

MODULE 2 (EARTH SCIENCE) INTRODUCTION

Module Name: Greenhouse Gases and Climate Change.

Content of this Introduction:

1. Overview of the Module.
2. Prerequisite knowledge and assumptions encompassed by the Module.
3. Standards covered by the Module.
4. Materials needed for the Module.
5. Pacing Guides for 5 Lessons, including Learning Objectives and Assessment Questions.

1. Overview of the Module

This Earth Science module explores climate change: what it means, what the difference is between climate and weather, and evidence of climate change. The global climate system is presented as a complex system with feedback loops and interconnected processes.

The goal is to clarify what is known, what scientists believe is happening and how climate change impacts our environment and species. Students use, modify and customize an agent-based model of the build-up of greenhouse gases and its impact on the climate.

2. Prerequisite knowledge and assumptions encompassed by the Module

This Earth Science module offers some disciplinary core concepts through direct instruction and activities but assumes the students already possess a certain level of knowledge in key areas.

Concepts such as climate change, greenhouse gases and the greenhouse effect, climate vs. weather, and evidence for climate change are reviewed, but in order to achieve deeper learning it is advisable that the students will have covered these concepts beforehand. A background document with information pertaining to these concepts is provided [Climate Change background document].

It is necessary to have completed Module 1 prior to commencing this module, in order to have the necessary skills to perform the modeling required in this module.

3. Standards covered by the Module

Please see the Standards Document for a detailed description of Standards covered by this Module, Lesson by Lesson.

4. Materials needed for this Module

You will need the following materials to teach this module:

- Computer and projector

- Climate Change background document [for reference]
- Link to the EPA video [in lesson plans and slide presentation]
- Link to the EPA carbon footprint calculator [in lesson plans and slide presentation]
- EPA carbon footprint calculator excel spreadsheet [for reference]
- Greenhouse Gas base StarLogo Nova models: base model, base model plus albedo slider, base model plus factory with CO₂, base model plus cars and CO₂, suggested modifications (detailed in Lesson plans).
- Guided Introduction to StarLogo Nova document [for reference]
- StarLogo Nova Blocks CS Concepts guide document [for reference & student handout]
- StarLogo Nova Blocks Reference Guide [for reference & student handout]
- StarLogo Nova Blocks Reference Guide Module 2 [for reference & student handout]
- USING a Computer Model to do Science document [student handout]
- Experimental Design form document [student handout]
- Model observation form [student handout]
- Project design form [student handout]
- Model design form [student handout]
- Lesson plans for 5 lessons
- Simple Slide presentation presentations with instructions
- New commands and concepts sheets for each lesson [student handout]

5. Pacing Guides for 5 Lessons, including Learning Objectives and Assessment Questions. (See following pages.)

DAY 1 - Introduction to Climate Change and Greenhouse Gases, Carbon Footprint activity, preview of model.

Pacing Guide

| | | |
|-----------------|--|---------|
| Getting Started | Review, watch & discuss EPA video – The Greenhouse Effect. | 15 mins |
| Activity 1 | Go to EPA webpage – and have students complete “Carbon Footprint Calculator” activity. | 15 mins |
| Activity 2 | Introduce StarLogo Nova base model. Investigate how the temperature behaves. | 15 mins |
| Wrap Up | How can modeling help us understand climate change? | 5 mins |

Learning Objectives: Students will...

| | |
|--------------------------|---|
| Complex Adaptive Systems | Be able to identify climate as a complex system: it is made up of many parts which are highly interconnected and interacting, there are feedback loops, there are non-linearities (evaporation, condensation), there are chaotic dynamics (small changes in initial conditions lead to large differences in outcomes), and there is distal causality (chain reactions can trigger events far away from an action's starting point) [LO2] . |
| Disciplinary Core Ideas | Differentiate between climate and weather [LO1] . Learn the importance of greenhouse gases for our survival [LO3] , and our role in climate change through the increase of carbon dioxide emissions [LO4] . Identify what behaviors can reduce their carbon footprints [LO5] . |
| Modeling and Simulation | Learn that models are important for climate change predictions [LO6] . Identify what aspects of climate change are included in the Greenhouse Gas base model: solar radiation, infrared radiation (tied to temperature), reflection [LO7] . |

Assessments of understanding:

| | |
|--------------------------|--|
| Complex Adaptive Systems | List two characteristics of global climate that show it is a complex system [LO2] . |
| Disciplinary Core Ideas | Explain how the Earth would be different without the greenhouse effect [LO3] . How is adding carbon dioxide to our atmosphere affecting our climate? Explain three things that will help you reduce your carbon footprint [LO5] . Compare and contrast climate and weather [LO1] . List three factors that are contributing to global warming, using what you learned from the short video and the carbon footprint activity [LO4] . |
| Modeling and Simulation | Why are modeling and simulation useful in climate science? [LO6] Describe how solar radiation behaves in the Greenhouse Gas base model [LO7] . |

DAY 2: Use StarLogo Nova Greenhouse Gas base model.

Pacing Guide

| | | |
|-----------------|---|---------|
| Getting Started | Review of the previous day's lesson and concepts. Connection to today's lesson. | 5 mins |
| Activity 1 | Use the Greenhouse Gas base StarLogo Nova model and change a variable. | 10 mins |
| Activity 2 | Inspect the code: what is familiar? What was included or left out? What is new? | 15 mins |
| Activity 3 | Add a slider for the albedo variable. Run an experiment. Record Data. Run multiple times. | 15 mins |
| Wrap Up | How could you improve the model? | 5 mins |

Learning Objectives: Students will...

| | |
|--------------------------|---|
| Complex Adaptive Systems | Identify randomness in the model. [LO1] |
| Disciplinary Core Ideas | Learn about feedback loops in the global climate system. [LO3] Understand the concept of albedo and how it relates to climate. [LO2] |
| Modeling and Simulation | Use the Greenhouse Gas base model to do science and conduct an experiment with repetition. [LO6] Identify limitations of the model. [LO7] Make observations (drawing simple correlations). [LO9] |
| Computer Science | Decode a model. [LO4] Learn to add a slider. [LO5] Practice Pair Programming and Iterative design, implement, test cycle. [LO8] |

Assessments of understanding:

| | |
|--------------------------|--|
| Complex Adaptive Systems | Where do we see randomness in the model? [LO1] |
| Disciplinary Core Ideas | Give one example of a feedback loop in the global climate system. [LO3] Give one example of a human action that could increase or decrease the Earth's albedo. [LO2] |
| Modeling and Simulation | What is the major variable in this model? [albedo] [LO4] What experiments did you run in the model? [LO6] Describe your experimental results and conclusions. [LO9] What limitations does this model have? [LO7] |
| Computer Science | Name three blocks of code you recognized and what they are used for. [LO4] What is the slider used for? [LO5] List the steps necessary for adding a slider to control a variable. [LO5] |

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Module 2: Greenhouse Gases and Climate Change

DAY 3: Adding CO₂.

Pacing Guide

| Pacing Guide | |
|-----------------|--|
| Getting Started | Review of the previous day's lesson and concepts and connection to today's lesson. |
| Activity 1 | Add CO ₂ |
| Activity 2 | Run an experiment to see the effect of the modification |
| Wrap Up | In the real world, where does most of the CO ₂ come from? How can computer models be helpful in understanding climate change? |

Learning Objectives: Students will...

| | |
|-------------------------|---|
| Disciplinary Core Ideas | Understand the impact of increased CO ₂ on global temperature. [LO7] |
| Modeling and Simulation | Learn to abstract: find the essential aspects of the modification to include in the model. [LO3] Run a climate change investigation using the greenhouse gas model. [LO5] |
| Computer Science | Modify a computer model by adding breeds and setting user-defined traits. [LO1] Learn CS concepts of user-defined traits and subclasses or breeds. [LO2] Practice Pair Programming and Iterative design, implement, test cycle. [LO4] |
| Other | Collect and analyze data to look for patterns. [LO6] |

Assessments of understanding:

| | |
|-------------------------|--|
| Disciplinary Core Ideas | Describe how your experimental results are related to the real world and climate change. [LO7] |
| Modeling and Simulation | What aspects of the modification did you decide to include in the model? What aspects did you leave out? Why? [LO3] What experiments did you run in the model and what did you learn from them? [LO5], [LO6] |
| Computer Science | What coding blocks did you build in the model? Choose one and describe how it works. [LO1] Describe step by step how you would add a small red house to the model located away from the center of the world. [LO1] |



DAY 4: Create your own Greenhouse Gas model.

Pacing Guide

| Pacing Guide | |
|-----------------|---|
| Getting Started | Review of the previous day's lesson and concepts and connection to today's lesson. |
| Activity 1 | Computational Science and Model Design. |
| Activity 2 | Design and Develop your model. |
| Wrap Up | What research is necessary to ground your model in reality? How will you check to see if your model is realistic? |

Learning Objectives: Students will...

| | |
|-------------------------|--|
| Disciplinary Core Ideas | Reflect on human CO ₂ emissions, as relates to their trips to school, to inform their model design [LO5]. |
| Modeling and Simulation | Develop a scientific question that can be answered with data output from running a model [LO2]. Use the key stages of computational science and model design to develop their question, create their model, and design their experiment [LO3]. |
| Computer Science | Develop their own design for a computational science project based on the Greenhouse Gases model [LO1]. Practice Pair Programming and Iterative design, implement, test cycle [LO4]. |

Assessments of understanding:

| | |
|-------------------------|---|
| Disciplinary Core Ideas | Give three examples of how students going to school contribute to climate change by creating greenhouse gases. [LO5] |
| Modeling and Simulation | State what research question you have chosen to investigate and explain why you chose it. [LO2] What aspects of the real world did you choose to include in your model? What did you leave out? Why? [LO3] |
| Computer Science | What procedures in the model have you built? Choose one and describe how it works. [LO3] [LO1] |

DAY 5: Experiment with your new Greenhouse Gas model.

Pacing Guide

| Pacing Guide | |
|-----------------|---|
| Getting Started | Review of previous day's lesson and concepts and connection to today's lesson. |
| Activity 1 | Complete and debug code. |
| Activity 2 | Run experiments. |
| Wrap Up | Analyze results and discuss conclusions. Relate the results back to the bigger issue of Climate Change and Greenhouse Gases. Prepare your model and results for presentation. |

Learning Objectives: Students will...

| | |
|--------------------------|--|
| Complex Adaptive Systems | Revisit the concept of feedback loops and come up with a possible feedback loop related to human greenhouse gas emissions [LO1] [the hotter it gets, the less people will walk, the more they will drive and use A/C, the more fossil fuels they will use, the more CO2 they will emit, the temperature will rise more]. |
| Disciplinary Core Ideas | Gain a deeper understanding of the effects of human activities on climate change through their experience creating and experimenting with a greenhouse gas model [LO2]. Gain an understanding of what actions can help mitigate human greenhouse gas emissions [LO3]. |
| Modeling and Simulation | Use their new model as a test-bed to run experiments [LO4]. Learn that the results of their experiments can feed back into their model to further improve it [LO5]. |
| Computer Science | Follow the correct execution of their models and apply debugging techniques to fix their code [LO6]. |

Assessments of understanding:

| | |
|--------------------------|--|
| Complex Adaptive Systems | Describe one human greenhouse gas emission feedback loop [LO1]. |
| Disciplinary Core Ideas | What human activities were the greatest drivers of increased temperature in your model [LO2]? How do you think this relates to the real world [LO2]? Describe what actions helped keep temperature and CO2 emissions down [LO3]. |
| Modeling and Simulation | What experiments did you run in the model and why [LO4]? What real world information could improve the model [LO5]? Complete the "USING a Computer Model to do Science" document. |
| Computer Science | Define debugging and give an example of some debugging you had to do in your code [LO6]. |

2

Lesson 1

Climate Change Overview and Introduction to the Greenhouse Gas Model

50 minutes (1 day)

Lesson Overview (New Learning – guided by teacher)

In this lesson students will engage in discussion on climate change and greenhouse gases, stimulated by a video and an online activity. The short video will serve to provide discussion points and introduce key concepts related to climate change. In the online activity, students will use an online carbon footprint calculator to investigate ways of reducing their carbon footprint. Finally, students will be introduced to the Greenhouse Gas base computer model and how to run it.

Teaching Summary

Getting Started: Climate Change overview – 15 minutes

1. Watch and discuss the EPA video
2. Climate vs. weather
3. Climate as a complex system
4. Evidence for climate change

Activity #1: Carbon Footprint Calculator – 15 minutes

5. Online calculation of carbon footprint
6. What activities help reduce the carbon footprint?

Activity #2: Previewing the Greenhouse Gas model – 15 minutes

7. Introduce StarLogo Nova Greenhouse Gas base model
8. Run the model and discuss the temperature fluctuations

Wrap Up – 5 minutes

9. How can modeling help us understand climate change?

Lesson Objectives

The student will:

- ✓ Differentiate between climate and weather [LO1]
- ✓ Identify climate as a complex system [LO2]
- ✓ Learn the importance of greenhouse gases for our survival [LO3]
- ✓ Be able to identify the role of human activity in the form of carbon dioxide emissions in climate change [LO4]
- ✓ Identify what behaviors can reduce their carbon footprints [LO5]
- ✓ Learn that models are important for climate change predictions [LO6]
- ✓ Identify what aspects of climate are included in the Greenhouse Gas base model [LO7]

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- Greenhouse Gas base StarLogo Nova model

For the Teacher

- Computer and projector
- Climate Change background document
- Link to the EPA video
- Link to the EPA carbon footprint calculator
- Greenhouse Gas base StarLogo Nova model

Getting Started: Climate Change Overview - 15 min

Creating and using a model on Climate Change and Greenhouse Gases first requires an understanding of the content and the issues. This understanding will allow the students to use abstraction to identify the most important aspects they would want to include in a model, by identifying the essential aspects of human greenhouse gas emissions. Some information has been given to help provide the Climate Change Overview. See also: Climate Change Background Document. However, this is not a comprehensive introduction to Climate Change and some prior knowledge of the issues and background science would be helpful.

1. Watch and discuss the EPA video.

- Ask the students what they know about climate change.
- Go to the website: <http://epa.gov/climatechange/kids/html>



- Navigate to “Learn the Basics.”
- Click on the link for the video in the green box on the right hand side.
- Pause the video to ask students pertinent questions, e.g.:

What is the greenhouse effect? The trapping of heat in the atmosphere by certain gases (water, carbon dioxide, methane). What is climate change? A long-term shift in the statistics of the weather (including its averages). It may appear as changes in expected average values for temperature and precipitation (rainfall) for a given place and time of year, from one decade to the next. **(Practice: Asking questions and defining problems)** **(CCC: Cause and Effect)** **(CCC: Stability and Change)** **(DCI: Global Climate Change)**

2. Climate vs. weather.

- Explore the differences between climate and weather:
 Weather is the experienced temperature and precipitation on a given day or for a few days.
 Weather models track changes in weather systems and lose accuracy after a few days.
 Climate deals with change over decades or even 100 years into the future. Climate by definition is the statistics of the weather of an area over a long period of time. **(Practice: Asking questions and defining problems)** **(CCC: Cause and Effect)** **(CCC: Stability and Change)** **(DCI: Weather and Climate)**

3. Climate as a complex system.

- Discuss in what way climate is a complex system:
 It is made up of many parts that are highly interconnected and interacting, there are feedback loops, there are non-linearities (evaporation, condensation), there are chaotic dynamics (small changes in initial conditions lead to large differences in outcomes), and there is distal causality (chain reactions can trigger events far away from an action’s starting point). **(DCI: Weather and Climate)** **(CCC: Cause and Effect)** **(CCC: Systems and Systems models)** **(CCC: Stability and Change)**

4. The evidence for climate change.

- Discuss what the evidence is for current climate change:
 The period between 1990 and today has been the warmest period in the global temperature record. Current climate change, according to the IPCC, is more than 90% likely to be human-induced. Carbon dioxide levels have been rising for at least 50 years. Carbon from fossil fuels is being added to the atmosphere. Evidence from ice cores show

a very strong correlation between carbon dioxide levels and global temperatures. As carbon dioxide levels go up, the temperature goes up.

(DCI: Global Climate Change) (CCC: Cause and Effect) (CCC: Stability and Change)

Activity #1: Carbon Footprint Calculator - 15 min

In this activity, students will navigate to the Online Carbon Footprint Calculator on the EPA website and work through the calculator to gain an understanding of how their actions contribute to greenhouse gas emissions. This calculator can be used individually. (DCI: Human impacts on Earth Systems)

5. Online calculation of carbon footprint

- Explain the concept of carbon footprint - [the amount of carbon dioxide and other carbon compounds emitted due to the consumption of fossil fuels by a particular person, group, etc.]. (CCC: Energy and Matter)
- Tell the students that in this activity they will evaluate how they could reduce their carbon footprint through simple actions. (CCC: Cause and Effect)
- Next, navigate to the online calculator. This calculator will work in any browser with JavaScript enabled. There is also a spreadsheet you can work from if Internet access is not available [<http://www.epa.gov/climatechange/students/calc/index.html>]. This spreadsheet also contains the formulas used to calculate the carbon savings. If there is enough time, these formulas could be examined in more depth or used in later lessons to instruct model creation.
- Have the students go through the calculator.
- Collect results and discuss. Who is saving more carbon, and why? (Practice: Analyzing and interpreting data) (Practice: Engaging in argument from evidence) (Practice: Constructing explanations and designing solutions)

Home > Calculator

Calculator



Your total savings: 0 pounds of carbon dioxide per year.
This is equivalent to the emissions from driving a car 0 miles.

