MODULE 1 (COMPUTER MODELING AND SIMULATION) INTRODUCTION

Module Name: Introduction to Computer Modeling and Simulation

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 6 Lessons, including Learning Objectives and Assessment Questions

1. Overview of the Module

This module introduces basic concepts in modeling complex systems through hands-on activities and participatory simulations. A scaffolded series of highly-engaging design and build activities guide students through developing their first computer model in StarLogo Nova, a modeling and simulation environment developed at Massachusetts Institute of Technology.

Students practice designing and running experiments using a computer model as a virtual test bed.

2. Prerequisite knowledge and assumptions encompassed by the Module

There are no prerequisites for Module 1. The module was designed to be an introduction to computer modeling and simulation for students with no prior background in the topic. It is necessary to complete this module prior to commencing the Earth, Life or Physical Science 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
- What is a CAS? document [for reference]
- Characteristics of a Complex Adaptive System document [for reference]

- Feedback Loops document [for reference]
- Turn and Walk StarLogo Nova models [for Lesson 1 activity]
- Red, blue, and black pens for students [for Lesson 3 activities]
- Dice and paper cups for students [for Lesson 4 activities]
- 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]
- Scientific Practices with Modeling & Simulation [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 6 lessons
- Slide presentation with instructions
- New commands and concepts sheets for each lesson [student handout]

5. **Pacing Guides for 6 Lessons, including Learning Objectives and Assessment Questions.** (See following pages.)

DAY 1- Introduction to Complex Adaptive Systems and Computer Modeling and Simulation

Pacing Guide

Getting Started (Assessment)	Pre-test / Assessment- Optional	10 min
Activity 1 (New Learning)	Turn & Walk: Participatory Simulation, Computer Model (Teacher-led demo), Correspondence between the real world and the virtual world, and Parts of a StarLogo Nova model.	25 min
Activity 2 (New Learning)	Complex Adaptive Systems: Video introduction, Characteristics of Complex Adaptive Systems.	10 min
Wrap up (Reflection)	What are computer models good for?	5 min

Learning objectives: Students will…

Complex Adaptive Systems	Experience being part of a complex adaptive system. (LO 1) Learn characteristics of complex adaptive systems. (LO 6) Learn that complex adaptive systems are 1) made of many interacting parts or agents, 2) each agent follows its own rules, 3) emergent patterns can result from the interaction of agents.
Modeling and Simulation	Compare and contrast a computer simulation vs. a real-world phenomenon. (LO 2) See a demo of using a computer model to run experiments. (LO 3) Speculate as to why computer models can be valuable scientific tools. (LO 5) Learn that models are representations of reality. Not all features of the real world are incorporated in to models. Models contain assumptions. Learn how to setup and run an experiment using a model as a test bed.
Computer Science	Investigate the parts of a StarLogo Nova user interface and paradigm. (LO 4) Learn that programs consist of simple instructions that are executed in a sequence. Each time the instructions are repeated in a loop. Each time through the loop is called an iteration.

Assessments of understanding:

Complex Adaptive Systems	What are four necessary characteristics of complex adaptive systems? [They are 1) made of many interacting parts or agents, 2) each agent follows its own rules, 3) emergent patterns can result from the interaction of agents and 4) hard to predict.]
Modeling and Simulation	Why are models useful? How can computer models be used to learn about the real world? What can be different about a model vs. the world?
Computer Science	What is an instruction? What is a loop? What is an iteration? What are the parts of the StarLogo Nova user interface?

DAY 2- Introduction to StarLogo NOVA and building Flower Turtles & Painting Turtles

Pacing Guide

Getting Started (Review)	Review of the previous day's lesson and concepts; connection to today's lesson.	5 min
Activity 1 (Guided Practice)	Guided Tour of StarLogo Nova: Guided Tour and Observations and Ethical considerations concerning remixing and sharing.	20 min
Activity 2 (Discovery/Creative)	Flower Turtles Challenge: Pair programming; new StarLogo Nova commands, and Flower Turtles Challenge with extension.	20 min
Wrap up (Reflection)	What does Flower Turtles have to do with Modeling and Simulation?	5 min

Learning objectives: Students will…

Complex Adaptive Systems	Learn that in complex adaptive systems one type of interaction is that agents impact their environment.(LO7)
Modeling and Simulation	Create a model in which agents impact their environment. (LO8)
Computer Science	Get comfortable with the StarLogo Nova programming environment. (LO9) Create a program containing simple instructions that are executed in a loop. (LO10) Trace a program's execution. (LO11) Change variables to alter turtle movement. Use randomness. (LO12)
Mathematics	Turn angles, random function, relative vs. absolute position, and heading. (LO13)

Assessments of understanding:

Complex Adaptive Systems	Which characteristics of a complex adaptive system are seen in Flower Turtles? Is Flower Turtles a model of a complex adaptive system? Why or why not?
Modeling and Simulation	Is the pattern made by turtles repeatable? If I run the program again, will it produce the same drawing? Why or why not?
Computer Science	What variables were used in Flower Turtles? What is the difference between right turn 90 degrees vs. right turn random 90 degrees?
Other	Math: turn angles, random function, relative vs. absolute.

