Stormwater and Green Infrastructure Curriculum for Boston Public Schools

Grade 5 | Does It Really Work? *Investigating Claims about Green Infrastructure*

Three schoolyard investigations in which students look for evidence in their schoolyard to support or refute claims about the impact of Green Infrastructure. For schools with Green Infrastructure on-site.

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Prepared for: Boston Water & Sewer Commission

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Preface

These two units were developed as part of a partnership between the Boston Water & Sewer Commission and the Boston Public Schools in which Green Infrastructure (GI) was installed at five (5) Boston Public School (BPS) sites. The partnership creates new opportunities for students to explore science, technology, and engineering—and issues of critical importance to the City of Boston today—in an authentic context that is immediately relevant to their lives. Both units align science and engineering concepts related to stormwater and Green Infrastructure with the MA Science, Technology/Engineering (STE) Standards and Science and Engineering Practices. The lessons draw on the ideas, materials, and suggestions of engineers and scientists working on installing GI at the BPS sites, as well as from BPS administrators and teachers.

This is a living document. It is intended to engage teachers as partners in thinking about how these concepts can be taught in ways that will be most meaningful for their students. These lessons provide a framework and a set of activities for you to test in your classrooms and modify in the context of your science curriculum.

cover photo credits: Kristin Metz and water image (modified): Flickr LamarGore/USFWS

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Grade 5 | Does It Really Work?

Three Investigations into Green Infrastructure

Before You Begin—A Note to Teachers

Stormwater runoff is the leading cause of water pollution today. Your school is helping to reduce pollution in the Charles River by using a new nature-based technology called Green Infrastructure (GI). GI replaces traditional "grey" infrastructure, including catch basins and storm drains (pipes), with natural elements, such as plants, soil, and gravel, to manage the enormous volume of stormwater generated in cities, and address related issues.

These GI features give students opportunities to investigate important innovations in technology right in their schoolyard.

Each of the following investigations introduce students to a problem facing the City of Boston in a context that relates to their everyday lives. They learn that GI is one solution to these problems. In each case, they investigate specific claims that GI is solution to the problem by applying the science concepts and practices they know to measure or model GI's impact on their schoolyard, and by extension the City.

Consider bringing students from different schools (or classes) together to share their findings from these investigations in a **joint symposium.** How does their evidence about the impact of GI in their respective schoolyards compare? Did they get the same, or different results? Did they arrive at the same, or different conclusions?

In the following investigations students explore three claims about GI:

- GI helps get more precipitation into the ground.
- GI helps reduce air temperatures/ and the urban heat island effect in cities.
- GI helps prevent sediment (and other pollutants) from being carried into storm drains and from there into rivers, streams and Boston Harbor.

Each investigation takes 3-5 class periods. They can be done in any combination or as stand-alone units.

OPTIONAL: Help students locate the nearest receiving water or water body on a map (the Charles, Neponset or Mystic rivers or Boston Harbor). Take a walk to visit them if you can.

Science & Engineering Standards

7.MS-LS2-4. Analyze data to provide evidence that disruptions (natural or human-made) to any physical or biological component of an ecosystem can lead to shifts in all its populations.

7.MS-LS2-6 (MA). Explain how changes to the biodiversity of an ecosystem—the variety of species found in the ecosystem—may limit the availability of resources humans use. Resources can include food, energy, medicine, and clean water.

Science & Engineering Practices

Asking questions and defining problems.

Analyzing and interpreting data.

Planning and carrying out investigations.

Develop and use models that explain how changes in land cover can lead to changes in populations.

Investigation 1—Can GI Get More Rainwater into the Ground?

The Water Cycle

Students apply what they know about the water cycle and making models to investigate the claim that bioretention features help reduce stormwater runoff. They work together to develop, and then improve, a model of the bioretention features on their schoolyard that describes its component parts and functions and explains how bioretention helps precipitation move back into the biosphere and geosphere.

Investigation 2—Can GI Make the City Cooler?