Instructions

There are many things you can do to help reduce climate change and its effects on people and the environment. Use this calculator to learn about some simple steps you can take to reduce your impact on the planet.

Instructions:
Select "Yes" if you will take an action, or "I already do this" if you are already taking this action.

Learn about an action by following the "Find out more" link.
See the results of your actions in the box at the top right.

At the end of this exercise, you will also see the total impact if all the students in the United States were to take the same actions as you.

This calculator requires you to have JavaScript enabled. [A spreadsheet version \(Xlsx\)](#) (37K, [Excel Viewer](#)) of the calculator is also available; it includes descriptions of the formulas used in each step of the calculator.

[Find Out More](#)

[Next Section](#)

6. What changes help reduce the carbon footprint?

- Go through the calculator together but only changing one aspect (e.g. taking the bus

instead of cars). (Practice: Asking questions and defining problems)

- What was most surprising? What would be the hardest and also the easiest changes to make? (Practice: Engaging in argument from evidence) (CCC: Cause and Effect)

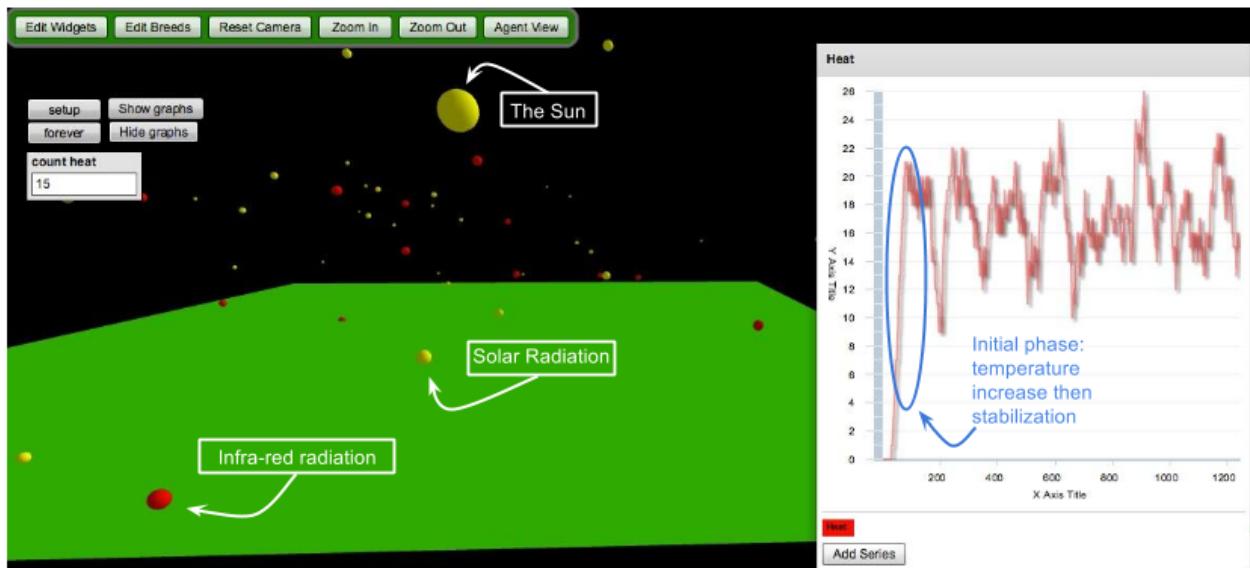
Teaching Tip *In a large class, have students do the carbon footprint activity in pairs. You can also use the spreadsheet to understand the calculations behind the activity, which could be informative for building the models later on.*

Activity #2: Previewing the Greenhouse Gas model - 15 min

7. Introduce StarLogo Nova Greenhouse Gas base model

This model contains the following elements: a sun, solar radiation, reflected solar radiation and infra-red radiation. When you first open the model, the world will be shown from above and will be partly hidden by the graph. Go to the “hide graphs” widget on the left, click it and the graph will disappear. You can open and close the graphs with the “show graphs” and “hide graphs” buttons. Then you will need to change the view from above to from the side. Move the world by clicking and dragging it to move it out from under the graph. Hold down the **alt** key and click and drag with the mouse and see the world rotate and move around. Try to get a sideways view. If you lose the world, don’t panic! Just refresh the page and start again. It will take a little practice to set the view up properly.

- Discuss why modeling is useful in climate science:
Climate is a complex system with many interacting components; modeling and simulation help to predict climate trends in the future. High performance computing is required to simulate the Earth’s environment, a system of great complexity. (DCI: Weather and Climate)
- Show the areas of a StarLogo Nova model (info, display, code).
- Look at the computer model of Greenhouse Gases together. Open the Climate Change and Greenhouse Gases base model in the StarLogo Nova public folder.



- Guide the students through running the model by asking questions. Discuss what abstractions exist in this model. Who are the agents, what is the environment, and what are the interactions between agents and environment? ([Practice: Asking questions and defining problems](#))
- Ask, “How would you get the model ready to start?”
You need to hit **setup**. This will add the sun to the world.
- Ask, “How would you start the model?”
Press the **forever** button. Yellow balls (solar radiation) will shoot out from the sun and fall to the Earth’s surface. As they touch the surface, some are reflected (yellow) and some become infra-red radiation (red, “heat”). This represents the absorption of solar radiation by elements of the Earth and later release of energy. This “heat” causes the Earth’s temperature to rise.

8. Run the model and discuss the temperature variations.

- Run the model, indicating the function of the buttons, and the graph.
Press **forever** and watch the world. Have students describe what they see when you run the model. Run the model a few times and have students note the final temperature.
- Ask, “What do you notice about the temperature, seen in the graph?” ([Practice: Engaging in argument from evidence](#))
If you hit “show graph,” a graph showing the temperature will show a drastic increase. This is because the model is not yet in equilibrium. First the world needs to come up to temperature, and then it stabilizes. It keeps fluctuating due to randomness in the model.
([Practice: Analyzing and interpreting data](#)) ([CCC: Stability and Change](#))
- Explain that they will be exploring the model further in future lessons.

Teaching Tip Put students into pairs when working on the computer. When possible use the pair programming paradigm of navigator and pilot and switch roles every 10 minutes.

Teaching Tip Encourage students to be skeptical of models.

Wrap-up - 5 min

Refer to the section on Climate Modeling in the Climate Background document and use this to guide a discussion on why modeling is important to understanding climate change.

9. How can modeling help us understand climate change?

- Would you trust this model if your life depended on it?
- What are models good for?

Assessment Questions

- Explain how the Earth would be different without the greenhouse effect [LO3].
- Compare and contrast climate and weather [LO1].
- List two characteristics of global climate that show it is a complex system [LO2].
- List three factors that are contributing to global warming, using what you learned from the short video and the carbon footprint activity [LO4].
- Explain three things that will help you reduce your carbon footprint [LO5].
- Why are modeling and simulation useful in climate science? [LO6]

- Describe how solar radiation behaves in the Greenhouse Gas base model [LO7].

Standards Addressed

NGSS Performance Expectations

Earth and Human Activity

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

NRC Disciplinary Core Ideas

ESS2.D. Weather and Climate

Complex interactions determine local weather patterns and influence climate, including the role of the ocean. [Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. Because these patterns are so complex, weather can only be predicted probabilistically.]

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.

Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

ESS3.D. Global Climate Change

Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

NRC Scientific and Engineering Practices

Practice 1. Asking questions and defining problems

1A: Ask questions to identify and clarify evidence of an argument.

1B: Ask question to identify and/or clarify evidence and/or the premise(s) of an argument

Practice 4. Analyzing and interpreting data

4A: Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.

4B: Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.

4D: Analyze and interpret data to provide evidence for phenomena.

4G: Analyze and interpret data to determine similarities and differences in findings.

Practice 6: Constructing explanations and designing solutions

6A: Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.

Practice 7. Engaging in argument from evidence

7C: Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

NRC Crosscutting Concepts

Patterns

1B: Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.

1C: Patterns can be used to identify cause and effect relationships.

1D: Graphs, charts, and images can be used to identify patterns in data.

Cause and Effect

2B: Cause and effect relationships may be used to predict phenomena in natural or designed systems.

2C: Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Scale, Proportion, and Quantity

3A: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Systems and Systems Models

4A: Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.

Energy and Matter

5B: Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter

5D: The transfer of energy can be tracked as energy flows through a designed or natural system.

Stability and Change

7B: Small changes in one part of a system might cause large changes in another part

7C: Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

7D: Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms

CSTA K-12 Computer Science Standards

| | | | |
|----|-----------------------|------|---|
| CT | Modeling & simulation | 2-9 | Interact with content-specific models and simulations to support learning and research. |
| CT | Modeling & simulation | 2-11 | Analyze the degree to which a computer model accurately represents the real world. |
| CT | Modeling & simulation | 3A-8 | Use modeling and simulation to represent and understand phenomena. |

Student Activity #1 Guide: Carbon Footprint Calculator

Name:

Date:

Instructions:

- 1) Go to the Online Carbon Footprint Calculator on the EPA website (<http://www.epa.gov/climatechange/students/calc/index.html>)
- 2) Start the calculator and follow the instructions.

Record your choices into the table below.

| Action | YES | NO | Already Do This |
|--|-----|----|-----------------|
| Turn off water when you brush your teeth | | | |
| Turn off the lights when you are not in your room | | | |
| Ask your family to replace incandescent light bulbs | | | |
| Bike or walk to school instead of getting a ride | | | |
| Reduce car trips for activities outside of school | | | |
| Take the bus or other public transport instead of getting a ride to school | | | |
| Ask your family to help arrange a carpool with your friends for going to and from school | | | |
| Recycle Magazines | | | |
| Recycle Newspaper | | | |
| Recycle Glass | | | |
| Recycle Plastic | | | |
| Recycle Aluminum and Steel Cans | | | |
| Turn off the television when you aren't watching it. | | | |
| Turn off the video game systems when you aren't using them. | | | |
| Unplug chargers when not in use. | | | |
| Enable the sleep feature on your computer. | | | |

- 3) Record your results in below.

I am avoiding _____ pounds of carbon dioxide emissions per year, compared with the average American.

This is equivalent to the emissions from driving a car _____ miles.

If I take the additional actions I checked above, I will avoid another _____ pounds of carbon dioxide emissions per year.

This is equivalent to the emissions from driving a car _____ miles.

If all the students in the United States took the actions I checked, together we would save a total of _____ pounds of carbon dioxide emissions per year.

This is equivalent to the emissions from driving a car _____ miles.

This is equivalent to the annual emissions of _____ cars.

- 4) What was the most surprising thing that helped reduce carbon your footprint?

 - 5) What would be the hardest change to make? What would be the easiest change to make?

Introduction to Climate Modeling

[Excerpts from “Mathematics of Climate Change: A new discipline for an uncertain century” a publication of the Mathematical Sciences Research Institute. Berkeley, CA 2007.]

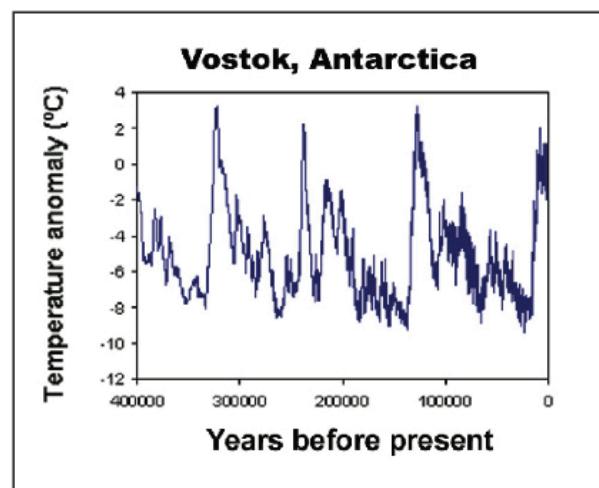
Background

In this document we will discuss climate change: what it means, what the difference is between climate and weather, and evidence of climate change. We will also discuss the global climate system as a complex system with feedback loops. Finally we will discuss the current state of the art in the computational modeling of climate change. Our goal is to clarify what is known, what scientists guess is happening, what our role is in driving current climate change and how climate change impacts our environment and species. This document draws from the best current research and thinking about climate change as described in the fourth report of the Intergovernmental Panel on Climate Change (IPCC) in 2007. In October of 2007, Al Gore and the IPCC shared the Nobel Peace Prize “for their efforts to build up and disseminate greater knowledge about man-made climate change and to lay the foundations for the measures that are needed to counteract such change.”

By definition, climate change is a “long-term shift in the statistics of the weather (including its averages).” It can be seen in changes in expected average values for temperature and precipitation (rainfall) for a given place and time of year, from one decade to the next.

An example of this change is seen in the plot of ice core data over the last 420,000 years. There is variability in the data showing that there has been large-scale climate change in the past.

We know that global climate change is occurring now as well. The period between 1990 and today has been the warmest period in the global temperature record. (This record of climate data has been collected since the mid 1800s.) The difference between past climate change and the climate change we are experiencing now is that according to the IPCC “it was very likely (meaning more than 90% likely) that most of the warming is anthropogenic or human-induced.”



Vostok, Antarctica
 Temperature changes in Antarctica determined from the deuterium proxy measured in the Vostok ice core record. (Reference: Petit, J.R., et al. 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* 399: 429-436.)
 Available at <http://www.ncdc.noaa.gov/paleo/abrupt/story2.html>

Weather vs. Climate

One key to climate modeling is understanding the difference between weather and climate. Weather is the experienced temperature and precipitation on a given day or for a few days. Weather models track changes in weather systems and lose accuracy after a few days. Climate, on the other hand, deals with change over decades or even 100 years into the future. Climate by definition is the statistics of the weather of an area over a long period of time.

The time scales used to think about weather and climate are vastly different:

Weather -> time scale of a day or a few days

Climate -> time scale of decades (10s of years) or more

Also, questions asked about weather and climate are very different:

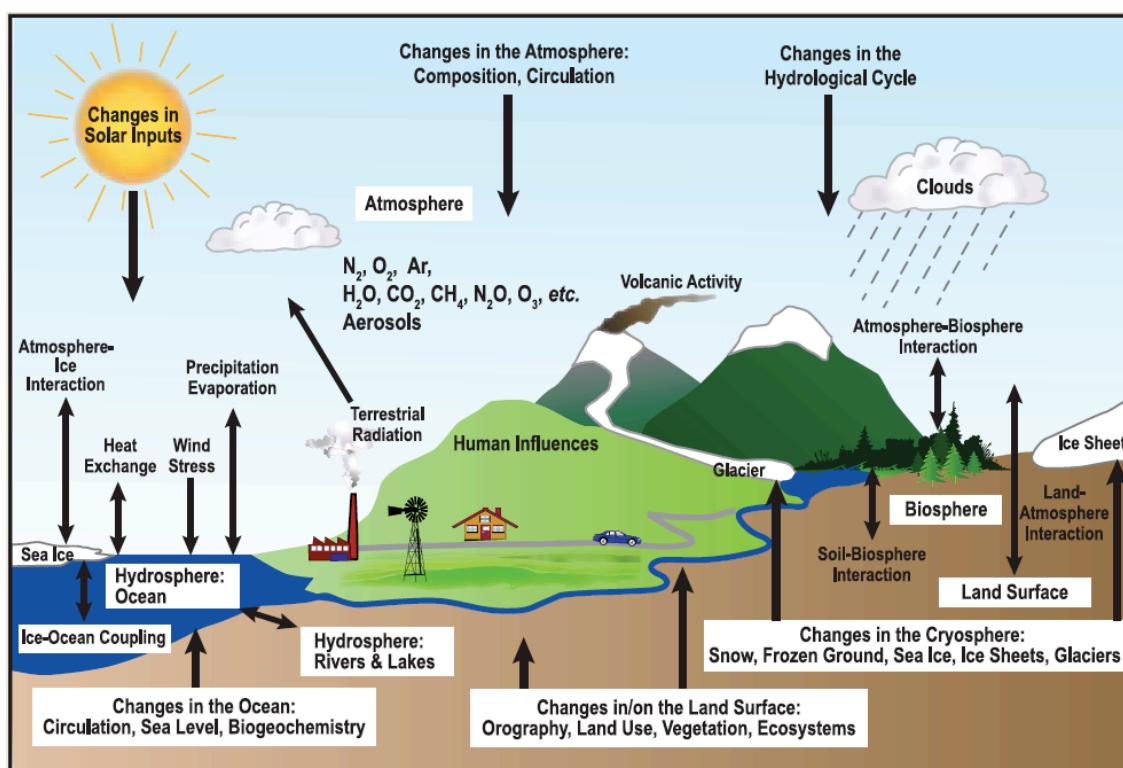
Weather -> "Will it rain tomorrow?" or "Do I need to wear boots?"