DAY 3- Conditional branching with Trailblazer and Bumper Turtles

Pacing Guide

Getting Started (Review)	Review of the previous day's lesson and concepts; connection to today's lesson.	5 min
Activity 1 (Guided Practice)	Trailblazer: Blazing a Trail and Comparing Solutions; and New CS Concepts: conditionals and Boolean.	20 min
Activity 2 (Discovery / Creative)	Bumper Turtles Challenge: Introduce new StarLogo Nova commands and the Challenge.	20 min
Wrap up (Reflection)	What does Bumper Turtles have to do with Modeling and Simulation? Is Bumper Turtles a model of a complex adaptive system? Why or why not?	5 min

Learning objectives: Students will…

Complex Adaptive Systems	Learn that in complex adaptive systems one type of common interaction is that agents react to their environment. (LO14)
Modeling and Simulation	Create a simple model in which agents react to their environment. (LO15)
Computer Science	Learn CS concepts of booleans, logic, and conditionals. (LO18) Use Boolean logic and conditional branching to implement agents that can react to their environment. (LO17) Trace a program's execution. (LO16) Compare solutions to Trailblazer using number of steps or number of instructions as a metric. (LO20)
Other	Practice Pair Programming and Iterative design, implement, and test cycle (LO19)

Assessments of understanding:

Complex Adaptive Systems	Which characteristics of complex adaptive systems do you see in Bumper Turtles?
Modeling and Simulation	Give an example of how agents reacting to their environment may be used to represent a behavior in the real-world. In your own words, how can if/then logic be used in a computer model?
Computer Science	How would you assess which Trailblazer solution is the best?
Other	Logic: What is the difference between a series of if/then statements and nested if/then/else statements?

DAY 4- Colliding Turtles and Probability in Models

Pacing Guide

Getting Started (Review)	Review of the previous day's lesson and concepts; connection to today's lesson.	5 min
Activity 1 (Guided Practice)	Probability with Dice and Data: "Chances Are" and "Wiggle Walk."	20 min
Activity 2 (Discovery / Creative)	Colliding Turtles: New concepts and the Challenge (adding a behavior that takes place upon collision).	20 min
Wrap up (Reflection)	What could collisions represent in the real world? How does probability play a role in modeling and simulation?	5 min

Learning objectives: Students will…

Complex Adaptive Systems	Learn that in complex adaptive systems one type of common interaction is of agents interacting with other agents. (LO21)
Modeling and Simulation	Create a simple model in which agents interact with other agents upon collision. (LO22) Use a random function to implement probabilistic outcomes/behaviors. (LO23) Learn the concept of random numbers. (LO24)
Computer Science	Understand the concept of collisions and bounding boxes around objects. (LO25)
Other	Learn mathematical concepts: probability; distributions resulting from 1 die and 2 dice throws. (LO26)

Assessments of understanding:

Complex Adaptive Systems	Which characteristics of complex adaptive systems can you identify in Colliding turtles?
Modeling and Simulation	Give an example of how agents interacting with other agents may be used to represent something in the real world. How does using probability impact the outcome when running simulations?
Computer Science	Identify variables used in Colliding Turtles.
Other	What is the difference in the outcome between "right turn random 90 degrees" and "right turn random 90 degrees followed by a left turn random 90 degrees"?

DAY 5: Modeling the Spread of Disease

Pacing Guide

Getting Started (Review)	Review of the previous day's lesson and concepts; connection to today's lesson.	5 min
Activity 1 (New Learning)	Introduction to Epidemiology: Methicillin resistant Staphylococcus Aureus and modeling the spread of disease as a complex adaptive system phenomenon.	10 min
Activity 2 (Guided Practice / Discovery)	Modeling the Spread of Disease: Altering colliding turtles to make an epidemic model; adding a slider for transmission rate; customizing the model by adding another factor (such as recovery rate).	30 min
Wrap up (Reflection)	What can this model tell you? Can it be trusted to tell us anything about the real world? What other things move through a population like a disease?	5 min

Learning objectives: Students will…

Complex Adaptive Systems	Learn about epidemiology and how epidemics can be modeled as complex adaptive systems. (LO27)
Modeling and Simulation	Alter the Colliding Turtles model to create the contagion model then use the contagion model as an experimental test bed. Conduct experiments, collect and analyze data.
Computer Science	Learn new CS concepts: procedures and variables. (LO29) Create and use sliders to set variables and initial conditions. (LO30) Create procedures and call procedures. (LO31)
Other	Use the random function to simulate probabilistic outcomes. (LO32)

Assessments of understanding:

Complex Adaptive Systems	Which characteristics of complex adaptive systems can you identify in the contagion model?
Modeling and Simulation	What are other things that spread through a population like a disease? How does using probability impact the outcome when running simulations? What assumptions are made in this contagion model?
Computer Science	How would you change the model to one in which sick agents get healthy again after colliding with a healthy agent?
Other	If time allows, discuss how model might be modified to reflect real world.