Earth and Human Activity

Students apply what they know about measuring temperature, planning, and carrying out investigations to explore the impact of GI. They work together to plan and conduct an investigation that involves collecting data to determine whether GI that uses plants (e.g., bioretention features, like rain gardens and tree pits) affects the temperature in their schoolyard, and by extension, the entire city.

Investigation 3—Can GI Clean Stormwater?

Earth and Human Activity

Students apply what they know about how water transports sediment, road salt, nutrients (i.e., phosphorus and nitrogen), and debris and work together to plan and conduct an investigation that includes collecting data to determine whether the GI in their schoolyard helps remove sediment and other materials from stormwater.

Teacher Preparation

Before you begin:

- Read *Background on Stormwater and GI (Appendix A*)
- Print out a *map of your schoolyard with GI diagrams* (*Appendix B)* Walk the site to locate these features on your schoolyard.
- Review the *GI Fact Sheets* (*Appendix C)* to learn more about specific GI practices.

Notes:

Making a Difference in the Community

In addition to investigating the claims about the impact of GI, these activities invite students to discover ways they can have a positive effect on their communities. Fresh water is a precious and limited resource. Stormwater at present is treated as a potentially destructive byproduct of rain that should be quickly and efficiently gotten rid of. Students will participate in the effort to treat stormwater as a valuable resource, returning rainwater to the natural cycle, which replenishes the earth's supply of fresh water.

- They learn that their school is helping to solve a serious water quality issue in Boston and that they can actively participate.
- They discover that where water is coming from/going to is very important—something real scientists and engineers do every day as part of their jobs. It's also fun and exciting.
- They learn that people can help mitigate problems like water pollution and climate change by using new ideas, technologies, and practices.
- To solve these problems, people in a wide range of jobs have to work together. They could be one of them!

Curriculum Connections

CCSS.ELA-Literacy.W.5.2. Write informative/explanatory texts to examine a topic and convey ideas clearly.

CCSS.ELA-Literacy.SL.5.4. Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

Notes:

Grade 5 | Investigation 1 | Can GI Get More Rain into the Ground?

Students apply what they know about the water cycle and making models to investigate the claim that bioretention features help prevent stormwater runoff. They work together to develop, and then improve, a model of the bioretention feature on their schoolyard that describes the component parts and functions of bioretention features and explains how bioretention features help precipitation move into the biosphere and geosphere.

The Problem: The land Boston sits on used to be covered by plants, forest and wetlands, but is now mostly covered by concrete and pavement. These changes have "broken" the water cycle because most of the rain that falls, instead of being absorbed into the soil, or being taken up by plants, just runs off the roads, sidewalks and rooftops into storm drains (called "stormwater runoff").

The Claim: A new nature-based technology, called Green Infrastructure (GI), is being used around the City, including in some schoolyards—and ours is one of them. The claim is that the use of GI can help rainwater in the schoolyard get back into the biosphere and geosphere.

The Task: We are going to be investigating one type of GI (bioretention features) sometimes called "rain gardens" to test that claim. Can we find evidence that the bioretention feature in our schoolyard can slow down stormwater runoff and help "repair" the water cycle in the City?

Teacher Preparation

Before you begin:

- Print out a *map of your schoolyard with GI diagrams* (*Appendix B*) Walk the site to locate these features on your schoolyard.
- Review the *GI Fact Sheets: Bioretention Features (Appendix C)* to learn about GI features that rely on the properties of plants.
- Identify the GI feature on your site that you will use for this activity—a bioretention feature/rain garden, bioswale, vegetated swale, tree pit, or stormwater planter.
- Print a diagram of the feature you have chosen to use from the *GI Fact Sheets: Bioretention Features (Appendix C)*, make copies (and laminate) for each student group.
- Review the *Guide to Outdoor Teaching and Learning (Appendix A)* for tips on teaching outdoors.
- Alert students that the class will be going outside for this investigation. Like all field scientists, they will need to wear appropriate clothing. (Discuss what this means given the season.)

Science & Engineering Standards: The Water Cycle

ESS2-1. Use a model to describe the cycling of water on Earth between the geosphere, biosphere, hydrosphere, and atmosphere through evaporation, precipitation, absorption, surface runoff, and condensation.