Climate -> "How will the climate system respond to a doubling of carbon dioxide?"

Weather forecasting seeks to answers how the weather of yesterday is going to change today whereas in Climate forecasting the predictions are about seeing what happens under different hypothetical scenarios. For example, a climate scientist might ask "how will the climate system respond given a change in the amount of energy from the Sun?"

Global climate system as a complex system

The global climate system is a system of highly interconnected parts that encompasses the atmosphere, the oceans, land masses and ice. The global climate system is also impacted by interaction between climate and human activities.



Some of the variety of changes and interactions in global climate models include changes in solar inputs (from the Sun); changes in the atmosphere such as air circulation; changes in the hydrological cycle (water cycle); changes in the oceans such as circulation patterns, sea level and salinity (salt content); changes in /on the land surface such as land use, vegetation and ecosystems; and changes in the cryosphere such as snow, ice sheets, sea ice and glaciers.

The diagram above illustrates some of the interacting processes and systems.

This global climate system can be seen as a complex system because it has many characteristics of a complex system:

- It is made up of many parts (some of these parts are systems themselves)
- The parts are highly interconnected or coupled
- There are interactions between the parts
- There are feedback loops*
- There are non-linearities* – precipitation processes such as evaporation and condensation are inherently non-linear.
- There are chaotic dynamics* – small changes in initial condition can lead to large difference in outcomes.
- There is distal causality – things that happen in one place can trigger events, occurrences or patterns that occur far away through a series of chain reactions.

* see appendix for definitions and examples.

Feedback loops in the Global Climate System

Feedback loops are an important feature of complex adaptive systems. Examples of feedback can be found in most complex systems in biology, physics, economics, social systems, and engineering. In some cases, the interaction of individual agents can create feedback loops that drive the emergence of patterns at the global scale.

Feedback is a circular process in which a system's output is returned or “fed back” into the system as input. There are two kinds of feedback: **reinforcing** (or positive) and **balancing** (or negative).

A feedback loop is a closed system that has feedback. Often, when talking about feedback in layman’s terms, we use the words “positive” and “negative” to describe how we feel about an outcome, or to describe whether or not a certain outcome is desirable or not. For example, people say “my boss gave me positive feedback on a new idea”. **This is not to be confused with the technical terms “positive feedback” and “negative feedback”.**

In the technical definition, **reinforcing or positive feedback** is feedback that amplifies or accelerates a change away from a starting point or equilibrium point whereas **balancing or negative feedback** is feedback that dampens, slows down or corrects a change in a system that is moving away from the starting point.

Here's one way to remember it:

In reinforcing (or positive) feedback loops
“More leads to more” OR “Less leads to less”

In balancing (or negative) feedback loops
“More leads to less” OR “Less leads to more”

An example of a feedback loop in the global climate system is the ocean-atmosphere carbon dioxide feedback loop. The ocean absorbs quite a lot of carbon dioxide, however, the more the earth warms up, the less CO₂ can be absorbed by the oceans. If less CO₂ is absorbed, more CO₂ accumulates in the atmosphere, causing even greater warming.

Can you diagram this feedback loop and visualize how it feeds back into itself? Would you classify this as an example of positive or negative feedback?

Climate Modeling

Climate scientists use models to study and predict climate change. Traditionally climate scientists have used mathematical models that incorporate physical processes. The main components of a climate model are atmosphere, the ocean, land, and ice.

The global climate system or some part of it is modeled as a system of non-linear mathematical equations to be solved by high performance computers.

The IPCC relies on 24 different climate models in its report. Because many of the models have different assumptions it is hard to connect them. For example, only some of the models include cloud formation and movement. Climate scientists use a variety of models and run them with a diverse set of parameters in order to capture the range of uncertainty in the global climate system. Most climate modelers agree that it is useful to have a variety of models to sample the space of different possibilities.

There are many uncertainties in these models. Climate models tend to agree on twenty-year projections but disagreement arises when projections are carried out over a long-term, say of 100 years. The differences in outcomes arise from uncertainties in feedback processes represented in the models. The differences in feedback processes used can amplify the direct effects, such as temperature increases, by two to three times.

Limitations of current climate models include:

1) Coarse grain, low resolution,

Even the highest resolution models run on the largest computers chop up the world into pieces that are 10 to 50 kilometers wide. They do not capture important details such as mountain ranges.

2) Cloud modeling

The effects of clouds have been added to existing IPCC models as an aggregate term (average cover by clouds) rather than incorporating individual cloud formation and movement.

3) Human activity

None of the IPCC models contain any humans but the changes in climate will cause changes in human behavior.

Computer science plays an important role in the study of climate change. To simulate the Earth's environment, a system of great complexity, will take high performance computing and new mathematical and computational tools.

Evidence of Climate Change

How do we know that Climate Change is happening? The basic scientific facts that lead us to the conclusion that climate change is happening, human activities are responsible for most of the change, and climate change is accelerating are:

- 1) Carbon dioxide levels and levels of other greenhouse gases have been rising for at least 50 years. See figure 1.1 to the right.

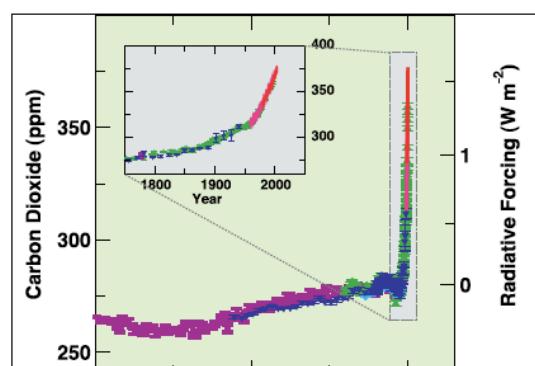
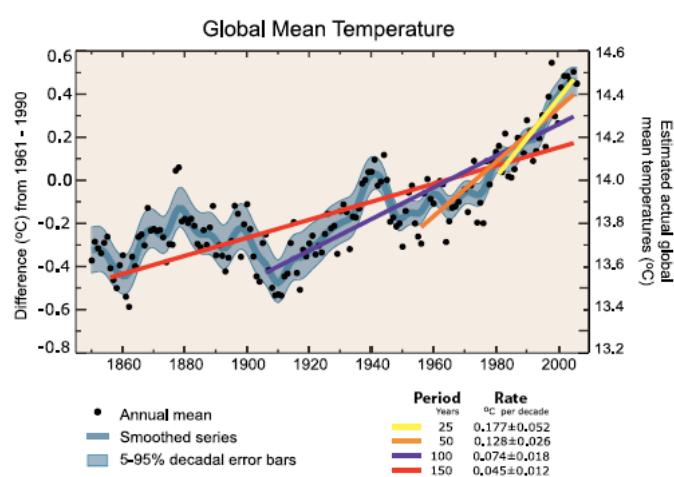
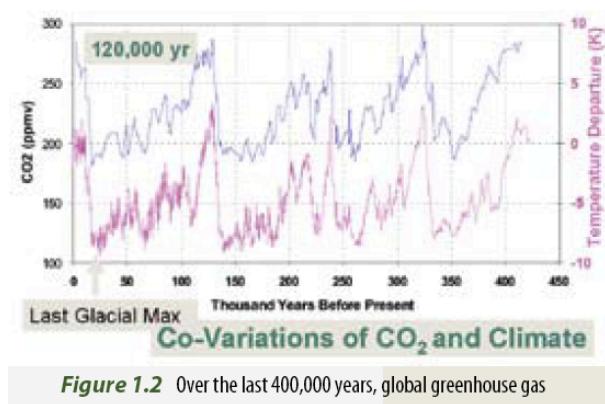


Figure 1.1 The concentration of carbon dioxide in the atmosphere over the last 10,000 years (main figure) and over the last 250 years (inset). Data from the last 50 years (pink and red) are based on direct measurement, and earlier concentrations are inferred from ice cores. At right, the concentrations are converted to an equivalent increase in solar radiation (using the year 1750 as a baseline).

Image from *Climate Change 2007: The Physical Science Basis*, Intergovernmental Panel on Climate Change.

- 2) Carbon from fossil fuels is being added to the atmosphere. We know this from tree-ring and ice-core data that show a lower ratio of the isotope carbon-13 to carbon-12 occurred at the same time the overall levels of carbon dioxide began to increase.
- 3) Evidence from ice cores show a very strong correlation between carbon dioxide levels and global temperatures (See figure 1.2). As carbon dioxide levels go up, the temperature goes up.
- 4) The greenhouse effect is not in dispute. An increase in greenhouse gases must lead to an increase in temperature.
- 5) The Earth's surface temperature has increased sharply in recent years. The warming effect is now too large to be explained as a statistical aberration.



The Greenhouse Effect

The physics behind the greenhouse effect are well-understood.

Human-induced change

Certain naturally occurring gases, such as carbon dioxide (CO₂) and water vapor (H₂O), trap heat in the atmosphere causing a greenhouse effect. Burning of fossil fuels, like oil, coal, and natural gas is adding CO₂ to the atmosphere. The current level is the highest in the past 650,000 years. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change concludes, "that most of the observed increase in the globally averaged temperature since the mid-20th century is very likely due to the observed increase in anthropogenic (of human origin) greenhouse gas concentrations."

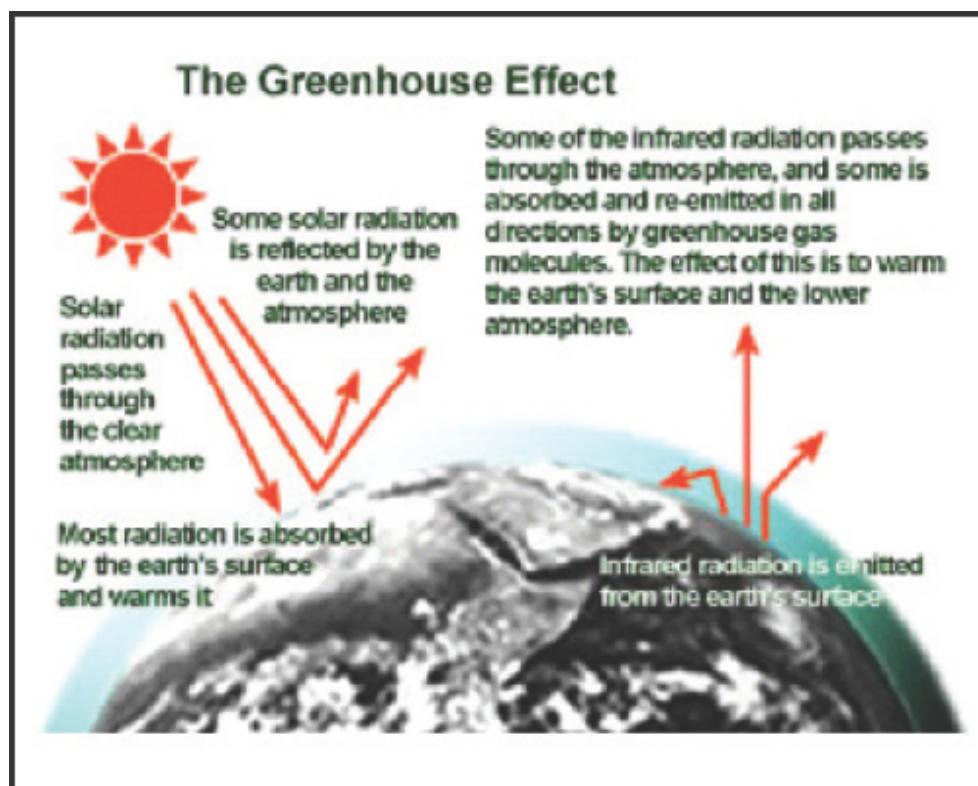
Impacts of Climate Change

Various impacts of climate change are projected. These include changes in surface temperature, precipitation and sea level changes. Depending on where these changes occur, different effects can be experienced.

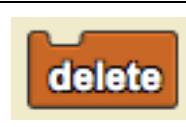
Some of the most disruptive effects of climate change are likely to involve precipitation such as severe storms, floods or droughts. Scientists predict increases in precipitation are very likely in polar regions while increases in droughts are likely in subtropical and tropical regions. Low-lying island nations will be threatened by rising sea levels. Extreme weather events, such as floods and hurricanes, are predicted to become more common.

Biological effects of climate change are already noticeable. Some plants are blooming earlier in the Spring. There have been shifts in the ranges of species and 20 – 30% of plant and animal species are likely to be at increased risk of extinction.

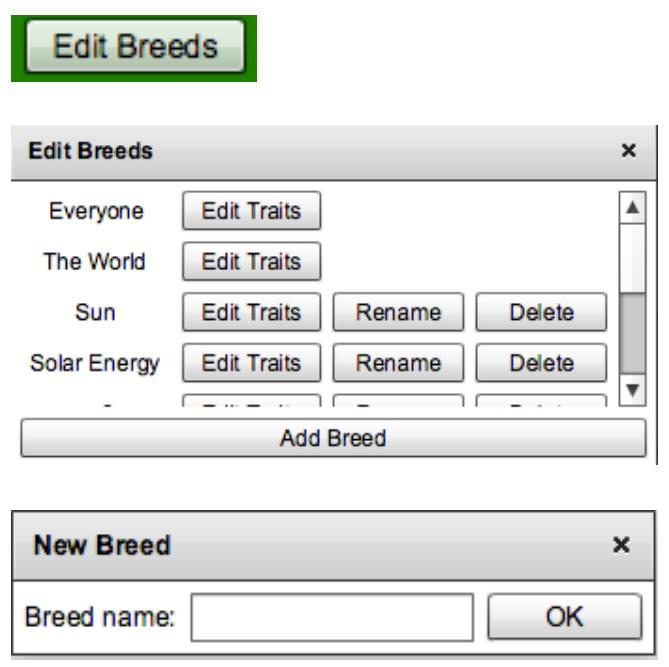
While a small amount of global warming (up to 3 degrees Centigrade) would be favorable for global food production, a greater than 3 degree Centigrade temperature increase would have a negative effect overall. In arid and tropical regions even a small increase in average temperature is expected to decrease crop productivity.



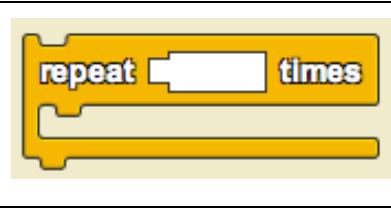
StarLogo Nova Blocks introduced in Module 2 Lesson 2

| | |
|---|---|
|  | <p>The delete block deletes the current agent.</p> |
|  | <p>"Horizontal Slider" – a slider to control the value of a variable.</p> |

StarLogo Nova Blocks introduced in Module 2 Lesson 3

| | |
|--|--|
|  | <p>Breeds are agents with specific characteristics. Adding a Breed will create a tab in the code window for that breed where you can give it traits and behaviors.</p> |
|--|--|

StarLogo Nova Blocks introduced in Module 2 Lesson 4

| | |
|---|---|
|  | <p>Repeat the procedure(s) a specified number of times.</p> |
|---|---|

2

Lesson 2

Use StarLogo Nova Greenhouse Gas Base Model

50 minutes (1 day)

Lesson Overview (New Learning and Exploration)

In this lesson, the students will USE the StarLogo Nova Greenhouse Gas model, change a variable to run an experiment, and add code for a slider. In the first activity, the students will learn how to use the model and how to change the variable related to albedo. In the second activity the students will be asked to inspect the code and identify code blocks they are familiar with. In this way they will learn to deconstruct a computer code into its building blocks. They will also be asked to identify new blocks of code, as well as “missing” code. In the third activity, students will add code to make an albedo slider, and then will run an experiment, using the slider. Finally, students will be asked to think of ways to improve the model from home, based on what they know about climate change, greenhouse gases and human emissions of CO₂.

Teaching Summary

Getting Started - 5 minutes

1. Review of the previous day's lesson and concepts. Connection to today's lesson.

Activity #1: Use the Greenhouse Gas base model and change a variable – 10 minutes

2. Run the Greenhouse Gas base model.
3. Discuss albedo.
4. Change the variable related to albedo. Run the model again to see the effect.

Activity #2: Inspect the code – 15 minutes

5. Ask students to identify familiar coding blocks.
6. Assign a part to decode to each pair of students.
7. Program loop and execution order – what calls what?

Activity #3: Add a slider for the albedo variable and run an experiment – 15 minutes

8. Add a slider for albedo.
9. Run an experiment using the albedo slider.
10. Discuss the results and relate them to climate change.