DAY 6: Adding Instrumentation to your model and running experiments

Pacing Guide

Getting Started (Review)	Review of the previous day's lesson and concepts; connection to today's lesson.	5 min
Activity 1 (Guided Practice)	Add instrumentation to your model: review qualitative vs. quantitative data, and add a line graph. Then test your model.	10 min
Activity 2 (Guided Practice / Discovery)	Running experiments: designing experiments, running experiments, and collecting and analyzing data output from models. Introduce the concept of parameter sweeps.	30 min
Wrap up (Reflection)	What patterns did you uncover? What conditions led to each pattern? Is the result of a simulation always the same?	5 min

Learning objectives: Students will…

Complex Adaptive Systems	Students will understand that computer models are used by scientists to study and understand real-world problems. (LO38)
Modeling and Simulation	Learn how to instrument a model with a line graph. (LO34) Learn experimental design using a computer model. (LO35) Conduct experiments using a model as an experimental testbed. (LO36) Record and analyze results. (LO37)
Computer Science	Learn how computer science is integrated into science through scientific inquiry using computer models and simulation.
Other	Learn the difference between qualitative vs. quantitative results. (LO33) Ask questions that arise from observations of your model's behavior. (SEP)

Assessments of understanding:

Complex Adaptive Systems	Which characteristics of complex adaptive systems can you identify in your epidemic model?
Modeling and Simulation	What is included and what is missing from your model? Name two things that happen in real life that are not part of this model.
Computer Science	How might you use computer science to investigate whether a new fad will spread through your school?
Other	If time allows, discuss how the model might be modified to help you study a real world disease.

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Lesson 1

Introduction to Complex Adaptive Systems and Computer Modeling and Simulation

50 minutes (1 day)

Lesson Overview

In this lesson students will participate in two activities. In the first activity is a participatory simulation called “Turn & Walk.” After playing the “game” consisting of following simple rules, students will see a computer model based on the same activity. Of particular interest is the comparison of real and virtual worlds and consideration of how a computer model might help us understand a phenomenon in the real world. Students will be exposed to characteristics of complex adaptive systems: many agents, simple rules, emergent patterns, and “adaptive” to change. In the second activity, students will be led “under the hood” and get an overview of some of the parts of a computer model.

Teaching Summary

Getting Started – 10 minutes

1. Pre-test / assessment (optional short survey to assess existing knowledge)

Activity #1: Turn and Walk – 25 minutes (New Learning)

2. Participatory Simulation
3. Computer model, teacher-led demonstration
4. Correspondence between real-world and virtual world
5. Under the hood: parts of a StarLogo Nova computer model

Activity #2: Introduction to Complex Adaptive Systems – 10 minutes (New Learning)

6. Video “Introduction to Complex Systems”
7. Characteristics of complex adaptive systems

Wrap-Up – 5 minutes (Reflection)

8. What are computer models good for?
9. Review of new terms used

Lesson Objectives

The student will:

- ✓ Experience being part of a complex adaptive system (LO1)
- ✓ Compare and contrast a computer simulation with a real-world phenomenon (LO2)
- ✓ See a demo of using a computer model to run experiments (LO3)
- ✓ Investigate the parts of a computer model (LO4)
- ✓ Speculate as to why computer models can be valuable scientific tools (LO5)
- ✓ Learn characteristics of complex adaptive systems (LO6)

Teaching Guide

Materials, Resources and Preparation

For the Students

- Pre-test/survey

For the Teacher

- Large open space
- Computer and projector
- Turn & Walk StarLogo Nova model
- Video link