Science & Engineering Practices

Students work with others to make or improve a model of a bioretention feature.

TEACHER NOTE

Try the same lesson with infiltration features (porous playground surfaces, or pavers) if you have them on your site, using appropriate materials for models.

Materials Needed

For the class

- Laminated pictures of *Boston in 1630 and Today (AppendixC)*
- Materials for demonstration: a sponge, sheet of hard plastic or other impervious surface
- Water to pour on surfaces

For each student group

- Materials for building bioretention/ rain garden models
- A 2-liter bottle
- Something to represent plants
- Soil
- Gravel of different sizes
- Newspaper
- Straws or other material to represent roots
- Laminated diagram of the bioretention feature in your schoolyard that you are using for this activity

For each student

- Clipboards or notebook and writing utensils

Investigation

Setting Up the Challenge

Let students know that they will be conducting an investigation in their schoolyard, and will be working outdoors as field scientists. Introduce or remind them of the outdoor classroom practices you have established.

INTRODUCE THE PROBLEM.

Show students the laminated photos of *Boston of 1630 and Today (Appendix A)*.

Discuss: What do you notice? What's the same? What's different? (The ground that used to be covered with vegetation/plants is now almost completely covered with concrete.) How do you think that change is affecting the water cycle?

When the ground was mostly covered with plants, what happened to rain that fell on the Earth's surface? What happens to rain that falls on the Earth's surface today? (Some goes into the ground where it's absorbed by soil and where roots drink the water. Some runs off the surface, flowing over rock or compacted soil until it finds its way into the ground and from there into a stream or lake. But when rain hits pavement it is almost all diverted into storm drains (pipes) that deliver it all to the Charles River).

See **Water Filtration Activity**
Role of Plants in Water Filtration

https://www3.epa.gov/safewater/kids/pdfs/activity_grades_4-8_plantsinwaterfiltration.pdf

If precipitation isn't absorbed into the ground, what does that mean for the plants? (the plants will die). Rivers also dry up when not enough rainwater has infiltrated into the ground to refill them. (In 2016 the Ipswich River became "bone dry"). How would a river drying up affect an ecosystem?

INTRODUCE THE CLAIM THAT GI IS HELPING TO SOLVE THIS PROBLEM.

Scientists and engineers have developed a new nature-based technology (GI) that Boston and other cities are using to help solve this problem. One goal of GI is to help more rain absorb into the ground where it falls—instead of being channeled away in storm drains.

INTRODUCE THE TASK.

This is a new nature-based technology that most people in Boston don't know about and don't understand. Boston needs help explaining to everyone who lives in the City how GI works and why it is important.

Our job is going to be to investigate how one GI feature works—the bioretention feature ("Rain Garden") in our schoolyard, and to make a model that explains how it works to help people understand it.

You will be working in teams to develop a model of a bioretention feature and then working together to see how you might want to improve that model.

Student Investigation

1. STUDENTS DRAW A MODEL TO PREDICT HOW A BIORETENTION FEATURE WORKS. (OUTDOORS)

As a demonstration, pour water on 2 materials: a sponge, and a hard sheet of plastic. Elicit observation that water behaves differently on different surfaces. Some surfaces shed water (impervious), some absorb water (porous). Discuss what might cause this difference.

- Pour water on one permeable/porous surface (the soil in a landscaped area) and one impervious surface (asphalt, concrete) in the schoolyard. What do you notice? Discuss the difference in what happens to the water.
- Allow students to pour water on both surfaces on their own to have another opportunity to make observations before they draw their models.
- Sit with your group and draw a model as a prediction for what you think is happening to the water underneath the surface in both cases: under the concrete and under the soil in the bioretention feature.

Notes:

2. GROUPS CHOOSE ONE MODEL FROM THEIR GROUP TO SHARE WITH THE CLASS.

Look at the models together. As the class looks at the models that are shared, what do they notice about each other's thinking? Are they mostly in agreement about what is happening to the water? What do they agree or disagree in their predictions? You may want to add sticky notes with questions that arise from looking at each other's models.