11. Discuss feedback loops.

Wrap Up – 5 minutes

12. Discuss limitations of the model and ask students to think of ways of improving it.

Lesson Objectives

The student will:

- ✓ Identify randomness in the model [LO1]
- ✓ Understand the concept of albedo and how it relates to climate [LO2]
- ✓ Learn about feedback loops in the global climate system [LO3]
- ✓ Decode a model [LO4]
- ✓ Learn to add a slider [LO5]
- ✓ Use the Greenhouse Gas base model to do science and conduct an experiment with repetition [LO6]
- ✓ Identify limitations of the model [LO7]
- ✓ Practice Pair Programming and Iterative design, implement, test cycle [LO8]
- ✓ Make observations (drawing simple correlations) [LO9]

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- Greenhouse Gas StarLogo Nova base model
- Model observation form [student handout]
- USING a Computer Model to do Science document [student handout]
- Experimental Design form document [student handout]
- New commands and concepts sheet [student handout]

For the Teacher

- Computer and projector
- Greenhouse Gas StarLogo Nova models: base model, base model plus albedo slider.
- Climate Change background document [for reference]
- Guided Introduction to StarLogo Nova document [for reference]
- StarLogo Nova Blocks CS Concepts guide document [for reference]
- StarLogo Nova Blocks Reference Guide [for reference]
- Slide presentation with simple base commands

Getting Started – 5 mins

1. Review of the previous day's lessons and concepts

- What do you remember from the video? What are Greenhouse Gases and how are we adding to them? [Refer to Lesson 1.] (DCI: Global Climate Change) (DCI: Human Impacts on Earth Systems)
- What do you remember from the Carbon Footprint Activity? What are good ways to reduce our carbon footprint? [Refer to Lesson 1.] (Practice: Engaging in Argument from

Evidence)

- What do you remember from the Greenhouse Gas model? What elements were modeled in it? [Have the students open the Greenhouse Gas model in pairs and identify elements, refer to Lesson 1.] **(Practice: Developing and using models)**

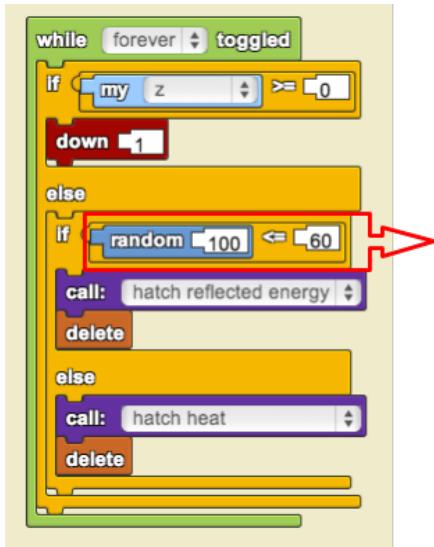
Activity #1: Use the Greenhouse Gas base model and change a variable - 10 mins

In this activity, the students will use the Greenhouse Gas base model in pairs. They will identify the agents and the environment in the model and track the different agents to identify the behavior of these. Students should pay particular attention to what happens when solar radiation reaches the “Earth.” 60% of the time, the radiation is simply reflected back to space, but 40% of the time a “heat” is generated, causing the temperature to increase. Students should reflect on this probability and learn that it is called **albedo** and is variable across the Earth, depending on the surface type. Students should go into the code and change the variable and start the model again. **(Practice: Developing and using models)**

2. Run the Greenhouse Gas base model

- Make the model run by clearing the graph, setting the view (using Alt-drag), and clicking setup, then forever. Call back the graph and see the trend. Click forever again to stop the simulation.
- Ask the students, what happens to the solar energy when it hits the ground? Some of the time, the solar energy turns into reflected energy and heads out into space (yellow). Other times it shows up as infra-red radiation (red, “heat”). The temperature of the Earth is determined by how many “heats” there are floating around. **(CCC: Energy and Matter)**

3. Discuss Albedo



- Ask the students, what do you think would happen if more solar energy were reflected instead of turning into heat? **(Practice 1: Asking questions and defining problems)**
- Navigate down to the code, and find the Solar Energy tab. Discuss the meaning of the code relating to Solar Energy in the Forever block.
 There are three blocks of code. The one on the left describes how solar energy moves when the forever button is toggled. There is an if/else code block with another if/else code block nested within it. The solar energy will go down 1 step at a time, until reaching the ground ($z=0$). When it touches the ground, a random 60 out of 100 times the solar energy will be reflected (a “reflected energy” breed will be created). The rest of the time infra-red radiation will be created (the “heat” breed). This represents the average **albedo** (reflectivity) of the Earth: 60% of solar radiation is sent back into space, and the rest is absorbed and then later emitted as heat.

- Ask the students, do you think there are some surfaces that reflect more solar energy than others? Think about the colors of cars - which cars get warmer?
Lighter colored surfaces reflect more heat than darker colored surfaces. Ice and snow are much lighter than other Earth surfaces and they reflect more solar energy.(Practice 6: Constructing explanations and designing solutions) (Practice 1: Asking questions and defining problems)

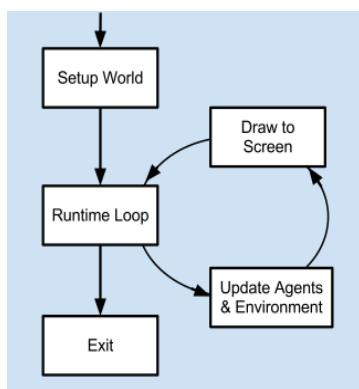
4. Change the variable related to albedo. Run the model again to see the effect.

- Change the value of "60" to another number.
- Save the code and run the model again.
- Ask the students, did you notice any difference in the model?

A value higher than 60 would cause more solar radiation to reflect and the overall temperature would be lower. A value lower than 60 would cause more solar radiation to be absorbed and converted to infra-red radiation, and the overall temperature would be higher.(Practice 4: Analyzing and interpreting data)

Activity #2: Inspect the code - 15 mins

[Excerpt from Guided Tutorial] There are three major abstractions in any agent-based model: agents with rules that they follow, the environment in which they coexist, and time. In StarLogo Nova, the first two are easy to see – the agents are the different turtles and the environment is Spaceland.



Time is harder to see; instead it can be thought of as a series of time slices or “clock ticks.” At each tick, all of the agents have a chance to update their position or state.

Ticks or time slices are not the same as seconds because it may take more or less than one second to update all of the agents. In StarLogo Nova, the time model is built into the forever buttons and the collision blocks; each time through the “run loop,” every agent gets updated.

Whenever we start looking at a new model we should ask how these three elements of a model have been implemented. A simple way to begin to understand a model is to ask, “Who are the agents?”, “How do they behave?”, “What is the environment they live in?”, and “What happens each time through the run loop?”

Here's an example of a model observation form:

Model observation form

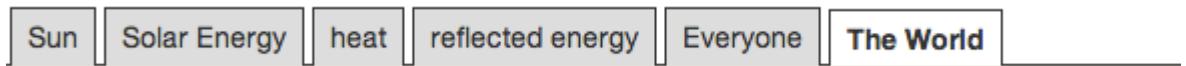
Name(s): _____ Date: _____

Model name: _____ Greenhouse
Gases _____

| |
|--|
| Abstractions |
| <i>Who are the Agents? What is the Environment? What are the Interactions? What do ticks represent?</i> |
| The agents are the Sun, solar radiation, reflected energy and heat. The environment is the Earth's surface and air. The sun emits solar radiation. The solar radiation bounces back as reflected energy 60% of the time. 40% of the time the solar radiation becomes heat. |
| Automation |
| <i>What happens each time through the forever (or main) loop?</i> |
| The sun emits solar radiation, which is reflected or converted to heat. |
| Assumption(s) |
| <i>What are the assumptions made in this model?</i> |
| One assumption is that the solar radiation is reflected 60% of the time. I don't think that's right. Sunlight doesn't reflect the same way on every surface, does it? |
| Analysis |
| <i>What patterns did you observe? Do these patterns occur in real-life?</i> |
| Temperature increases until it reaches a point where it starts going up and down repeatedly. That makes sense; we have seasons with temperatures going up and down! |

5. Review familiar and new command blocks.

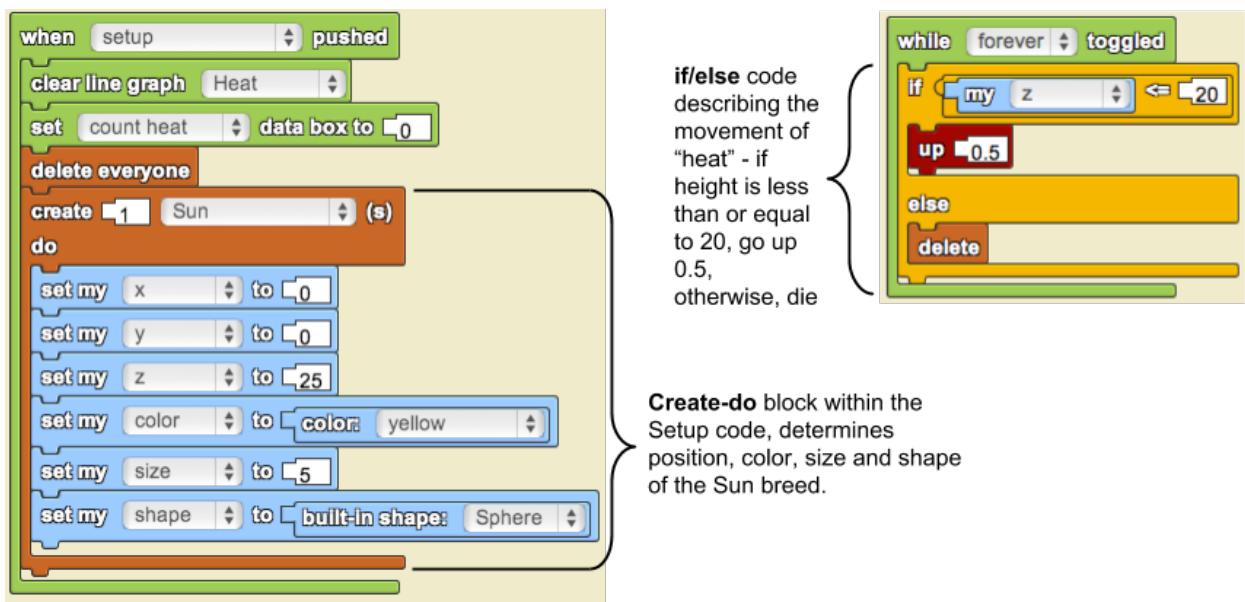
- Keep track of familiar command blocks. Students can refer to their StarLogo Nova Command Blocks and CS Concepts reference sheets from Module 1.
- Review what the new command blocks do [New commands and concepts sheet].
- As a group, look at the different sections of code for the Greenhouse Gas model.



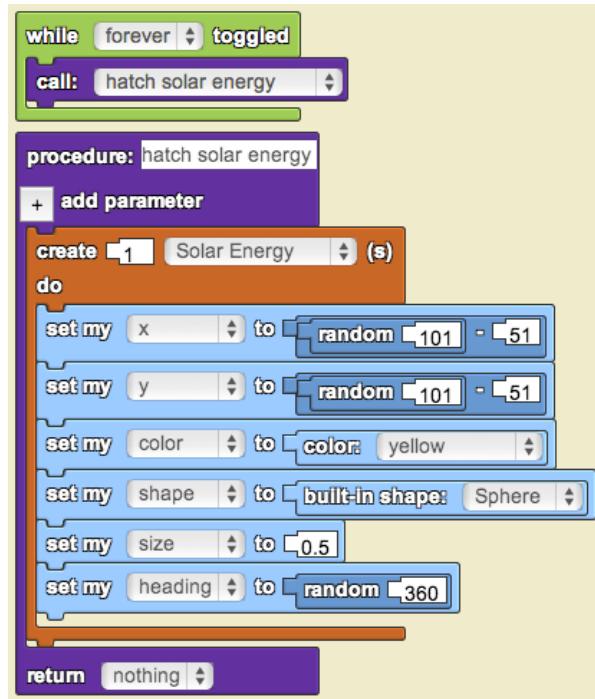
Ask the students to match parts of the model with the tab names. Open up “The World” and indicate that this is where the setup code lives.

6. Assign a part to decode to each pair of students.

- Assign partners to share a computer.
- Assign each pair a piece of the model to decode: Sun, Solar Energy, Heat, Reflected Energy or The World. The detailed description of what an agent's procedures are can be added to the model observation form.
- Give the students 5 minutes to decode then ask students to share out.



- **Procedures:** these are “called” in other coding blocks. If a procedure is placed in the “Everyone” tab, then any breed can call it.



In the example on the left, in the Sun tab, the Sun creates an agent of the Solar Energy breed, and the code to create the Solar Energy is contained in a procedure which is “called” from the Forever block.

By doing this, we could re-use this procedure many times. In this case the procedure is only available for the Sun.

If we placed this procedure in the Everyone tab, all breeds could call it and create solar energy.

- **Line graph:** there are various parts of the code relating to creating the Heat line graph, within the Setup tab. In the “when setup is pushed” block, there is a command to “clear line graph” which is as important as “delete everyone” when you want to clear the world and start a new run. Before coding a line graph, however, you need to add a line graph widget in the “add widget” section of Spaceland. Then you add the code block “Add data to line graph” and select the graph name from the drop-down. Usually, the x-axis will be set to the clock, and the y-axis can be set to a count of whatever you want to measure.



- **Data box:** a data box can show different data (for example a count of how many individuals of one breed there are) and can also serve as an input box. In this model we have a data box to show the current heat count, or temperature in degrees Celsius. To code a data box, first you have to add the widget, and then put the code into the setup and forever blocks of the world.

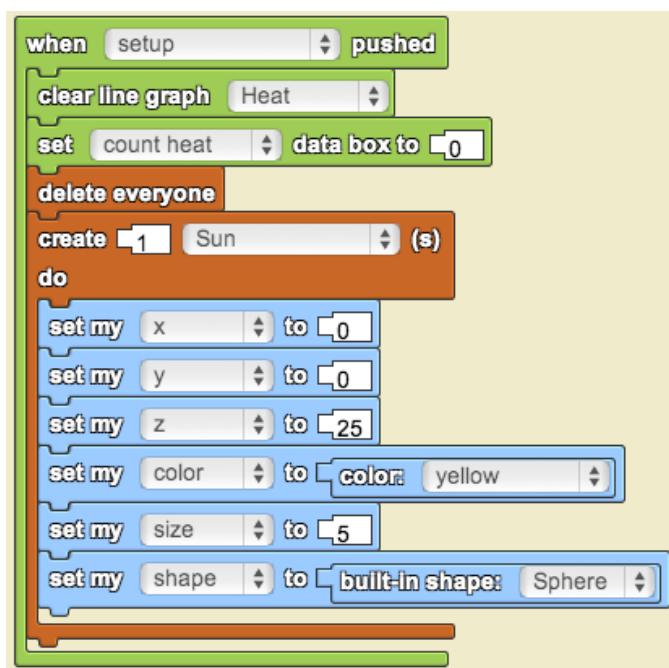


- **Delete:** When one breed creates another breed, as for example Solar Energy creating Reflected Energy, sometimes we want the original breed individual to disappear from the code, or die. We use the Delete block for this, after the create-do block for the new breed.

7. Program loop and execution order – what calls what?

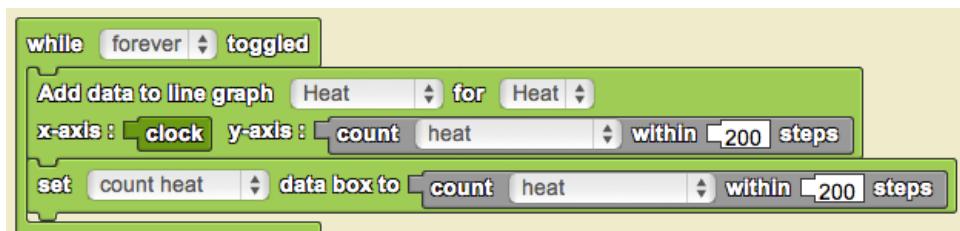
- Demonstrate how to trace execution of the program starting with the Setup button.
- As a group, trace execution of the program starting with Run button.

Clicking the **setup** button in Spaceland causes the execution of this procedure in the World:

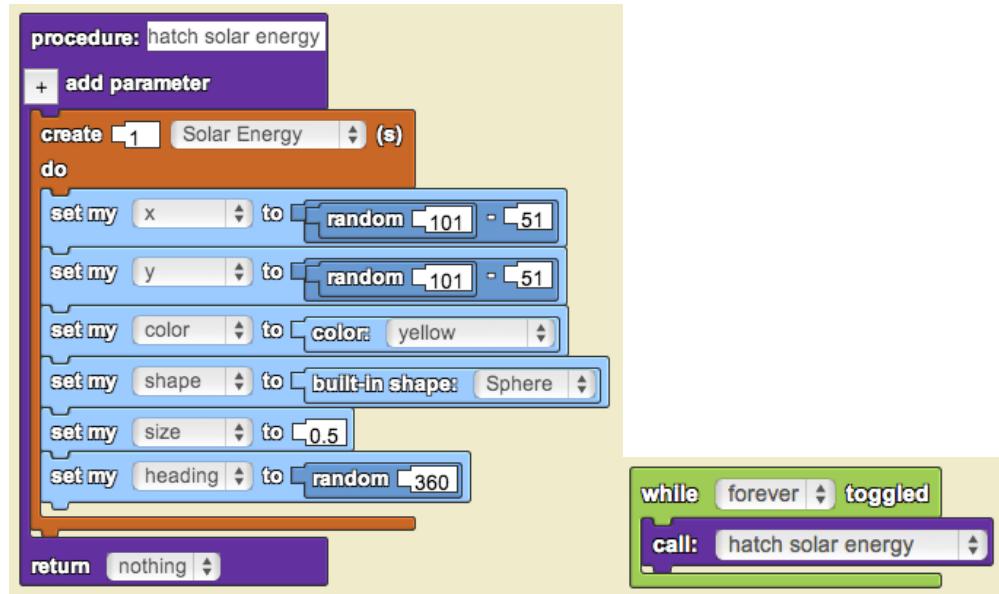


First everyone gets deleted and the data box and line graph get cleared. One sun is created with its shape set to Sphere, size set to 5, color set to yellow, and position set to the center of the world with a height of 25. Toggling the **forever** button to its “ON” state in Spaceland causes the execution of the following procedures.