Getting Started - 10 min

1. Pre-test / assessment (optional)

Activity #1: Turn and Walk - 25 min

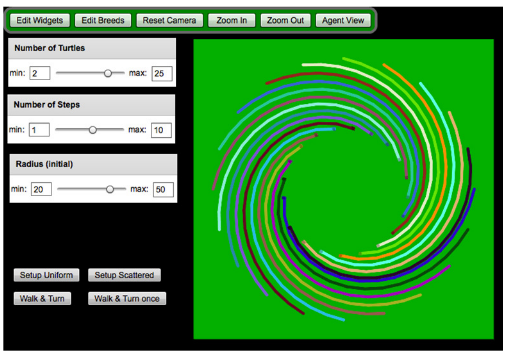
2. Participatory simulation

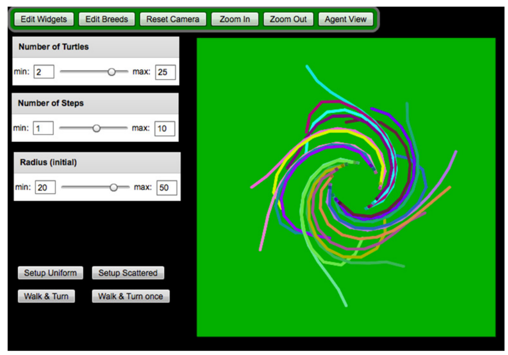
- Tell the students that in "Talk & Wurn" each student will play the role of an "agent" following "simple rules." Ask students to form a circle standing at least 5 feet apart. (You can also ask students, "How would you go about forming a circle if you all started out bunched up in the center of the space?")
- Next, explain the following rules: "Turn to face the person on your left while keeping this heading, take three steps." Demonstrate how agents are supposed to keep the same heading rather than adjust the heading at each step. If necessary, have the "agents" close their eyes when taking steps to keep the heading.
- Have students try it once then ask for predictions about what will happen if they repeat the rule over and over again. (Use the term "iteration" as "doing something over and over again.") (Practice 1: Asking questions and defining problems)
- Have students design and conduct an experiment and test their predictions in real life.

- After playing a few times ask what they observed and if their predictions were correct.
- Ask students what questions they have about the phenomenon. (Practice 1: Asking questions and defining problems)
- If they don't offer one, ask "What if, instead of forming a circle, you spread out randomly?"
- Ask what the result of following the simple rules would be if, at the start, the agents were scattered randomly, rather than arranged in a circle. Have students make predictions then conduct the experiment and test their predictions in real-life.

  Teaching Tip *In a large class, select 8-12 students to play the part of agents in the Turn & Walk participatory simulation. The other students can be "observers."*

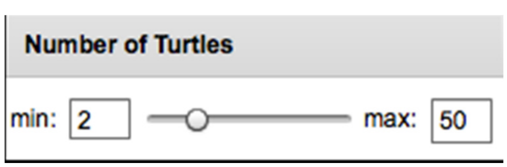
  Teaching Tip *To ensure that students keep their heading constant for three steps, have students close their eyes before taking three steps.*





3. Computer model, teacher-led demonstration

- Bring students back into the classroom and together look at a computer model of the Turn and Walk activity. Open the computer model and project it on a screen.
- Tell students that this is a computer model that was designed by a "modeler" to resemble the activity we just completed.
- Some aspects of the real world were included in the model; others were left out.
- Introduce StarLogo Nova as an agent-based modeling tool to be used by them. It has a user interface through which students will build a computer program.
- Demonstrate what is happening with agents starting in a uniform circle versus scattered.
- Using the computer model as a test bed, ask students what questions they would like to investigate or what experiments they would like to run, and what to change in the model in order to run experiments. (Practice 1: Asking questions and defining problems)
- Demonstrate running the experiment using the model as-is and change the settings one at a time. (Practice 2: Developing and using models)
- Demonstrate changing settings such as the number of agents or the size of the circle.
- Ask what other "variables" you could change. [number of steps to take, direction to turn (left or right)]



- Ask “What pattern do you see forming?” (CCC: Patterns)
- Ask “Does the same pattern emerge, regardless of the setting of the variable?”
- Ask “Does this model and its outcome match what we experienced in real-life?” and “What are some similarities and differences between the model and what we did in real life?” [Example: In the model, all people took the same size steps and they all followed directions, while in real life, people have different strides and don’t always follow directions.]
- Discuss the pattern or lack of pattern that the computer model produced. (CCC: Patterns)
- Ask “Was your prediction accurate?” (Practice: Analyzing and Interpreting Data)
- Does the real-life outcome match what the model generated? Why or why not?
- Ask “Did the outcome (the emergent pattern) match what happened the first time when students were in a circle?” and “Would we get the same pattern again if we scattered randomly again and followed the simple rules?”
- Explain that a system that adjusts to changes and produces similar patterns is called “adaptive” and that being adaptive is a characteristic of complex adaptive systems.

4. Correspondence between real-world and computer model?

- Discuss the relationship between the computer model and the real world phenomenon.
- What were some of the parts of the real world that were represented in the model?
- What was left out of the model? [stride length, people not following directions]
- What assumptions were made in the model? [people form perfect circles]
- Review the new terms used in this activity: agent, simple rules, heading, iteration, prediction, emergent patterns, random, initial condition, outcome, phenomenon, and adaptive.

  Teaching Tip *Keeping a “word wall” with new terminology and definitions is highly recommended.*

  Teaching Tip *Some teachers find it helpful to relate simulations to computer games but do so with caution. Computer games often have pre-determined conclusions or predictable behavior that was “programmed in,” but, in contrast, computer models of complex adaptive systems do not.*

5. Under the Hood: Start with a new project

- StarLogo Nova is an agent-based modeling tool. StarLogo Nova has a user interface, or way that a user can interact with it. Within StarLogo Nova you can build your “computer model” by building a computer program. Your computer program is your “project” that is stored online.
- Show the three areas of a StarLogo Nova User Interface (info, display, code)
  - The top part, called **the Information area,** is a place for you to give your model a title and record notes about your model.
  - The middle part, called **Spaceland,** is a 3D world where the agents are displayed. It consists of a green flat plane (called the terrain). Note that it has several buttons that can be used to control the simulation. The “**setup**” button, “**forever**” button and “**score**” box are called “**widgets**” or “user interface elements.”
  - The bottom part, called the **workspace** or **blocks area**, contains drawers of blocks that represent the programming commands, and pages where you snap the blocks together to write programs.