3. STUDENTS BUILD AND TEST THEIR MODEL. (INDOORS OR OUTDOORS)

Look at a diagram of the rain garden/bioretention feature/tree trench. What are the component parts (*plants, roots, soil, gravel*)? What do you think each part does? How do they change the path of the water?

- In groups, have students build a simple model using the information they gained from looking at the diagram. They should have a layer representing plants, soil, gravel—using their knowledge from earlier terrariums they've built—using gravel, maybe a layer of newspaper as a filter. (Doing this outdoors helps with the mess.)
- Groups test their model by pouring water over it. Record observations about what happens to the water as it moves through each layer. (Does water move slower through some layers than others?)
- Discuss: what happened with the models we built? What did you notice? Where did the water go? How did it move? How is this different from what happens with water on asphalt?
- Did what you observe match what you predicted? (Students may have only predicted one layer of soil; or that all the water is absorbed by the roots.)

4. STUDENT GROUPS REVISE THEIR ORIGINAL MODELS TO BETTER EXPLAIN HOW A BIORETENTION FEATURE WORKS.

Now that we've learned more about what happens in a bioretention feature let's go back to our original models and revise them so they do a better job of explaining what happens. (Students might add more layers than just soil, maybe gravel, deeper layers; or more roots.)

Teacher Notes:

You may want to let students know that plants also help water get into the *atmosphere* by releasing water through pores in their leaves into the air—a process called **evapotranspiration**.

The root systems of plants also create paths that water can travel through the soil.

Drawing Conclusions

WRITE IN YOUR NOTEBOOKS:

- Did you make changes to your model? What changes did you make? What made your thinking change?
- Did we find out if bioretention features help rainwater get into the ground?

STUDENT GROUPS PRESENT THEIR MODELS. (INDOORS OR OUTDOORS)

Do you think bioretention features help rainwater get back into the ground? into the biosphere? and geosphere?

- Use your model to explain how bioretention features help rainwater get back into the ground/ the geosphere, and/or the biosphere?
- Explain how biofilters affect the environment.

Literacy and Community Engagement Opportunity

Students could create PSAs, videos, and/or leaflets either to explain how bioretention features like rain gardens or tree pits help rainwater absorb into the ground and why that is important; and/or to advocate for more bioretention features in the city.

Notes:

Grade 5 | Investigation 2 | Is GI Cool?

Students apply what they know about measuring temperature, planning and carrying out investigations to explore the impact of Green Infrastructure (GI). They will work together to plan and conduct an investigation that involves collecting data to determine whether GI features that use plants (bioretention features like rain gardens, bioswales, and tree pits) affect the temperature in their schoolyard and, by extension, the entire city.

The Problem: Cities like Boston are getting hotter. The temperature in cities is often warmer than in the surrounding towns and rural areas and that is causing problems. One reason cities are hotter is because of the great quantity of heat-absorbing materials, such as asphalt and other types of pavement, covering the ground. Another is that there are fewer trees and less vegetation creating shade. (And, though not the focus here, less water vapor gets into the air through evapotranspiration).

The Claim: GI, a new nature-based technology, is being used around the City, including in some schoolyards—like ours! The main function of GI is to help manage and clean stormwater, but some GI features, like bioretention features, can also help to reduce temperatures in the schoolyard, and by extension in the city.

The Task: Students design an investigation to see if they can find evidence that bioretention features do reduce the temperature in the schoolyard.

Teacher Preparation

- Review *Background on Stormwater and GI* (*Appendix A*) and the *GI Fact Sheets: Bioretention Practices (Appendix C)*
- Review your *schoolyard map* (*Appendix B)* and walk the site to locate these features on the ground. Choose the bioretention feature you will use for this investigation.
- Print and make copies of schoolyard site maps for students.
- Review *Guide to Outdoor Teaching and Learning* (*Appendix A*)
- Alert students that the class will be going outside and like all field scientists, they need to wear appropriate clothing.