World



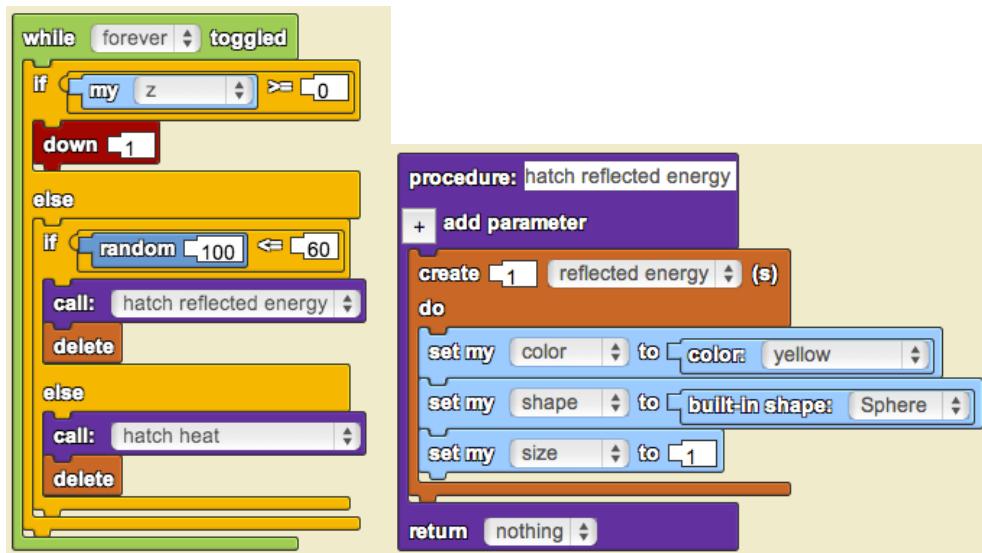
Data is added to a line graph and a data box to show the number of **heat** breeds (a proxy for temperature).

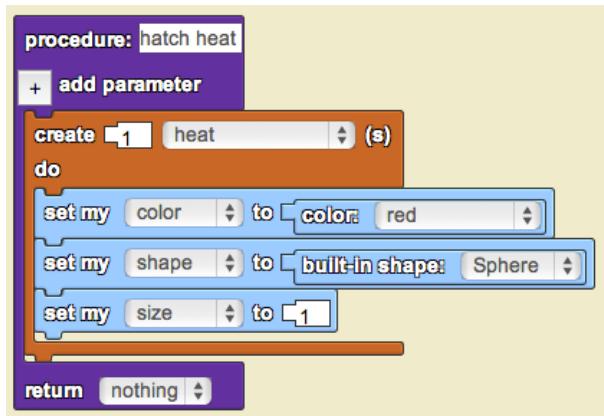
Sun

The Sun starts creating solar energy when the forever button is toggled. This solar energy has the properties outlined in the procedure above.

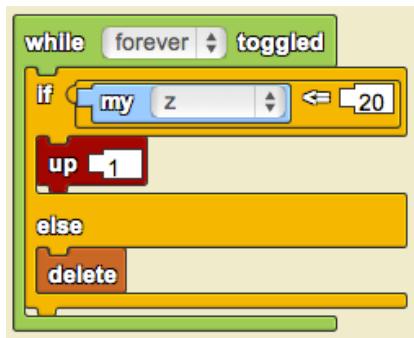
Solar Energy

Two procedures are called for Solar Energy, if the Solar Energy reaches the “ground”: hatch reflected energy (60% of the time) and hatch heat (40% of the time). This is the albedo which we covered earlier.





Heat and Reflected Energy



Both the Heat and the Reflected Energy breeds have the same behavior when forever is toggled. They rise up and once they reach a height of 20, they disappear (they are deleted). In the real world most things happen in *parallel*. That is, all the people move at once. But in the computer we can only move one agent at a time. How does StarLogo Nova make it look like all of the agents are moving at once? [Notes for the teacher: In StarLogo Nova, we simulate parallelism; when each tick starts we give all of the agents a chance to move (each takes a turn) and then say that this tick is now over. Many moves took place one at a time but we say they took place together in one slice of time or tick. We call this method of advancing time “discrete time steps.” In this system of time there is one clock that all of the agents share. The clock has a series of “ticks.” During each tick every agent is given a chance to move once. When all agents have been given a turn, the clock is moved forward another “tick” and the whole cycle is repeated.] (Practice 1: Asking questions and defining problems) (Practice 2: Developing and using models) (CCC: Systems and systems models)

Teaching Tip *The program execution loop can be diagrammed on the board to give visual clues as to what is happening as time advances in the simulation.*

Teaching Tip *The program execution loop can be acted out with a “clock.” At each tick, have each student take a turn, before the clock advances. When the clock advances, take a snapshot of the agents’ positions at that time. Then flip through the snapshots to see what the computer shows us (discrete time slices).*

Activity #3: Add a slider for the albedo variable and run an experiment

- 15 mins

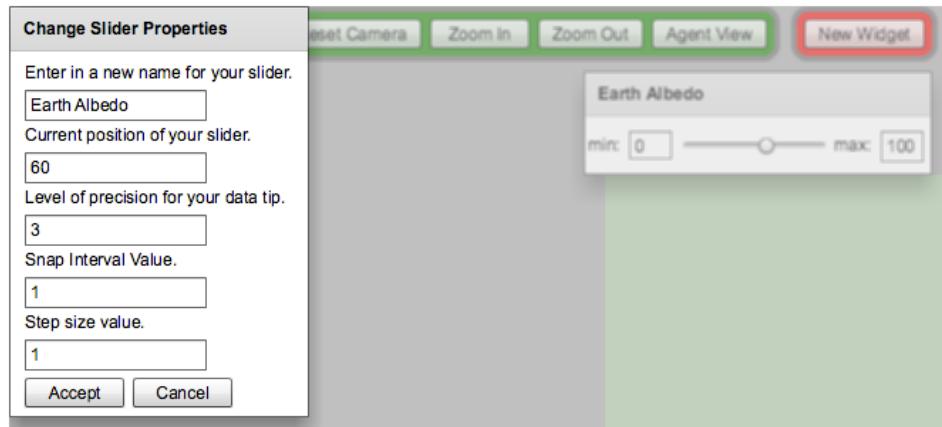
In this activity students will run an experiment using the model, but first they will add a slider to the model to allow them to run the experiment more effectively. They should propose questions about the effect of albedo on the climate system as modeled here, and they should reflect on the real-world implications of their discoveries. Direct instruction from the teacher about feedback loops, in particular the ice-albedo feedback loop, will support this. See Climate Change Background document and this Lesson Plan for more information. ([Practice 1: Asking questions and defining problems](#)) ([Practice 2: Developing and using models](#)) ([CCC: Patterns](#))

8. Add a slider for albedo.

- Have the students remix the model and rename it by adding “mod 1.”
- Go back to the part of the code that controls albedo.
- Ask the students if they can think of a way of changing the albedo without going to the code.
- Introduce the **slider** widget.

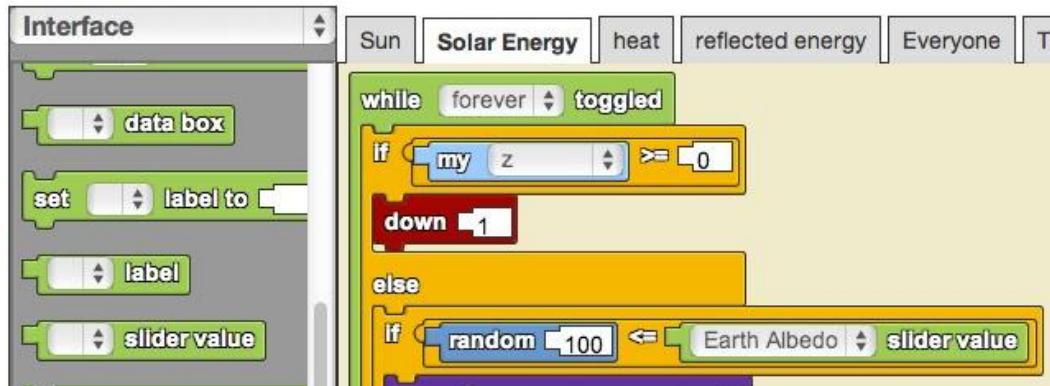
Click edit widgets in Spaceland. Add a widget in Spaceland - slider - and give it a name. Ask the students if they could use this for changing the albedo WHILE running the model, WITHOUT going to the code.

Change the maximum and minimum and step size for the albedo (double click on the slider). Click edit widgets again to get out of the widget page.



- Ask the students to run the code.
Does it work? Why not? Check the code for the albedo variable. It's still the same. We need to change the code here too, not just by adding a widget.

- Find the slider block and add it to the code. Give it the correct name (of the widget we already added).



- Save and run the code again. Change the albedo on the slider. Has anything happened?

9. Run an experiment using the albedo slider.

- Now that it's easy to change the albedo we can run an experiment! We can observe the system from the global perspective to see the relationship between albedo and the world's temperature, and use the instrumentation in the model to gain a quantitative understanding of global climate dynamics. (CCC: Scale, proportion, and quantity)
- Experimental Design
Asking scientific questions.
Use the “Experimental Design” form as a guide and guide students as they develop a scientific question in pairs. Emphasize the need to use trials and to clearly identify the variables, as well as the difference between a question and a *testable* question.

The next page shows an example of how the form can be filled out.

Experimental Design form

Name(s): _____ Date: _____

Model name: _____

| |
|---|
| Question |
| <i>What is your question?</i> Does changing the albedo change the temperature? |
| Variables |
| <i>What are the dependent and independent variables in your experiment?</i> The dependent variable is the amount of solar radiation coming from the sun, the independent variables are time and the albedo. |
| Range |
| <i>What is the range of values you will use for each variable?</i> Time will run from 0 to 500 ticks. The albedo will be either 60, 10 or 90. |
| Trials |
| <i>How many trials will you run at each setting? Why?</i> We will run 5 trials at each setting: 5 at 60, 5 at 10 and 5 at 90. We run it more than once to make sure the results are repeatable and not a result of randomness. |
| Data Collection |
| <i>What data will you collect?</i> We will collect temperature data. We will collect the temperature of each trial at each setting after each run. |
| Data Analysis |
| <i>How will you analyze your data?</i> We will put it in a table. We will get the average for each setting across the 5 trials. We will compare the three averages and see if the final temperatures were different. |
| Interpretation |
| <i>How does the analysis of your data help you answer your question?</i> If the temperature is higher or lower with different albedos then we can say the albedo affected the temperature. |
| Prediction |
| <i>What is your prediction? Why?</i> I predict that when the albedo is higher, more solar radiation will become reflected energy instead of heat and so the temperature will be lower. |

- Run your experiment in pairs so the question can be answered. Which variable will you be changing? What range? How many trials at each setting? This information should be written into their template documents before beginning.
- Collecting and analyzing data. Using the instrumentation in the model (the graph and the data boxes) to monitor temperature under the different scenarios you are testing. Record the data. Look for patterns in your data [draw a graph and/or make a table, record

observations]. ([\(CCC: Patterns\)](#)

10. Discuss the results and relate them to climate change.

- Share out your experimental results.
- Did the experiment work as you expected?
- What do you think will happen if the ice caps melt? ([\(Practice 1: Asking questions and defining problems\)](#)

11. Discuss feedback loops.

- Talk about feedback loops in complex adaptive systems.

Feedback loops are an important feature of complex adaptive systems. Examples of feedback can be found in most complex systems. In most cases, the interaction of individual agents can create feedback loops that drive the emergence of patterns at the global scale. ([\(Practice 2: Developing and using models\)](#) ([\(Practice 4: Analyzing and interpreting data\)](#) ([\(DCI: Weather and Climate\)](#)

A feedback loop is a closed system that has feedback. There are two kinds of feedback: reinforcing (or positive) and balancing (or negative). In the technical definition, reinforcing or positive feedback is feedback that amplifies or accelerates a change away from a starting point or equilibrium point whereas balancing or negative feedback is feedback that dampens, slows down or corrects a change in a system that is moving away from the starting point.

One way to remember it is:

In reinforcing or positive feedback loops, MORE leads to MORE or LESS leads to LESS.

In balancing or negative feedback loops, MORE leads to LESS or LESS leads to MORE.

- Feedback loops in the Global Climate System.

There are many feedback loops in the global climate system, and some are not very well known yet. One example of a positive feedback is the ocean-atmosphere carbon dioxide feedback loop. The ocean absorbs quite a lot of carbon dioxide, however, the more the earth warms up, the less CO₂ can be absorbed by the oceans. If less CO₂ is absorbed, more CO₂ accumulates in the atmosphere, causing even greater warming. Another example is the release of methane from ocean and frozen soil deposits (like permafrost). The most commonly used example of a positive feedback is the increase of water vapor in the atmosphere with increasing temperatures. Water vapor is also a greenhouse gas.

The ice albedo feedback loop describes the effect that melting ice caps and glaciers will have on climate change. As the temperature rises, ice will melt, and there will be fewer white, reflective surfaces on the planet, decreasing the planet's albedo and causing it to absorb more solar radiation, which will heat the planet up even more.

Wrap Up - 5 mins

12. Discuss limitations of the model and ask students to think of ways of improving it as homework.

- What's missing from this Greenhouse Gas model? Greenhouse gases! (Practice 2: Developing and using models)
- Do humans produce greenhouse gases?
Refer back to lesson 1 and the carbon footprint activity. (DCI: Global Climate Change)
- How can we add CO₂ to our model? (Practice 1: Asking questions and defining problems) Discuss adding a building that emits CO₂ to the model. Discuss how CO₂ traps heat as a Greenhouse Gas. [Note: a factory that emits CO₂ is one possible modification that is quite simple, as it does not move.]

Assessment Questions

- Where do we see randomness in the model? [LO1]
- What is the major variable in this model? [LO4]
- What experiment did you run in the model? [LO6]
- Describe your experimental results and conclusions. [LO9]
- What limitations does this model have? [LO7]
- Name three blocks of code you recognized and what they are used for. [LO4]
- What is the slider used for? [LO5]
- List the steps necessary for adding a slider to control a variable. [LO5]
- Give one example of a feedback loop in the global climate system. [LO3]
- Give one example of a human action that could increase or decrease the Earth's albedo. [LO2]

Standards Addressed

NGSS Performance Expectations

Earth and Human Activity

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

NRC Disciplinary Core Ideas

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.

Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

ESS3.D. Global Climate Change

Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

NRC Scientific and Engineering Practices

Practice 1. Asking questions and defining problems

- 1A: Ask questions that arise from careful observation of phenomena, models, or unexpected
- 1B: Ask questions to identify and clarify evidence of an argument.
- 1C: Ask questions to determine relationships between independent and dependent variables and relationships in models.
- 1D: Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.
- 1F: Ask questions that can be investigated within the scope of the classroom, outdoor environment, and based on observations and scientific principles.

Practice 2. Developing and using models

- 2A: Evaluate limitations of a model for a proposed object or tool.
- 2B: Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed.
- 2C: Use and/or develop a model of simple systems with uncertain and less predictable factors.
- 2D: Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.
- 2E: Develop and/or use a model to predict and/or describe phenomena.
- 2G: Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Practice 3. Planning and carrying out investigations

- 3A: Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- 3B: Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
- 3D: Collect data to produce data to serve as the basis for evidence to answer scientific questions or test.

Practice 4. Analyzing and interpreting data

- 4A: Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
- 4B: Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
- 4D: Analyze and interpret data to provide evidence for phenomena.
- 4F: Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).
- 4G: Analyze and interpret data to determine similarities and differences in findings.

Practice 5. Using Mathematics and Computational Thinking

- 5D: Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.

Practice 6. Constructing explanations and designing solutions

- 6A: Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
- 6B: Construct an explanation using models or representations.
- 6E: Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.
- 6F: Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.

Practice 7. Engaging in argument from evidence

- 7C: Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

Practice 8. Obtaining, evaluating and communicating information

- 8E: Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.

NRC Crosscutting Concepts

Patterns

- 1C: Patterns can be used to identify cause and effect relationships.
 1D: Graphs, charts, and images can be used to identify patterns in data.

Cause and Effect

- 2B: Cause and effect relationships may be used to predict phenomena in natural or designed systems.
 2C: Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability

Scale, proportion and quantity

- 3A: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Systems and Systems models

- 4A: Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.
 4B: Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
 4C: Models are limited in that they only represent certain aspects of the system under study.