- Show some simple commands on blocks, and say that they snap together like Lego blocks.
- Show where these blocks are located in drawers and if time allows setup a simple sequence of steps and execute.

Activity #2: Introduction to Complex Adaptive Systems - 10 min

6. Watch the video "Introduction to Complex Systems" (http://youtu.be/CPHjsWSzOY0)

7. Review the characteristics of complex adaptive systems (Characteristics of CASv.pdf)

Wrap-Up - 5 min

8. What are computer models good for?
- Would you trust a computer model if your life depended on it?
  [What features of the real world are left out? Do those features matter?]
- What are models good for?
- New Terms: agent, simple rules, heading, iteration, prediction, emergent patterns, scatter, initial conditions, outcomes, phenomenon, and adaptive.

Assessment Questions

- How can computer models be used to learn about the real world?
- What kinds of things would you rather model on a computer than in real life?
- What are some key differences between a model and the real world?
- We've learned about three characteristics of complex adaptive systems (many interacting agents or parts, simple rules and emergent pattern). Given those characteristics, is a clock a complex adaptive system? Why or why not?

Background information (Optional reading assignment for students)

- What is a Complex Adaptive System? (What is a CAS.pdf)
- Characteristics of Complex Adaptive Systems (Characteristics of CAS.pdf)
- Feedback Loops (Feedback Loops.pdf)

Standards Addressed

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.
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 of a system (not for a proposed object or tool.)
2C: Use a model of simple systems with uncertain and less predictable factors.
2E: Use a model to predict and/or describe phenomena.
2G: 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
3D: Produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

3E: Collect data about the performance of a proposed system under a range of conditions.

Practice 4: Analyzing and interpreting data
4B: Use graphical displays to identify temporal and spatial relationships.
4D: Analyze and interpret data to provide evidence for phenomena.

Practice 5: Using mathematics and computational thinking
5A: Use digital tools (e.g., computers) to analyze data sets for patterns and trends.
5B: Use mathematical representations to describe and/or support scientific conclusions and design solutions.

Practice 6: Constructing explanations and designing solutions
6B: Construct an explanation using models or representations.

Practice 7: Engaging in argument from evidence
7C: Construct and present an oral argument to support or refute a model for a phenomenon.

NRC Crosscutting Concepts

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

3. 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.
3E: Phenomena that can be observed at one scale may not be observable at another scale.

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.

7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

CSTA K-12 Computer Science Standards

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 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.

Responsiveness to Varied Student Learning Needs

In Project GUTS, we integrate teaching strategies found to be effective with learners with various backgrounds and characteristics such as economically disadvantaged students (EDS), students from groups that are underrepresented in STEM (URG), students with disabilities (DIS), English Language learners (ELL), girls and young women (FEM), students in alternative education (ALT), and gifted and talented students (GAT).

In each lesson we describe the accommodations and differentiation strategies that are integrated in the activities to support a wide range of learners.

Module 1 Lesson 1 Activity #1: Turn and Walk

(EDS) *We validate the use of place [by situating the experiment within the school setting] to keep the students engaged and make a connection of science and school/neighborhood.*

(URG) *We use technology to present information in multiple modes of representations. We choose a modeling and simulation activity that involves student movement, a strategy that uses a multi-modal experience to increase student engagement.*

(DIS) *We use technology to present information in multiple modes of representations. We provide multiple means of action, expression, representation and engagement. These are all principles of Universal Design for Learning.*

Module 1 Lesson 1 Activity #2: Introduction to Complex Adaptive Systems

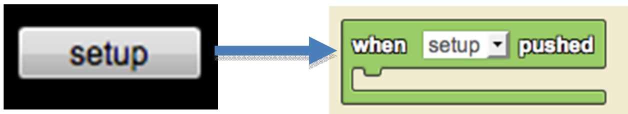
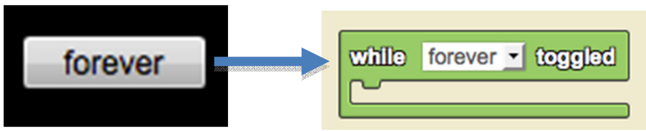
(EDS) *We validate the sense of place [by describing neighborhood phenomena such as traffic patterns and ecosystems as complex adaptive systems] to keep the students engaged and make a connection of science and neighborhood.*

(ELL) *We recommend using a word wall with words with photos or to represent concepts as a language support strategy for English language learners.*

(FEM) (URG) *We choose a curriculum topic, Complex Adaptive Systems, which has relevancy and real-world application, to interest and engage the girls and students from underrepresented groups in STEM in the class.*

StarLogo Nova Blocks introduced in Module 1 Lesson 1

Event Handling

	When “setup” (on the interface) is clicked, code blocks placed inside this block will run once.
	When “forever” (on the interface) is clicked it runs code blocks inside this block until “forever” is clicked again.