Science & Engineering Standards: Earth and Human Activity

5-ESS3-1. Obtain and combine information about ways communities reduce the impact on the Earth's resources and environment by changing an agricultural, industrial, or community practice or process. Examples of changed practices include treating sewage, reducing the amounts of materials used, capturing polluting emissions from factories or power plants, and preventing runoff from agricultural activities.

Background Notes:

"Urban heat islands" occur when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat. This effect increases energy costs (e.g., for air conditioning), air pollution levels, and heat-related illness and mortality. – EPA

https://www.epa.gov/green-infrastructure/reduce-urban-heat-island-effect

Materials Needed

For the class

- *Land Cover in Boston 1630 and Today (Appendix C)*
- Class data table developed in this investigation
- Urban Heat Island effect graphic (at the end of this Investigation)

For each student group

- Planning worksheet
- Thermometers
- Data recording worksheet—developed in the investigation
- Printed maps of the schoolyard

For each student

- "Climate Change in the U.S. Northeast" https://newsela.com/read/govt-EPA-climate-northeast/id/28810/
- Clipboards or notebook and writing utensil

Investigation

Setting up the Challenge

Let students know that they will be conducting an investigation in their schoolyard, and will be working outdoors as field scientists. Introduce or remind them of the outdoor classroom practices you have established.

INTRODUCE THE PROBLEM.

- Look at the laminated images of *Land Cover in Boston 1630 and Today* and discuss the changes in land cover (from marsh and wetland and woods to mostly asphalt). Explain that the huge increase in asphalt and concrete that comes with the growth of cities causes many changes to the environment. One is that cities are usually hotter than any of the areas around them.

- Engage students in discussing the *Urban Heat Island Effect* graphic. What do they think the graphic means? What could explain this? Why would cities be warmer?

- *Optional*: Have students read "Climate Change in the U.S. Northeast"

- Why do you think hotter temperatures in cities could be a problem? (People have to spend more money for air conditioning and fans, using more energy to stay cool. Plants, and animals may not be able to survive in higher temperatures. Warmer cities contribute to a warmer planet, etc.).

"Having a lot of people in one place makes cities much warmer. Buildings and concrete also trap heat. This is called the urban heat island effect."

Climate Change in the U.S. Northeast, newsela
https://newsela.com/read/govt-EPA-climate-northeast/id/28810/

"Green infrastructure can help mitigate the urban heat island effect by creating shade, reducing heat-absorbing materials, and emitting water vapor that cools the air.

It also can help create an attractive environment, clean the air by filtering airborne pollutants, and reduce building energy costs through shading and recyclable water."

Climate Ready Boston
www.boston.gov/sites/default/files/20161207_climate_ready_boston_digital2.pdf

INTRODUCE THE CLAIM THAT GI IS HELPING TO SOLVE THIS PROBLEM.

GI is a science-based solution that mimics the natural environment to reduce the impact of humans on the environment. One claim is that GI features that use plants (e.g., rain gardens, bioswales, and tree trenches) help lower temperatures.

INTRODUCE THE TASK.

Our task is to see if we can find evidence that GI does really lower temperatures, using our own schoolyard as a test case. How do you think we could we do that? How can we find out if this bioretention feature (rain garden, bioswale, tree trench, etc.) has any effect on the temperature in our schoolyard?

Have students turn and talk to discuss their ideas. (The goal here is to facilitate a conversation where students share ideas, ideally arriving at a plan to record temperatures in different parts of the schoolyard).

Planning and Carrying Out an Investigation

1. DECIDE WHAT DATA TO COLLECT.

Let's think about what we already know about temperature in the schoolyard. Where is it hottest? Where is it coolest? If we're going to test this claim we need to decide what data to collect to test our hypotheses and what procedure to use.

- Students work together in groups to fill out the planning worksheet. If this is outdoors they can walk around to identify areas to test.
- Give students a planning sheet titled: How can we find out if this bioretention feature has any effect on the temperature in our schoolyard? Decide what data we should collect (temperature in Fahrenheit)? What materials will you need to test this (thermometers)? What areas in the schoolyard should we test (under trees, in the GI areas, on asphalt, near the building, near the street)?
- Go over the answers to the questions on the worksheet and come to agreement as a class for each question.