Energy and Matter

- 5C: Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).
 5D: The transfer of energy can be tracked as energy flows through a designed or natural system.

Stability and Change

- 7C: Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

CSTA K-12 Computer Science Standards

| | | | |
|-----|-----------------------------|-------|---|
| CT | Abstraction | 2-12 | Use abstraction to decompose a problem into sub problems. |
| CT | Abstraction | 3A-9 | Discuss the value of abstraction to manage problem complexity. |
| CT | Connections to other fields | 2-15 | Provide examples of interdisciplinary applications of computational thinking. |
| CT | Data representation | 2-8 | Use visual representation of problem state, structure and data. |
| CT | Data representation | 3A-12 | Describe how mathematical and statistical functions, sets, and logic are used in computation. |
| CT | Modeling & simulation | 1:6-4 | Describe how a simulation can be used to solve a problem. |
| CT | Modeling & simulation | 2-9 | Interact with content-specific models and simulations to support learning and research. |
| CT | Modeling & simulation | 2-11 | Analyze the degree to which a computer model accurately represents the real world. |
| CT | Modeling & simulation | 3A-8 | Use modeling and simulation to represent and understand natural phenomena. |
| CT | Modeling & simulation | 3B-8 | Use models and simulation to help formulate, refine, and test scientific hypotheses. |
| CT | Modeling & simulation | 3B-9 | Analyze data and identify patterns through modeling and simulation. |
| CPP | Data collection & analysis | 2-9 | Collect and analyze data that are output from multiple runs of a computer program. |
| CPP | Data collection & analysis | 3B-7 | Use data analysis to enhance understanding of complex natural and human systems. |
| CPP | Data collection & analysis | 3B-8 | Deploy various data collection techniques for different types of problems. |
| CPP | Programming | 3A-3 | Use various debugging and testing methods to ensure program correctness. |

Student Activity #1 Guide: Use the Greenhouse Gas base model and change a variable

Change a variable

You previewed this model in Lesson 1 – Now you get to **use it!**

- 1) Make sure you know who your programming partner is. You will be taking turns **driving** and **navigating**.

The **driver** should be in charge of the computer, while the **navigator** should tell the driver what to do.

- 2) Navigate to the StarLogo Nova Greenhouse Gas base model and open it.
- 3) **REMIX** it and change the name to: “Greenhouse Gas Base **NAME 1 NAME 2**” where Name 1 and Name 2 are you and your partner’s names. Then, hit **setup** and then **forever** to see the model working. Hit **forever** again to stop it.
- 4) In your own words, what is the **albedo**?
- 5) Where is the albedo in the base model’s code?
- 6) Change the albedo variable in the code. Hit **save**. Write down what the original albedo was and what you changed it to.
- 7) Run the model again. Has anything changed? Record your observations. If you can’t remember what the model looked like before change the albedo back to the first amount again to compare. Record what the temperature was for both versions of the model when you stopped it.

Here are a few tips:

- You can add your programming partner as a **collaborator** to the model so that you can both work on it together.

When you are done, upload and share your project.
Don’t forget to put both partners names in the project title.

Student Activity #2 Guide: Inspect the code

Going under the Hood

Now we are going to get to know the code that makes up the base model!

- 1) Open your saved StarLogo Nova Greenhouse Gas base model.
- 2) Navigate to the code section.
- 3) Use the **model observation form** as you and your programming partner take turns looking at the code (remember to use your **driver** and **navigator** roles and switch roles from time to time). Complete the form by running the model and looking at the code.
- 4) Which part of the code have you and your partner been assigned?
- 5) Write down what the code in your assigned section does.
- 6) Diagram the program's execution loop.

Here are a few tips:

- You can refer to your StarLogo Nova Command Blocks and CS Concepts reference sheets from Module 1

Model observation form

Name(s): _____ Date: _____

Model name: _____

Abstractions

*Who are the Agents? What is the Environment? What are the Interactions?
What do ticks represent?*

What are the variables of interest?

Automation

What happens each time through the forever (or main) loop?

Assumption(s)

What are the assumptions made in this model?

Analysis

What patterns did you observe? Do these patterns occur in real-life?

Student Activity #3 Guide: Add a slider for Albedo

Adding a Slider

In Activity 2 you edited the code to change the albedo. In this activity you will learn a better way to change the albedo.

- 1) **REMIX** your model and edit the name to “Greenhouse Gas Base **your name your partner’s name mod1**”
- 2) Add a slider for the albedo and all necessary code.
- 3) Write down the slider settings you set.

- 4) Run an experiment using the albedo slider. Use the **Experimental Design Form** to design your experiment first.

- 5) Record the data from your experiment and summarize your results.

- 6) What do you think will happen if the ice caps melt?

Here are a few tips:

- You can write up your results on a separate piece of paper. You can use graphs and/or tables to help you.

When you are done, upload and share your project.

Experimental Design form

Name(s): _____ Date: _____

Model name: _____

Question

What is your question?

Variables

What are the dependent and independent variables in your experiment?

Range

What is the range of values you will use for each variable?

Trials

How many trials will you run at each setting? Why?

Data Collection

What data will you collect?

Data Analysis

How will you analyze your data?

Interpretation

What is the answer to your question?

Interpretation

How does the analysis of your data help you answer your question?

Scientific Practices with Computer Modeling & Simulation

Name:

Date:

The table below lists scientific practices. Please provide an example of what you did that matches the practice.

| Practices: | |
|---|--|
| Asking questions and defining problems | |
| Develop and use a model | |
| Plan and carry out an investigation | |
| Analyze and interpret data | |
| Use mathematics and computational thinking | |
| Construct explanations and design solutions | |
| Engage in argument from evidence | |
| Obtain, evaluate, and communicate information | |

2

Lesson 3

Adding CO₂

50 minutes (1 day)

Lesson Overview (New Learning and Exploration)

In this lesson, the students will modify the Greenhouse Gas base model by adding a factory that emits CO₂ to answer the question, “Does adding CO₂ affect the temperature?” In the first activity, the students will add a factory that emits CO₂ to the model and work together to create the necessary code to implement it. In the second activity, students will use the new model as an experimental test bed, creating a hypothesis, running an experiment and analyzing the results to see what effect the modification had on the model.

Teaching Summary

Getting Started – 5 minutes

1. Review of the previous day's lesson and concepts and connection to today's lesson.

Activity #1: Add CO₂ – 20 minutes

2. CS review: code and concepts useful for the modification.
3. Discuss human greenhouse gas emission sources.
4. Identify the essential aspects of the modification to include in the model and code them.
5. Testing your model.

Activity #2: Run an experiment to see the effect of the modification – 20 minutes

6. Designing your experiment.
7. Running your experiments.
8. Collecting and analyzing data.

Wrap Up – 5 minutes

9. In the real world, what is the source of most of the CO₂ that we as individuals emit?
10. How can computer models be helpful in understanding climate change?

Lesson Objectives

The student will:

- ✓ Modify a computer model by adding breeds and setting user-defined traits [LO1]
- ✓ Learn CS concepts of user-defined traits and subclasses or breeds [LO2]
- ✓ Learn to abstract: find the essential aspects of the modification to include in the model [LO3]
- ✓ Practice Pair Programming and Iterative design, implement, test cycle [LO4]
- ✓ Run a climate change investigation using the greenhouse gas model [LO5]
- ✓ Collect and analyze data to look for patterns [LO6]
- ✓ Understand the impact of increased CO₂ on global temperature [LO7]

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- Greenhouse Gas StarLogo Nova base model
- Experimental Design form document [student handout]
- New commands and concepts sheet [student handout]
- Model design form document [student handout]

For the Teacher

- Computer and projector
- Greenhouse Gas StarLogo Nova models: base model, base model plus albedo slider, base model plus factory
- Climate Change background document [for reference]
- Guided Introduction to StarLogo Nova document [for reference]
- StarLogo Nova Blocks CS Concepts guide document [for reference]
- StarLogo Nova Blocks Reference Guide [for reference]
- Slide presentation with simple commands

Getting Started - 5 mins

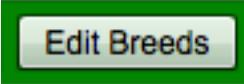
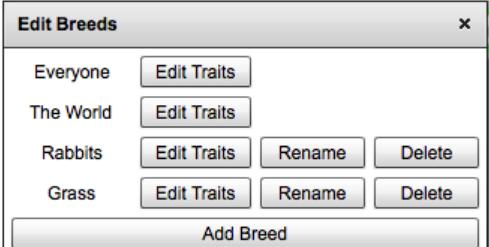
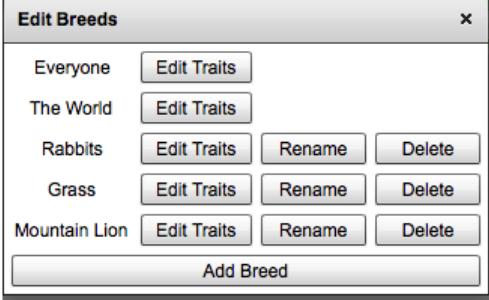
1. **Review of the previous day's lessons and concepts and connection to today's lesson – 5 mins**
 - Last time we learned about and experimented with the Greenhouse Gas base model. Now we are going to add CO₂ to the model, and a factory that will emit that CO₂. We will then run experiments to see how that CO₂ from the factory has affected the World's temperature. What do you predict will happen? What effect do you think CO₂, a greenhouse gas, will have on heat? **(Practice 1: Asking questions and defining problems)** **(Practice 2: Developing and using models)** **(CCC: Cause and Effect)**
 - Review concepts of solar radiation, infra-red radiation, and what heat is and how greenhouse gases contribute to warming. **(DCI: Global Climate Change)**

Activity #1: Add CO2 - 20 mins

We'll be adding a factory that emits CO2 into our Greenhouse Gas model. Both the factory and the CO2 are new "breeds" or types of agents, because they behave differently from the other breeds or agents in the model at present. [Note for teachers: in this lesson plan, one potential way to add a factory that emits CO2 is presented. However, this activity allows for student freedom in terms of breed traits, number of factories, and also the way they emit CO2. Incorporating this freedom in the lesson can allow students to have more control over their learning.]

2. CS Review: code and concepts useful for the modification.

- Adding breeds (a factory and CO2) and using create and do block
- Giving breeds new traits (defining and setting user-defined traits)
- [Optional: introduce the repeat block]

| | |
|---|---|
|  | <p>Use the Edit Breeds button in the Spaceland area to create a new breed.</p> |
|  | <p>Click on "Add Breed" to add a new breed.</p> |
|  | <p>In the "New Breed" dialog box, give the breed a name and press OK.</p> |
|  | <p>Now do the same thing again and add a breed called "CO2."</p> <p>We will be giving the two new breeds traits in the code a bit later on.</p> |

3. Discuss human greenhouse gas emission sources.

- Have the students use the "Model Design Form" to guide their modification process.
- What are we missing from this model? Greenhouse gases!
- Let's make this model into a representation of greenhouse gases coming from human

activities. How about a factory that emits CO2? (Practice 2: Developing and using models) (Practice 6: Constructing explanations and designing solutions)

4. Identify the essential aspects of the modification to include in the model and code them.

- Let's think about factories emitting CO2 and what are the essential parts of that we might be able to include in our model. Keep it simple! (Practice 1: Asking questions and defining problems) (CCC: Scale, proportion, and quantity)

Factory – it's a building that emits a lot of CO2 while it's running.

CO2 - it comes from the factory and rises. It blocks heat from escaping. It eventually decays if left alone for enough time.

- In pairs, open up your Greenhouse Gas model - the first version. We don't need the albedo slider for this. Take turns driving and navigating.
- Remix it and call it Greenhouse Gases with a Factory and CO2.
- Add a breed for CO2 and a breed for the factory.
- Navigate to the code. Are there tabs for CO2 and factory now? Great! Now it's time to code some behavior for our new agents.
- Add a factory:* We want one factory to appear in a random location. Go to the World tab and add the necessary code for the factory to appear. Give the factory a size, shape, color and location. [Option: students can choose traits, including number of factories.] We want to give the factory a behavior: emitting CO2. Navigate to the Factory tab.

Create a new procedure called **hatch CO2**. Add a create-do block and give the CO2 traits related to number, size, shape and color.

[Optional step – now or later – adding a slider to control the number of CO2 agents emitted by the factory.]

Now we want to **call** this procedure, but do we want to call it with the forever loop? Probably not, because we want to control when CO2 is emitted by the factory. So we need a new push-button widget. Create a push-button widget called **run factory** and call the hatch CO2 procedure within it.

[Optional step – now or later – adding a repeat loop to call the hatch CO2 procedure multiple times. Also, the number of times the loop is repeated could be controlled by a slider.]

- Add CO2:* We want to give the CO2 behavior related to hovering and decaying. Go to the CO2 tab and create two procedures, one called **hover** one called **decay**. In the **hover** procedure, have the CO2 move upwards in 0.2 steps at a time, until it reaches a height of 12. Once there it should just wiggle forward at the same height. In the **decay** procedure, set a probability that CO2 will be deleted. If a random number less than 10000 returns a 1 or 0, then the CO2 will be deleted. This is equivalent to 0.1% of the time.

Create a **when forever toggled** block and **call** the two procedures within it.

We also want the CO2 to **trap heat**. We can achieve that by adding a collision block to the heat tab. On collision with CO2, have the heat set its height to 0 (goes back down to the earth). Also, if random 100 is less than or equal to 10 (this is equivalent to 10% of the time), a heat creates another heat agent, with the same characteristics. In this way, we approximate CO2 causing heat to increase.

5. Testing your model.

- Run the code. Hit setup. Did the factory appear as well as the Sun? Did it go to a

random location? Yes? Now hit forever. The sun shoots out solar energy that bounces back as reflected energy and heat. Wait until the heat graph shows that the heat is more or less stable, then push run factory. Did the factory emit CO₂? Yes? Great! Did the CO₂ rise to a certain height and then stop? Yes? Great! (Practice 3: Planning and carrying out investigations)

- How much CO₂ do we have? We don't know! So, what do we need to add to the model to be able to monitor the CO₂ levels? A graph and a data box. Add these in. Test the graph and data box – do they change when we add CO₂ now? Does the CO₂ slowly decay with time? (Practice 4: Analyzing and interpreting data)

Teaching Tip Showing students how to lasso around a block of code then copy and paste that code into a new agent page or the same page can speed up their development time.

Teaching Tip This lesson can be scaffolded based on students' learning abilities by adding or removing the Optional sections. More advanced classes can learn about repeat loops in this lesson and activity.

Activity #2: Run an experiment to see the effect of the modification - 20 mins

In this activity students will run an experiment using the model they have modified by altering the amount of CO₂ entering the system from the factory. Students will have freedom to design their own experiments and there are many options, from simple to more complex experiments (particularly if students have added in sliders).

6. Designing your experiment.

- Experimental Design

Use the "Experimental Design" form as a guide and guide students as they develop a scientific question in pairs. Emphasize the need to run replicates and to clearly identify the variables, as well as the difference between a question and a *testable* question.

Refer to the example in Lesson 2 as a guide. (Practice 1: Asking questions and defining problems) (Practice 3: Planning and carrying out investigations) (Practice 5: Using Mathematical and computational thinking)

- Run your experiment in pairs so the question can be answered. Which variable will you be changing? What range? How many trials at each setting? This information should be written into your template documents before beginning.
- Collecting and analyzing data.

Using the instrumentation in the model (the graph and the data boxes) to monitor temperature under the different scenarios you are testing. Record the data. Look for patterns in your data [draw a graph and/or make a table, record observations].

7. Running your experiment.

- Example simple experiment: Run the experiment for 400 ticks without adding CO₂. Hit forever to pause it. Write down the temperature from the data box. Hit run factory, then hit forever. CO₂ is now present. Run for 400 ticks. Pause. Write down the temperature. Hit run factory, then forever, and run again for 400 ticks. Repeat the process until you reach approximately 2400 ticks. Then, clear everything and repeat the whole experiment as many times as you think you should.

This experiment is just an example. The number of ticks could be changed, a slider could be added to modify how much CO₂ is emitted by the factory, or the number of factories created, among many others, and then these could be the basis for this or future experiments.

8. Collecting and analyzing data.

- Graph your data points. Do you notice any trend? Did temperature increase, decrease or stay the same over time? What can you say now about your testable idea?
- Share out your experiment and results with the class.
- Discuss the difference between **correlation** and **causation**.

Teaching Tip *The experimental design can be tailored to students' abilities.*

Wrap-Up - 5 mins

8. In the real world, what is the source of most of the CO₂ that we as individuals emit?

- We don't all own or work in factories. What do we or our families do every day? [Drive cars, go in buses, go to school]
- Let's think about ways to make this model more relevant to us: students going to school.

9. How can computer models be helpful in understanding climate change?

- Discussion point. A possible example: by "seeing" temperature increase after a human action, we feel closer to the phenomenon of climate change; it's almost like seeing it first-hand.