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Lesson 2

Introduction to StarLogo Nova and Building Flower Turtles

50 minutes (1 day)

Lesson Overview

In this lesson students will participate in two activities. The first activity is a guided introduction to the StarLogo Nova simulation environment. In the second activity, students will learn a few simple commands and then create their first computer program. Students will progress from single turtle explorations to instructing many turtles to follow their commands in parallel.

Teaching Summary

Getting Started – 5 minutes (Review)

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

Activity #1: Guided Tour of StarLogo Nova – 20 minutes (Guided Practice)

1. Guided tour
2. Observations and ethical considerations

Activity #2: Flower Turtles Challenge – 20 minutes (Discovery / Creative)

3. Pair programming
4. New StarLogo Nova commands
5. The Challenge

Wrap-Up – 5 minutes (Reflection)

6. What does Flower Turtles have to do with Modeling and Simulation?

Lesson Objectives

The student will:

- ✓ Learn that in complex adaptive systems one type of interaction is that agents impact their environment (LO7)
- ✓ Make a model in which agents impact their environment (LO8)
- ✓ Get comfortable with the StarLogo Nova programming environment (LO9)
- ✓ Make a program that contains simple instructions that are executed in a loop (LO10)
- ✓ Trace a program's execution (LO11)
- ✓ Change variables to alter turtle movement, use randomness (LO12)
- ✓ Use turn angles, random function, relative vs. absolute position and heading (LO13)

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- Student Activity sheet for Lesson 2, Activity 2
- Module 1 Lesson 1 & 2 Blocks reference (optional)
- Module 1 Lesson 1 & 2 CS Concepts (optional)

For the Teacher

- Computer and projector
- StarLogo Nova Guided tour handout
- Slide presentation with simple commands

Getting Started - 5 min

1. Review of previous day's lesson and link to where we are going today.

- What do computer models let you do that you cannot in real life?
- What was NOT captured in the Turn & Walk model that happened in real-life?

Activity #1: Guided Tour of StarLogo Nova - 20 min

2. Guided tour

- Teacher-led overview of the first pages of the Guided Introduction from creating a new project to end of Flower Turtle project.
- Assign partners to share a computer or work individually.
- Have students progress through the new project, completing each task before moving on.

3. Observations and ethical considerations

- What did you notice about the way the StarLogo Nova drawers are organized?
- What does it means to be a web-based environment – where does my program live?
- What does it mean to REMIX a program? Is it cheating?

Teaching Tip *This guided tour activity can be run as a group activity by asking a pair of students to come up to the projecting computer and attempt to complete a task in front of the class before moving on to the next task with a new pair of students demonstrating.*

Activity #2: Flower Turtles - 20 min

4. Pair programming

- Describe the roles of navigator and pilot.
- "We will be using a programming practice called 'Pair Programming.' In this practice two people are paired to work together on a project. One person takes the role of the navigator who tell the other person, the pilot, what to do. The pilot listens to the navigator and puts the blocks in place. After 10 minutes I will tell you to switch roles and keep on working."
- Let students know that they are to switch roles after 10 minutes on your command.

5. New commands

- Review the commands: create agents, forward, left by __ degrees, pen down, when ___ pushed, and while ___ toggled.
- Show new StarLogo Nova commands: right by __ degrees, backward, and random.
- Review a basic framework (setup and runtime) and tell students that they are going to create their own Flower Turtles program by programming or giving the agents instructions.
- Ask students to start a new project (from the 'My Profile' page.

6. Flower Turtle Challenge optional extensions

- Have students remix their Flower Turtle projects.
- Give the students the specifications for the program. It must do the following: Create turtles, have the turtles move around the space leaving trails, and have a wiggle to their walk. [Hint: use the random block inside of the right and left turn block to introduce randomness into a turtle's walk. We call this a "wiggle."]
  (CT-Algorithms 3A-3; CT-Data representation 3A-12)
- If time allows, have the students upload and share their projects.
- If time allows, talk about the execution model. Why does execution order matter?

Wrap-Up – 5 min

7. What does Flower Turtles have to do with Modeling and Simulation?

- What could these trails represent? (CT-Modeling and simulation 2-9)
- Review the new terms used: agent, location, heading, steps, iteration, setup, runtime, random.

Assessment Questions

- Is Flower Turtles a model of a complex adaptive system? Why or why not?
- What variables were used in Flower Turtles and the extension?
- What is the difference between turning 90 and turning random 90?
- Is the painting made by turtles repeatable? If I run the program again, will it produce the same drawing? Why or why not? (CPP-Data collection & analysis 2-9; CT-Modeling & simulation 2-9)

Background Information

Guided Introduction to StarLogo Nova

Standards Addressed

CSTA K-12 Computer Science Standards

CT	Algorithms	3A-3	Explain how sequence, selection, iteration and recursion are the building blocks of algorithms.
CT	Modeling & simulation	2-9	Interact with content-specific models and simulations to support learning and research.
CPP	Data collection & analysis	2-9	Collect and analyze data that are output from multiple runs of a computer program.
CPP	Programming	2-5	Implement a problem solution in a programming environment using looping behavior, conditional statements, logic, expressions,

Responsiveness to Varied Student Learning Needs

In Project GUTS, we integrate teaching strategies found to be effective with learners with various backgrounds and characteristics such as economically disadvantaged students (EDS), students from groups that are underrepresented in STEM (URG), students with disabilities (DIS), English Language learners (ELL), girls and young women (FEM), students in alternative education (ALT), and gifted and talented students (GAT).