2. DECIDE ON A PROCEDURE FOR COLLECTING DATA.
Note: The procedure can be as simple as: go outdoors with your thermometers, locate your site, leave your thermometer in place for 3 minutes, put the thermometer in same place each time (tie to tree branch, set on the ground, etc.), repeat for as many trials as needed.

Notes:

- Now that we have agreed on the data we want to collect, we need to agree on a procedure for collecting it and recording it so we know we're all doing the same thing. Elicit student ideas on how to collect the data and agree on a procedure.
- How much data do you need to make a convincing case? How many trials will we need? How many areas should we test? Should we record qualitative observations?
- Decide which areas will be tested and which group is responsible for which area (e.g., 3 areas in or near the GI and 3 non-GI areas).
- Each group will record data on their own data sheet, which they will later transfer to the class data table.
- Create a data recording sheet (or table in notebooks) for groups to use to record their data. For example: columns list: date | time | temperature | weather. Rows list: each location.

3. COLLECT DATA (OUTDOORS).

Have students first record their predictions in their notebooks.

- Convene outdoors in the gathering area to review instructions. Groups collect data as planned.

4. CREATE AND ANALYZE A CLASS DATA TABLE.

Have each group report or transfer their data from their recording sheet to the class data table.

- Discuss, as a class, what the data shows. Invite students to share their interpretations and try to arrive at a conclusion as a class. Does this support the claim that bioretention features can make the air cooler?

5. DECIDE HOW TO REPRESENT THE DATA.

Review options with students. Elicit their ideas on how to represent this information. You can introduce the idea of temperature maps as one tool scientists use (color coding the temperatures of different areas of the schoolyard). Ideas may include: graphs, tables, schoolyard temperature maps, written text. Talk about how, for some people, visual representations are easier to read, for others numerical tables or text.

6. STUDENTS PRESENT THEIR DATA.

Student groups share their representations of the data. Do they agree? Which representations are easiest to understand?

Background Notes:

Some materials absorb more heat than others. GI helps lower temperatures by reducing the amount of pavement, providing shade, or (in the case of green roofs) reducing roof warming.

This is an energy saving consideration for green roofs.

Students could also explore the temperature of different materials: grass, concrete, asphalt, and synthetic turf. Does the color matter? Which materials are warmer?

Drawing Conclusions

STUDENTS REFLECT ON WHAT THEY LEARNED.