Assessment Questions

- What aspects of the modification did you decide to include in the model? What aspects did you leave out? Why? [LO3]
- Describe step by step how you would add a small red house to the model located away from the center of the world. [LO1]
- What experiments did you run in the model and what did you learn from them? [LO5], [LO6]
- What coding blocks did you build in the model? Choose one and describe how it works. [LO1]
- Describe how your experimental results are related to the real world and climate change. [LO7]

Standards Addressed

NGSS Performance Expectations

Earth and Human Activity

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

NRC Disciplinary Core Ideas

ESS3.C. Human Impacts on Earth Systems

Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

ESS3.D. Global Climate Change

Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

NRC Scientific and Engineering Practices

Practice 1. Asking questions and defining problems

Ask questions to identify and clarify evidence of an argument.

Practice 2. Developing and using models

Evaluate limitations of a model for a proposed object or tool.

Develop and/or use a model to predict and/or describe phenomena.

Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Practice 3. Planning and carrying out investigations

Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

Collect data to produce data to serve as the basis for evidence to answer scientific questions or test.

Practice 4. Analyzing and interpreting data

Analyze and interpret data to provide evidence for phenomena.

Practice 7. Engaging in argument from evidence

Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

Practice 8. Obtaining, evaluating and communicating information

Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.

NRC Crosscutting Concepts

Cause and Effect

Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Stability and Change

Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

Energy and Matter

The transfer of energy can be tracked as energy flows through a designed or natural system.

Patterns

Patterns can be used to identify cause and effect relationships.

Graphs, charts, and images can be used to identify patterns in data.

Scale, proportion and quantity

Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Systems and Systems models

Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.

Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

Models are limited in that they only represent certain aspects of the system under study.

CSTA K-12 Computer Science Standards

| | | | |
|----|-------------|------|---|
| CT | Abstraction | 2-12 | Use abstraction to decompose a problem into sub problems. |
|----|-------------|------|---|

| | | | |
|-----|-----------------------|-------|--|
| CT | Abstraction | 3A-9 | Discuss the value of abstraction to manage problem complexity. |
| CT | Abstraction | 3B-10 | Decompose a problem by defining new functions and classes. |
| CT | Algorithms | 2-4 | Evaluate ways that different algorithms may be used to solve the same problem. |
| CT | Modeling & simulation | 1:6-4 | Describe how a simulation can be used to solve a problem. |
| CT | Modeling & simulation | 2-11 | Analyze the degree to which a computer model accurately represents the real world. |
| CT | Modeling & simulation | 2-9 | Interact with content-specific models and simulations to support learning and research. |
| CT | Modeling & simulation | 3A-8 | Use modeling and simulation to represent and understand natural phenomena. |
| CT | Modeling & simulation | 3A-8 | Use modeling and simulation to represent and understand phenomena. |
| CT | Modeling & simulation | 3B-8 | Use models and simulation to help formulate, refine, and test scientific hypotheses. |
| CT | Modeling & simulation | 3B-9 | Analyze data and identify patterns through modeling and simulation. |
| CPP | Programming | 2-5 | Implement a problem solution in a programming environment using looping behavior, conditional statements, logic, expressions, variables and functions. |
| CPP | Programming | 3A-3 | Use various debugging and testing methods to ensure program correctness. |
| CPP | Programming | 3A-4 | Apply analysis, design and implementation techniques to solve problems. |

Student Activity #1 Guide: Add CO2

Add CO2

In this activity you and your programming partner will add CO2 to the base model by adding a factory that emits CO2. You don't need the albedo slider so we will work from the base model.

1. Open up your version of the base model. **REMIX** and rename to “Greenhouse Gas Base **your name your partner's name mod2**”
2. Use the **model design form** to plan your modification.
3. Get coding!
4. Test your model to make sure it is working correctly.

Here are a few tips:

- Remember to use the **driver** and **navigator** roles and switch with your programming partner regularly.
- Ask for help if you need it.

When you are done, upload and share your project.

Don't forget to put both partners' names in the project title.

Student Activity #2 Guide: Run an experiment

Run an experiment

In this activity you will use your new model to run an experiment.

1. Use the **Experimental Design form** to plan your experiment.
2. Record your data and analyze your results.

Here are a few tips:

- You can write up your results on a separate piece of paper. You can use graphs and/or tables to help you.

Experimental Design form

Name(s): _____ Date: _____

Model name: _____

Question

What is your question?

Variables

What are the dependent and independent variables in your experiment?

Range

What is the range of values you will use for each variable?

Trials

How many trials will you run at each setting? Why?

Data Collection

What data will you collect?

Data Analysis

How will you analyze your data?

Interpretation

What is the answer to your question?

Interpretation

How does the analysis of your data help you answer your question?

Model Design Form

Name(s): _____ Date: _____

Model name: _____

| MODEL DESCRIPTION | |
|--|--|
| What will be modeled? | |
| | |
| What abstractions are used? | |
| <i>What do the agents represent?</i> | |
| | |
| <i>What does the space or environment represent?</i> | |
| | |
| <i>What are the Interactions?</i> | |
| | |
| <i>What do ticks represent?</i> | |
| | |
| <i>What are the assumptions made?</i> | |
| | |
| How will it be modeled? | |
| <i>What happens when simulated time advances?</i> | |
| | |

Scientific Practices with Computer Modeling & Simulation

Name:

Date:

The table below lists scientific practices. Please provide an example of what you did that matches the practice.

| Practices: | |
|---|--|
| Asking questions and defining problems | |
| Develop and use a model | |
| Plan and carry out an investigation | |
| Analyze and interpret data | |
| Use mathematics and computational thinking | |
| Construct explanations and design solutions | |
| Engage in argument from evidence | |
| Obtain, evaluate, and communicate information | |

2

Lesson 4

Create your own Greenhouse Gas Model

50 minutes (1 day)

Lesson Overview (New Learning and Exploration)

In this lesson, students design their own Greenhouse Gas projects consisting of a question, experimental design and model. In the first activity, students will learn about computational science and how to design a model, and will use this knowledge to scope their project. This leads to a second activity, in which they start designing and implementing their model, using the Greenhouse Gas base model as a starting place.

Teaching Summary

Getting Started – 5 minutes

1. Review of the previous day's lesson and concepts and connection to today's lesson

Activity #1: Computational Science and Model Design – 20 minutes

2. Introduce key ingredients of computational science model design
3. Define your computational science project

Activity #2: Design and develop your model – 20 minutes

4. Agents and environment
5. Interactions

Wrap-Up – 5 minutes

6. What research is necessary to ground your model in reality?
7. How will you check to see if your model is realistic?

Lesson Objectives

The student will:

- ✓ Develop their own design for a computational science project based on the Greenhouse Gases model [LO1]
- ✓ Develop a scientific question that can be answered with data output from running a model [LO2]

- ✓ Use the key stages of computational science and model design to develop their question, create their model, and design their experiment [LO3]
- ✓ Practice pair programming and iterative design, implement, test cycle [LO4]
- ✓ Reflect on human CO₂ emissions, as relates to their trips to school, to inform their model design [LO5]

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- Greenhouse Gas StarLogo Nova model
- USING a Computer Model to do Science document [student handout]
- Experimental Design form document [student handout]
- Project design form [student handout]
- New commands and concepts sheet [student handout]

For the Teacher

- Computer and projector
- Greenhouse Gas StarLogo Nova models: base model, base model plus albedo slider, base model plus factory.
- Climate Change background document [for reference]
- Guided Introduction to StarLogo Nova document [for reference]
- StarLogo Nova Blocks CS Concepts guide document [for reference]
- StarLogo Nova Blocks Reference Guide [for reference]
- Slide presentation with simple base commands

Getting Started - 5 mins

1. **Review of the previous day's lessons and concepts and connection to today's lesson**
 - Last time we added CO₂ to the Greenhouse Gas model, and a factory that emits that CO₂. We ran experiments to see how that CO₂ from the factory affected the World's temperature. What did we learn? **(DCI: Global Climate Change) (DCI: Human impacts on Earth Systems)**
 - Today, using what you've learned in the first three lessons about climate change, carbon footprints, and computational science, you'll come up with your own modifications in teams.
 - Review concepts from the carbon footprint activity related to transport and connect this to their own way of getting to school.

Activity #1: Computational Science and Model Design - 20 mins

In this activity, the teacher will introduce the key aspects of designing a model for computational science. Students will work together in teams to develop their questions and projects. Students should be given creative freedom, within the scope of investigating and modeling their trips to school and CO₂ emissions.

2. Introduce key ingredients of computational science model design.

- Computational scientists in STEM fields have a process when designing models for computational science. They go back and forth between different stages within this overall process.
- Key stages of this process are:
 - *Select a real-world problem to study.*
Discuss what makes a problem suitable for studying using computational methods. Make simplifications to the model through abstraction. Answer “What real world issue are you interested in investigating? What are measurable aspects of the problem?” and check that the question you ask could be answered through modeling and simulation. (CCC: Systems and systems models)
 - *Simplify the scope of the model using abstraction.*
What aspects of the problem are important to model? Narrow the scope of the problem to one that can be modeled given the time and computing resources available. Diagram the model components and the simulation loop.
 - *Convert your diagram of the model into a computational model.*
Use fundamental concepts in CS. Design and implement algorithms that will be needed. [An iterative design, implement and test process is used when developing the model.]
 - *Parameterize the model.*
Describe the range of values and increments for the variables and parameters in your experimental design. Describe the collection and analysis of data output from models.
 - *Simulate and collect data.*
Use the computational model as a test bed for running experiments.
 - *Analyze/Interpret.*
Search for patterns in your data. Discuss your findings and whether or not they constitute “proof” or help you answer your question. Discuss the limitations of the computer model, what assumptions were made, and what the model tells us, if anything, about the real world.
 - *Repetition.*
While working through the different stages, we often find verification errors (bugs in the code) or validation errors (when comparing model behavior to real world data, there are differences that suggest that the wrong assumptions or simplifications were made). When this happens, we revisit the necessary stages to refine and improve our model.
 - *Share your model and findings*
- If time allows, you could use the Greenhouse Gas base model with factory and CO₂ as an example when describing these stages.

3. Define your computational science project

- Hand out the “*Project design form*” to students in teams or pairs. (Practices 1-8 are fulfilled throughout Activity #1 and #2).
- Discuss ways of getting to school and how they think these contribute to human CO₂ emissions. (CCC: Patterns) (CCC: Cause and Effect)
- Have students specify their question and describe the model and experimental design on the form. Encourage students to use research to inform their model design.

[There are many potential modifications students may choose to incorporate, for example: cars driving to school, buses, carpooling, lower emission cars (hybrids/electric), walking, cycling, etc.]

[As an example, we might add cars to the model in the following way:

Cars - they move, and when they move, they make CO₂. They don't move forever, so we need a way of stopping them after a while.]

[As an example, we may *also* add a bus in the following way:

What are the essential aspects of a *bus* that we would want to include? It would look different, it would emit CO₂ but more than a car, and the more kids that would go on the bus, the fewer should be in cars.]

Teaching Tip *Students should be encouraged to develop their own Climate Change questions they would like to address with their models. The teacher should help them simplify their questions to ensure they will be able to create an appropriate model.*

Activity #2: Design and develop your model - 20 mins

In this activity, students will work in pairs using the pair programming technique to design and develop their chosen model, by working from their planning worksheets and their StarLogo Nova Blocks and CS Concepts reference guides. [Example provided to show how to add cars to the model]

4. Agents and Environment.

- The students should first create code that adds in their agents and any modifications to the environment they want. This will usually include adding new breeds, etc. The following bullet points refer to adding a car that emits CO₂.
 - First you will need to add a new breed - car! We already have a CO₂ breed.
 - Now, create a number of cars in the setup block. You need to give them a shape, a color, a size and a position (scatter).

5. Interactions.

- The students should then create code that gives their chosen agents behaviors and interactions with other agents and the environment. Below is an example for adding cars.
 - You need to give the car behaviors.

We want the cars to have **movement**. Go to the car tab. Make a procedure called drive which will cause the cars to move forward in a tight wiggle motion.

We want the cars to **give off a CO₂** every time they move. Go back to the cars tab. We should make another procedure for hatching car CO₂, and in it we should describe the shape, color and size of the CO₂. We then want to **call** that procedure within the drive procedure.

We don't want the cars to run all of the time, just the amount of time it would take to drop kids off at school. So, we need to limit their drive time. There are a number of ways of doing this. In the model provided we have used an **if-then** block and the

clock to limit drive time. If the clock is > 100 and ≤ 300 , for example, the cars move. This allows time for the temperature to stabilize in the beginning. This if-then should be called within a **forever** block. Another way of achieving this could be by a repeat loop.

If for example we also want to add a bus, we need the bus to generate CO₂ as well. Copy the block from the car tab into the bus tab related to CO₂. Change the name to hatch bus CO₂. A bus makes more CO₂ than a car, so we could change the probability of generating a CO₂ from random 100 ≤ 5 to random 100 ≤ 30 .

- Now we need to **monitor** the CO₂ that comes from the cars.

Using the example CO₂ graph for factory-CO₂, modify it and the code pertaining to it to work with the cars.

- Run the code and test it. Does everything behave how you think it should?
- **Sliders** can be used to control the number of cars created at setup, or the amount of time the cars drive (by changing the end “clock” value).

Go to Spaceland, and click **edit widgets**. Add a slider widget and call it something like **# of cars**. Set the maximum to the number of kids in the class, for example, or kids in the school, and the minimum to 1. Set the interval to 1.

Go back to the code, and the World tab. Go to the part of the setup that states how many cars are created. Change the number to the **# of cars** slider.

Teaching Tip There are many different levels of coding that can take place in this activity. More advanced learners could incorporate several modifications at once – e.g. two types of cars with different emissions. They would need to understand how to track and experiment with these as well as how to code them. Other less advanced learners should at least achieve adding cars to the model and one slider so they can experiment in the next lesson. Students should be encouraged to think for themselves.

Wrap-Up - 5 mins

6. What research is necessary to ground your model in reality?

- How does this relate to your own way of getting to school?
- How does this relate to other students' ways of getting to school? (Practice 1: Asking questions and defining problems)

7. How will you check to see if your model is realistic?

Teaching Tip Encourage the students to differentiate between reality and their models, while at the same time encouraging them to do research to make their model more realistic.

Assessment Questions

- Give three examples of how students going to school contribute to climate change by creating greenhouse gases. [LO5]
- State what research question you have chosen to investigate and explain why you chose it. [LO2]
- What procedures in the model have you built? Choose one and describe how it works. [LO3]
[LO1]
- What aspects of the real world did you choose to include in your model? What did you leave out? Why? [LO3]

Standards Addressed

NGSS Performance Expectations

Earth and Human Activity

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

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

NRC Disciplinary Core Ideas

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.

Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

ESS3.D. Global Climate Change

Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

NRC Scientific and Engineering Practice Standards

Practice 1: Asking questions and defining problems

1A: Ask questions that arise from careful observation of phenomena, models, or unexpected results.

1D: Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.

1E: Ask questions that require sufficient and appropriate empirical evidence to answer.

Practice 2: Developing and using models

2A: Evaluate limitations of a model for a proposed object or tool.

2B: Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed.

2C: Use and/or develop a model of simple systems with uncertain and less predictable factors.

2D: Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.

2E: Develop and/or use a model to predict and/or describe phenomena.

2F: Develop a model to describe unobservable mechanisms.

2G: Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Practice 3: Planning and carrying out investigations

- 3A: Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- 3B: Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.

Practice 4: Analyzing and interpreting data

- 4A: Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
- 4B: Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
- 4F: Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).

Practice 5: Using mathematics and computational thinking

- 5A: Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.
- 5B: Use mathematical representations to describe and/or support scientific conclusions and design solutions.
- 5C: Create algorithms (a series of ordered steps) to solve a problem.
- 5D: Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.

Practice 6: Constructing explanations and designing solutions

- 6E: Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.
- 6F: Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.

Practice 7: Engaging in argument from evidence

- 7C: Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

Practice 8: Obtaining, evaluating, and communicating information

- 8C: Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.

NRC Crosscutting Concepts

1. Patterns:

- 1C: Patterns can be used to identify cause and effect relationships.

2. Cause and Effect:

- 2B: Cause and effect relationships may be used to predict phenomena in natural or designed systems.

4. Systems and Systems models

- 4B: Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

- 4C: Models are limited in that they only represent certain aspects of the system under study.

CSTA K-12 Computer Science Standards

| | | | |
|----|-------------|-------|---|
| CT | Abstraction | 2-12 | Use abstraction to decompose a problem into sub problems. |
| CT | Abstraction | 3A-9 | Discuss the value of abstraction to manage problem complexity. |
| CT | Abstraction | 3B-10 | Decompose a problem by defining new functions and classes. |
| CT | Algorithms | 3A-3 | Explain how sequence, selection, iteration and recursion are the building blocks of algorithms. |

| | | | |
|-----|-----------------------|-------|--|
| CT | Modeling & simulation | 1:6-4 | Describe how a simulation can be used to solve a problem. |
| CT | Modeling & simulation | 2-10 | Evaluate the kinds of problems that can be solved using modeling and simulation. |
| CT | Modeling & simulation | 2-11 | Analyze the degree to which a computer model accurately represents the real world. |
| CT | Modeling & simulation | 3A-8 | Use modeling and simulation to represent and understand natural phenomena. |
| CT | Modeling & simulation | 3A-8 | Use modeling and simulation to represent and understand phenomena. |
| CT | Modeling & simulation | 3B-8 | Use models and simulation to help formulate, refine, and test scientific hypotheses. |
| CPP | Programming | 2-5 | Implement a problem solution in a programming environment using looping behavior, conditional statements, logic, expressions, variables and functions. |
| CPP | Programming | 3A-4 | Apply analysis, design and implementation techniques to solve problems. |

Student Activity #1 Guide: Project Design

Design your project

In this activity you and your programming partner will come up with your own model based on the Greenhouse Gas base model.