In each lesson we describe the accommodations and differentiation strategies that are integrated in the activities to support a wide range of learners.

Module 1 Lesson 2: Guided Tour of StarLogo Nova and Flower Turtles

(URG)(DIS) *We use technology to present information in multiple modes of representations. In the StarLogo Nova modeling and simulation environment students can present information as code blocks, text, visual imagery, and as data in tables and graphs.*

(FEM) *We recommend careful planning of partners for pair programming in the Guided Tour and Flower Turtles on-computer activities, a practice that encourages participation for the girls in science.*

Guided Introduction to StarLogo Nova

Reference Guide for Teachers

Who is this for?
This is a Guided introduction to StarLogo Nova that was designed for teachers and students. Teachers participating in the Code.org Project GUTS Middle School Computer Science in Science Program are being asked to complete the tutorial before showing up to the face-to-face workshop.

What is StarLogo Nova?
StarLogo Nova is an agent based modeling (ABM) environment that was created by the Scheller Teacher Education Program at Massachusetts Institute of Technology. StarLogo Nova is the newest version in a long line of Logo based educational environments. StarLogo Nova is special because it is entirely web-based. Since it is web-based, you do not need to download or install any software on your computer or school's server.

Where can I find it?
To get started in StarLogo Nova, all you need to do is go to slnova.org and request an account.

When will I use it?
In Code.org's Computer Science in Science modules we will use StarLogo Nova to build and experiment with models of complex adaptive systems within regular school day classes.

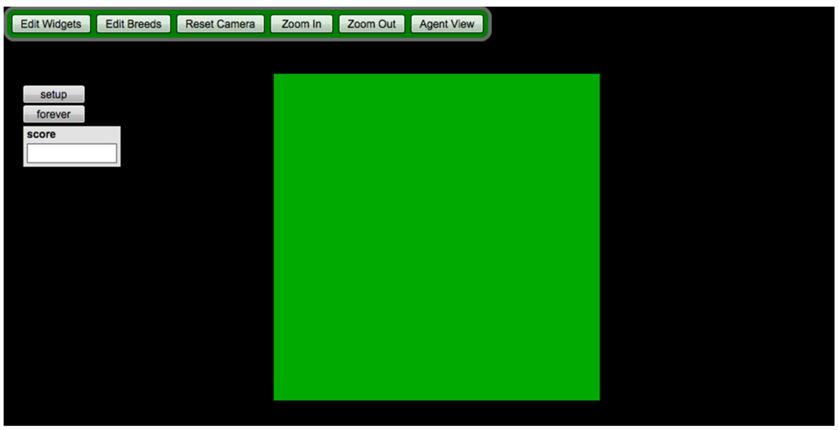
Why is this important?
StarLogo Nova gives students and teachers access to tools, similar to those used by scientists and researchers, with which to study systems in the world around them.

Now let's move on to some background information and a tour.

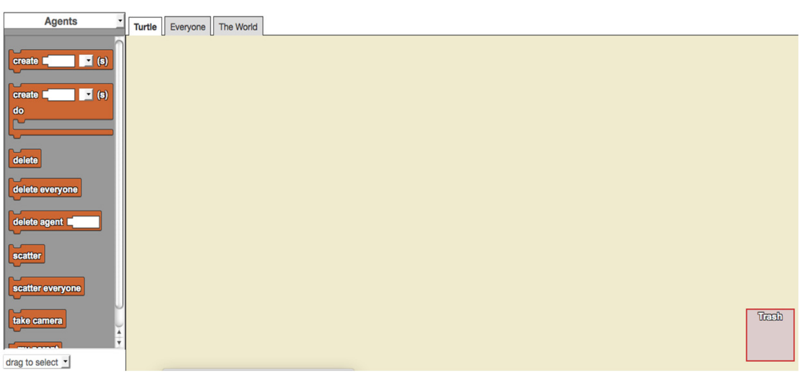
The StarLogo Nova User Interface:

The StarLogo Nova User Interface is made up of three parts.

The top part, called **the Information area,** is a place for you to give your model a title and record notes about your model.



The middle part, called **Spaceland,** is a 3D world where the agents are displayed. It consists of a green flat plane (called the terrain). Note that it has several buttons that can be used to control the simulation. The "**setup**" button, "**forever**" button and "**score**" box are called "**widgets**" or "use interface elements".