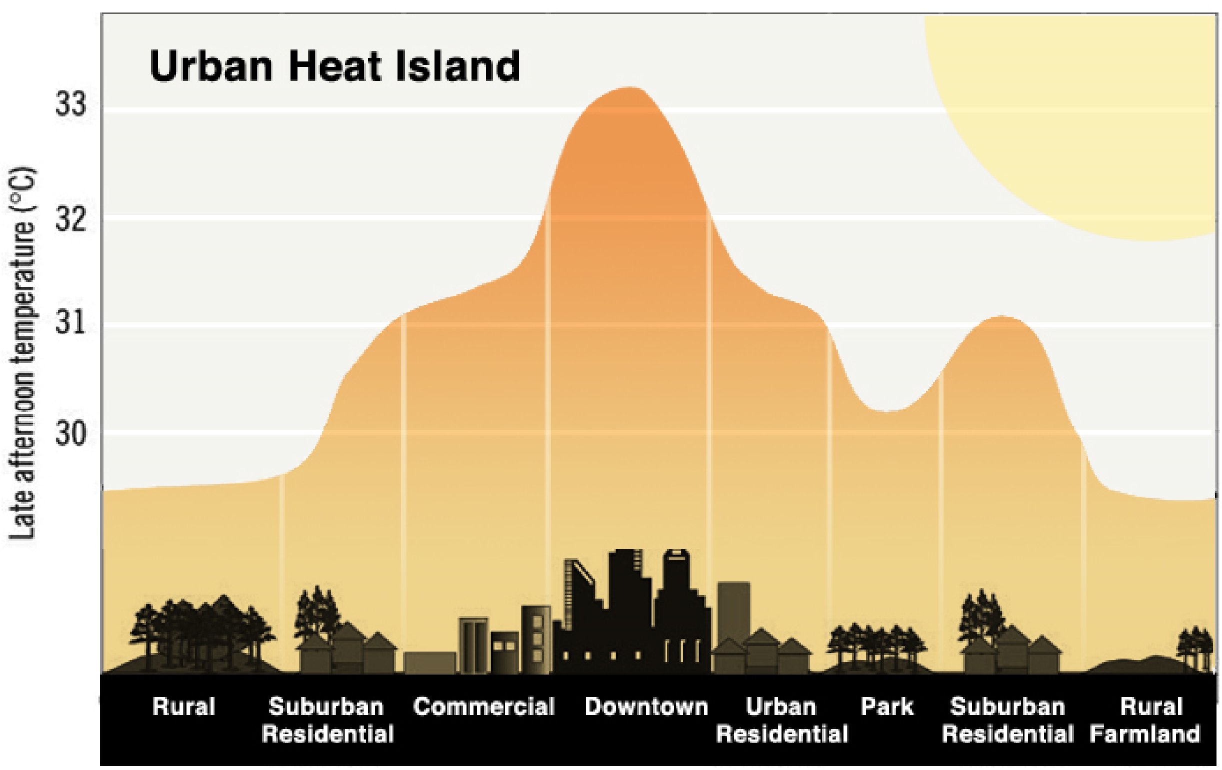
Write reflections in your notebooks: You designed and conducted an experiment.

- What did you find? Did what you found match your predictions?
- What did you learn about GI? What could other people learn about GI from our investigation?

Literacy and Community Engagement Opportunity

Create a PSA for Boston residents; a leaflet, video or other way of reporting the results of our investigation to the public.

Notes:



Grade 5 | Investigation 3 | Can GI Clean Stormwater?

THIS LESSON COULD BE DEVELOPED WHEN THE NEW GRADE 5 CURRICULUM IS IMPLEMENTED. THE STRUCTURE OF THE INVESTIGATION WILL DEPEND ON THE UNIT AND CONTENT KNOWLEDGE IT IS DESIGNED TO ADVANCE.

Students apply what they know about [how water transports sediment, road salt, nutrients (i.e., phosphorus and nitrogen) and debris,] to work together to plan and conduct an investigation, including collecting data to determine whether the GI in their schoolyard helps remove sediment and other materials from stormwater.

The Problem: When stormwater runs across impervious surfaces it picks up anything on those surfaces (including sediment, grease, oil, litter, leaves, and more) and carries it all through storm drains to rivers and streams, polluting the water and harming the organisms that live there.

The Claim: GI, a new nature-based technology, is being used around the City to trap pollutants and filter them out of stormwater before it goes into the storm drains. The claim is that GI— including rain gardens, bioswales, tree trenches, other bioretention systems, and infiltration chambers— are making the stormwater flowing into our rivers and streams cleaner.

The Task: We are going to design an investigation to help test whether the GI in our schoolyard is helping to remove sediment and pollutants from the stormwater runoff that washes across impervious surfaces.

Let students know that they will be conducting an investigation in their schoolyard, and will be working outdoors as field scientists. Introduce or remind them of the outdoor classroom practices you have established.

Drawing Conclusions

Students write an argument that GI can help remove sediment and pollutants from stormwater, making the runoff that flows into rivers and streams cleaner.

Science & Engineering Standards: Earth and Human Activity

5-ESS3-1. Obtain and combine information about ways cities reduce the impact on the Earth's resources and environment by changing an agricultural, industrial, or community practice or process. Examples of changed practices include treating sewage, reducing the amounts of materials used, capturing polluting emissions from factories or power plants, and preventing runoff from agricultural activities.

Science & Engineering Practices

Students work together to plan and conduct an investigation that includes collecting data.