2012. "Sun." Posted at *Openclipart.org*, https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link81

radcliffe dacanay. 2008. "People Walking on City Street San Francisco 01." Posted at *Flickr*, https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link82

USGS. 2015. Earth Explorer. https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link83

Cities are **systems [CCC-4]** with interacting components that meet a wide range of human needs. Like the broader Earth system, a city is also an example of a system of systems: transportation, utilities, commerce, education, and other sectors of society are all systems of their own that interact with one another. Game-based learning opportunities allow students to explore some of these complexities and the impact that city policies can have on the long-term sustainability of the natural environment (see ElectroCity at https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link84 and SimCityEDU at https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link85). These computer simulations allow students to explore complex real-world problems with numerous constraints and criteria (HS-ETS1-4).

Engineering Connection: Reducing Urban Runoff

One of the biggest **changes [CCC-7]** an urban landscape makes upon the world is covering soil with impermeable concrete and structures. These **changes [CCC-7]** disrupt the natural hydrologic cycle, preventing water from soaking in and becoming groundwater and instead sending it into river channels where it can cause flooding, increased erosion, or both. As water moves across the surface in the built environment, it carries contaminants into these waterways contaminating the water. Students can apply their knowledge of Earth materials to explore solutions to the urban runoff problem by designing systems to catch and filter runoff before it enters waterways (see Engineering is Elementary *Don't Runoff* at https://www.cde.ca.gov/ci/sc/cf/ch8.asp#link86) (HS-ESS3-4; HS-ETS1-2). Harmful pollutants are just one of the many ways that urban areas have significant impact on plant and animal life in a region (anthrosphere-biosphere interactions, LS4.D; EP&C II).