1. Open up your version of the base model. **REMIX** and rename to “Greenhouse Gas **your name** **your partner’s name NEW**”
2. Use the **project design form** to plan your modeling.

Here are a few tips:

- Try to think of things to put in your model that will help you answer your question, but keep it simple!

When you are done, move on to Activity #2.

Don’t forget to put both partners’ names in the project title.

Student Activity #2 Guide: Model Development

Code your model

In this activity you and your programming partner will put your planning into practice and you will make your new model.

1. Open up your model ("Greenhouse Gas **your name your partner's name NEW**")
2. Use the **project design form** to guide you as you take turns **driving** and **navigating**.

Here are a few tips:

- You can copy and paste code from other models to help you work more quickly: for example, the code describing CO₂ behavior from your "mod2" version from lesson 3 could be useful.

When you are done, upload and share your project.

Don't forget to put both partners' names in the project title.

Experimental Design form

Name(s): _____ Date: _____

Model name: _____

Question

What is your question?

Variables

What are the dependent and independent variables in your experiment?

Range

What is the range of values you will use for each variable?

Trials

How many trials will you run at each setting? Why?

Data Collection

What data will you collect?

Data Analysis

How will you analyze your data?

Interpretation

What is the answer to your question?

Interpretation

How does the analysis of your data help you answer your question?

Project Design Form

Name(s): _____ Date: _____

Model name: _____

| |
|--|
| PROJECT DESCRIPTION |
| What question do you seek to answer? |
| |
| What observation of phenomenon, model, or unexpected result led you to this question? |
| |

| |
|---|
| MODEL DESCRIPTION |
| What will be modeled? |
| <i>What question do you seek to answer?</i> |
| |
| How will it be modeled? What abstractions are used? |
| <i>Who are the Agents? What is the Environment? What are the Interactions? What do ticks represent?</i> |
| |
| <i>What are the parameters of interest?</i> |
| |



EXPERIMENTAL DESIGN

Variables

What are the dependent and independent variables in your experiment?

Range

What is the range of values you will use for each variable?

Trials

How many trials will you run at each setting? Why?

Data Collection

What data will you collect?

Data Analysis

How will you analyze your data?

Interpretation

What question do you seek to answer?

Interpretation

How does the analysis of your data help you answer your question?

Scientific Practices with Computer Modeling & Simulation

Name:

Date:

The table below lists scientific practices. Please provide an example of what you did that matches the practice.

| Practices: | |
|---|--|
| Asking questions and defining problems | |
| Develop and use a model | |
| Plan and carry out an investigation | |
| Analyze and interpret data | |
| Use mathematics and computational thinking | |
| Construct explanations and design solutions | |
| Engage in argument from evidence | |
| Obtain, evaluate, and communicate information | |

2

Lesson 5

Experiment with your New Greenhouse Gas Model

50 minutes (1 day)

Lesson Overview (New Learning and Exploration)

In this lesson, students will finish coding their chosen modifications. Students will then debug their code, checking to make sure it works as they intended, and fixing errors as they find them. In the second activity, students will use their new model as an experimental test bed. They will modify the question they came up with in Lesson 4 if necessary, and they will run experiments to address this question, using replication. Students will critically analyze their results, as well as their model, and relate it back to the bigger picture - climate change. Students will reflect on what modeling with Greenhouse Gases has taught them about climate change and their actions. Students should share their findings with the whole class.

Teaching Summary

Getting Started – 5 minutes

1. Review of previous day's lesson and concepts and connection to today's lesson
2. Revisit feedback loops

Activity #1: Complete & Debug Code – 15 minutes

3. Use pair programming to complete the model
4. Test the new model – trace execution and debug the model

Activity #2: Run Experiments – 15 minutes

5. Review the question first formulated in the model design
6. Design experiments to run in the new model
7. Run experiments, using multiple trials

Wrap-Up – 15 minutes

8. Analyze results and discuss conclusions
9. Relate the results back to the bigger picture of Climate Change and Greenhouse Gases
10. Share your model and experimental results with the class

Lesson Objectives

The student will:

- ✓ Revisit the concept of feedback loops and come up with a possible feedback loop related to human greenhouse gas emissions [LO1]
- ✓ Gain a deeper understanding of the effects of human activities on climate change through their experience creating and experimenting with a greenhouse gas model [LO2]
- ✓ Gain an understanding of what actions can help mitigate human greenhouse gas emissions [LO3]
- ✓ Use their new model as a test bed to run experiments [LO4]
- ✓ Learn that the results of their experiments can feed back into the model to improve it [LO5]
- ✓ Follow the correct execution of their models and apply debugging techniques to fix the code [LO6]

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- Greenhouse Gas StarLogo Nova model
- USING a Computer Model to do Science document [student handout]
- Project design form [student handout from Lesson 4]
- New commands and concepts sheet [student handout]

For the Teacher

- Computer and projector.
- Climate Change background document [for reference].
- Greenhouse Gas StarLogo Nova models: base model plus cars and CO2
- StarLogo Nova Blocks CS Concepts guide document [for reference]
- StarLogo Nova Blocks Reference Guide [for reference]
- Slide presentation with simple commands

Getting started - 5 mins

1. **Review of previous day's lesson and concepts and connection to today's lesson**
 - During the last lesson you came up with your own design for a model to answer a question you had regarding greenhouse gas emissions from driving to school. How far along did everyone get in your coding?
 - We will have a chance today to finish our models, check to see if they are working correctly and fix them, and also run an experiment.
2. **Revisit feedback loops**
 - Before starting, briefly revisit the concept of feedback loops, mentioning that these are important to include in Climate Change models and that they add complexity to the system. The students will most likely not be able to build feedback loops into their models but should be aware of their importance. Refer to the Climate Change

- background document. (CCC: Patterns) (CCC: Cause and Effect) (CCC: Systems and systems models) (CCC: Stability and change) (DCI: Weather and Climate)
- Come up with a possible feedback loop for humans: for example, the hotter it gets, the less likely it is for people to walk places, they may use more cars and more A/C which run with fossil fuels, causing more CO₂ to be emitted to the atmosphere, and causing the temperatures to rise even more. (Practice 1: Asking questions and defining problems) (DCI: Human impacts on Earth Systems)
 - Ask the students to diagram a feedback loop and visualize how it feeds back into itself. Is it an example of positive or negative feedback? (Practice 7: Engaging in argument from evidence) (DCI: Global Climate Change)

Activity #1: Complete and debug code - 15 mins

In this activity, the programming pairs should work together, alternating pilot and navigator roles, to complete their model and to test and debug it as well. Students will naturally work at a different paces, but they should be encouraged to avoid overcomplicating their model and to move on to experimentation as soon as they can. (Practice 3: Planning and carrying out investigations) (Practice 5: Using Mathematical and computational thinking) (Practice 6: Constructing explanations and designing solutions) (CCC: Patterns) (CCC: Scale, proportion, and quantity)

3. Use pair programming to complete the model

- Finish up your model if necessary.

4. Test the new model – trace execution and debug the model

- Refer to the “Guide to debugging” document to help you fix your code during this activity.
- After finishing your coding, test your setup.

Did everything appear that you had coded in your setup and did it behave the way you wanted it to?

- Test your forever loop. Are all of the behaviors you created that you want running when you toggle forever working as you had hoped?
- Test your model. Did you create other action buttons, sliders, graphs and other monitors? Check each of these to make sure they are working correctly.

Watch your agents – when they collide, are they following the code you created for them in their collision blocks?

Teaching Tip Students may need more or less time to complete their coding than is allotted. Students that finish earlier can move on to Activity 2 (experiments). They should be encouraged to be more thorough in their experimentation.

Activity #2: Run experiments - 15 mins

In this activity, students will work on their experiments, following the plan they set out in Lesson 4, editing it as needed. Students should aim to be done with experimentation quickly and working on analyzing their results and preparing them for discussion with the class. (Practice 1-8 are addressed in this activity #2 and the Wrap-Up activity.)

5. Review the question first formulated in the project design

- Check your Project Design Form. Review the question you wrote down. Think about your

model. Is it a good question to ask and answer with simulations using your model? If not, change it to match your model.

6. Design experiments to run in the new model

- Check your Project Design Form again. Look at the experimental design you prepared in Lesson 4. Do you think it still works with your model now that it is done? Run one experiment as set out on your Project Design Form and check if you need to change anything. For example, maybe you need to run the simulations for more ticks. Change your design as needed.

7. Run experiments, using multiple trials

- Run your experiments following along with your design. Make sure you write down your results as you go along. Make sure you are running the simulations enough times to take randomness into account.

Wrap-Up - 15 mins

8. Analyze results and discuss conclusions

- Once you have finished your experiments and written down your results, summarize them using a table and/or a graph.
- Think about the results and what they mean. Write down your thoughts.

9. Relate the results back to the bigger picture of Climate Change and Greenhouse Gases

- Now think about the bigger picture. What do your results say about human greenhouse gas emissions? Can you make recommendations based on your results for the other students in the class?
- Write down your “bigger picture” results.

10. Prepare your model and experimental results for presentation

- Have students prepare their models and results in pairs to show to the rest of the class following the guidelines below. They should aim to use presentation tools and a projector.

Guidelines for students:

1. State the question you were seeking to answer or the problem that you were studying.
2. Tell us about any background research you did on the topic.
3. Tell us about your model (what's included and what was left out).
4. Tell us about your experimental design.
5. Show your model running and how you collected data.
6. Show any collected data and analysis.
7. Tell us about any relationships you noticed between variables that help you understand or predict the phenomenon.
8. Summarize your findings; what was the outcome of running your experiments.
9. Do you think you learned anything about the real world?
10. Show us a piece of code you are proud of.
11. Question and answers.

Teaching Tip This lesson could be expanded into a sixth and seventh lesson to allow for more time for the students to prepare, present and discuss their models and results.

Assessment Questions

- Describe one human greenhouse gas emission feedback loop. [LO1]
- What human activities were the greatest drivers of increased temperature in your model? [LO2]
How do you think this relates to the real world? [LO2]
- What experiments did you run in the model and why? [LO4]
- What real world information could improve the model? [LO5]
- Define debugging and give an example of some debugging you had to do in your code. [LO6]
- Complete the “USING a Computer Model to do Science” document.

Standards Addressed

NGSS Performance Expectations

Earth and Human Activity

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

NRC Disciplinary Core Ideas

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. Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

ESS3.D. Global Climate Change

Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

ESS2.D. Weather and Climate

Complex interactions determine local weather patterns and influence climate, including the role of the ocean. [Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. Because these patterns are so complex, weather can only be predicted probabilistically.]

NRC Scientific and Engineering Practices

Practice 1: Asking questions and defining problems

1A: Ask questions that arise from careful observation of phenomena, models, or unexpected results.

1D: Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.

1E: Ask questions that require sufficient and appropriate empirical evidence to answer.

Practice 2: Developing and using models

- 2A: Evaluate limitations of a model for a proposed object or tool.
- 2B: Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed.
- 2C: Use and/or develop a model of simple systems with uncertain and less predictable factors.
- 2D: Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.
- 2E: Develop and/or use a model to predict and/or describe phenomena.
- 2F: Develop a model to describe unobservable mechanisms.
- 2G: Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Practice 3: Planning and carrying out investigations

- 3A: Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- 3B: Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.

Practice 4: Analyzing and interpreting data

- 4A: Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
- 4B: Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
- 4F: Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).

Practice 5. Using Mathematics and Computational Thinking

- 5A: Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.
- 5B: Use mathematical representations to describe and/or support scientific conclusions and design solutions.
- 5C: Create algorithms (a series of ordered steps) to solve a problem.
- 5D: Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.

Practice 6. Constructing Explanations and Designing Solutions

- 6E: Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.
- 6F: Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.

Practice 7: Engaging in argument from evidence

- 7C: Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

Practice 8. Obtaining, evaluating and communicating information

- Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.

NRC Crosscutting Concepts

Cause and Effect

Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Stability and Change

Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

Energy and Matter

The transfer of energy can be tracked as energy flows through a designed or natural system.

Patterns

Patterns can be used to identify cause and effect relationships.

Graphs, charts, and images can be used to identify patterns in data.

Scale, proportion and quantity

Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Systems and Systems models

Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

Models are limited in that they only represent certain aspects of the system under study.

CSTA K-12 Computer Science Standards

| | | | |
|-----|-----------------------|-------|--|
| CT | Abstraction | 2-12 | Use abstraction to decompose a problem into sub problems. |
| CT | Abstraction | 3A-9 | Discuss the value of abstraction to manage problem complexity. |
| CT | Abstraction | 3B-10 | Decompose a problem by defining new functions and classes. |
| CT | Algorithms | 3A-3 | Explain how sequence, selection, iteration and recursion are the building blocks of algorithms. |
| CT | Modeling & simulation | 1:6-4 | Describe how a simulation can be used to solve a problem. |
| CT | Modeling & simulation | 2-10 | Evaluate the kinds of problems that can be solved using modeling and simulation. |
| CT | Modeling & simulation | 2-11 | Analyze the degree to which a computer model accurately represents the real world. |
| CT | Modeling & simulation | 3A-8 | Use modeling and simulation to represent and understand natural phenomena. |
| CT | Modeling & simulation | 3A-8 | Use modeling and simulation to represent and understand phenomena. |
| CT | Modeling & simulation | 3B-8 | Use models and simulation to help formulate, refine, and test scientific hypotheses. |
| CPP | Programming | 2-5 | Implement a problem solution in a programming environment using looping behavior, conditional statements, logic, expressions, variables and functions. |
| CPP | Programming | 3A-4 | Apply analysis, design and implementation techniques to solve problems. |

Student Activity #1 Guide: Code Debugging

Debug your model

In this activity you and your programming partner trace execution of your model and using **debugging** to fix and issues you find.

1. Open up your model ("Greenhouse Gas **your name your partner's name NEW**")
2. Refer to the **guide to debugging** document and test your model out and fix any issues you find.

Here are a few tips:

- Try to look at the code and model in sections to avoid getting overwhelmed.

When you are done, move on to Activity 2.

Don't forget to put both partners names in the project title.

Student Activity #2 Guide: Run experiments

Run experiments

In this activity you and your programming partner will use your new model to run experiments.

1. Open up your model ("Greenhouse Gas **your name your partner's name NEW**")
2. Use your **project design form** to guide your experimentation.
3. Record your results and perform **data analysis** on them. Record your conclusions.

Here are a few tips:

- You may need to modify your experimental design now that you have finished your model.

When you are done, start preparing your results for a presentation.

Don't forget to put both partners names in the project title.

Student Activity Guide: Prepare Presentations

Prepare Presentations

In this activity you and your programming partner will prepare a ten minute presentation using tools like slide presentation and a projector. Follow the guidelines below:

1. State the question you were seeking to answer or the problem that you were studying.
2. Tell us about any background research you did on the topic.
3. Tell us about your model (what's included and what was left out).
4. Tell us about your experimental design.
5. Show your model running and how you collected data.
6. Show any collected data and analysis.
7. Tell us about any relationships you noticed between variables that help you understand or predict the phenomenon.
8. Summarize your findings; what was the outcome of running your experiments.
9. Do you think you learned anything about the real world?
10. Show us a piece of code you are proud of.
11. Allow time for question and answers.

Here are a few tips:

- Take turns presenting different sections. Plan on going between the presentation (slide presentation, for example) and the model.

When you are done, practice your presentation with your partner.

Don't forget to put both partners names in the project title.

Project Design Form

Name(s): _____ Date: _____

Model name: _____

| |
|--|
| PROJECT DESCRIPTION |
| What question do you seek to answer? |
| |
| What observation of phenomenon, model, or unexpected result led you to this question? |
| |

| |
|---|
| MODEL DESCRIPTION |
| What will be modeled? |
| <i>What question do you seek to answer?</i> |
| |
| How will it be modeled? What abstractions are used? |
| <i>Who are the Agents? What is the Environment? What are the Interactions? What do ticks represent?</i> |
| |
| <i>What are the parameters of interest?</i> |
| |



EXPERIMENTAL DESIGN

Variables

What are the dependent and independent variables in your experiment?

Range

What is the range of values you will use for each variable?

Trials

How many trials will you run at each setting? Why?

Data Collection

What data will you collect?

Data Analysis

How will you analyze your data?

Interpretation

What question do you seek to answer?

Interpretation

How does the analysis of your data help you answer your question?

Scientific Practices with Computer Modeling & Simulation

Name:

Date:

The table below lists scientific practices. Please provide an example of what you did that matches the practice.

| Practices: | |
|---|--|
| Asking questions and defining problems | |
| Develop and use a model | |
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| Analyze and interpret data | |
| Use mathematics and computational thinking | |
| Construct explanations and design solutions | |
| Engage in argument from evidence | |
| Obtain, evaluate, and communicate information | |