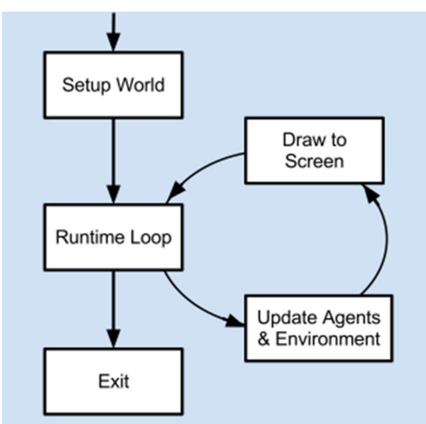


The bottom part, called the **Workspace or blocks area**, contains drawers of blocks that represent the programming commands, and pages where you snap the blocks together to write programs. Programming is basically putting together a logical sequence of instructions.

The StarLogo Nova Modeling and Simulation Paradigm

In StarLogo Nova, a model consists of the environment or terrain, the agents who represent individual characters in the model (whether they are water molecules, fish, or even humans), and interactions. Interactions can take place between agents and their environment or agents and other agents.
A "model" is the virtual world you set up in StarLogo Nova. It can contain agents, the environment and behaviors that have been specified in computer code. We call "running the model" forward in time "Simulation."

There are two main phases in Simulation. The first phase is called the "Setup" or "Initialization" phase in which the world and the agents are created. The second phase is called the "forever" or "runtime" phase. In this second phase, each agent follows its set of instructions then waits for the other agents to finish their set of instructions before taking another turn. Before taking another turn, time moves forward, and Spaceland gets redrawn with the updated state of the world and the agents.



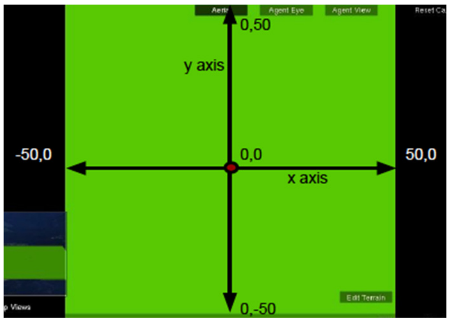
There are three major parts of any agent-based model: agents with rules that they follow, the environment in which they coexist, and time. In StarLogo TNG, the first two are easy to see – the agents are the different turtles and the environment is made up of square tiles called patches. Time is harder to see, instead it can be thought of as a series of time slices or "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.

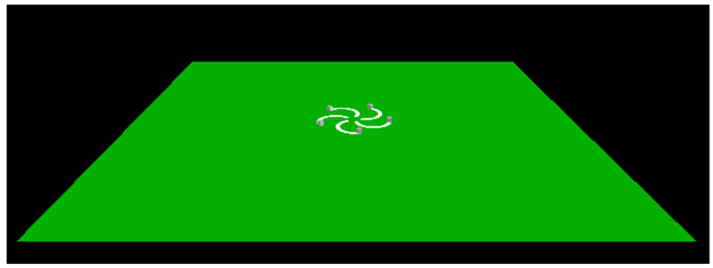
As a modeler, you decide what gets included (and what gets left out) of the model, and you get to write the instructions that tell each agent what behaviors to carry out.

StarLogo Nova Components:

Terrain

The Terrain is a coordinate plane that is 101 tiles long by 101 tiles wide. The center of the terrain has coordinate (0,0). You can see different views of the terrain by maneuvering the "camera" using the control, option, and command keys. Simply click on the key and click and drag on the terrain. Try seeing the world from various perspectives.



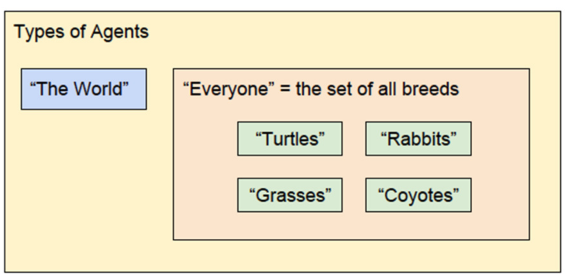


Heading of Agents

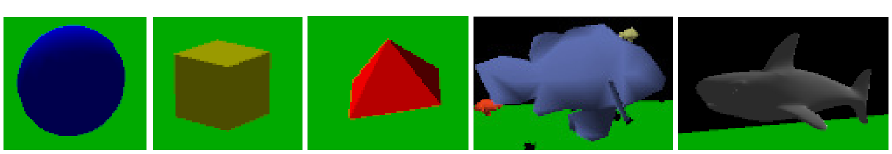
When turtles are created, they are facing out from the center. To have your turtles go in a specific direction you will need to set their heading, which is based on the degrees in a protractor. Notice the start of the circle is at 0 degrees, which also becomes 360 degrees after going around the circle. To go towards the top of Spaceland, the turtle would need to set its heading towards 90 degrees.

Agents and Breeds

Agents can take on different characteristics and behaviors. We often call agents "turtles" for historical reasons – the first agents in Logo were robot like "turtles". Each agent can be represented by a 3D model. You can select shapes for your agents from the library of 3D models.



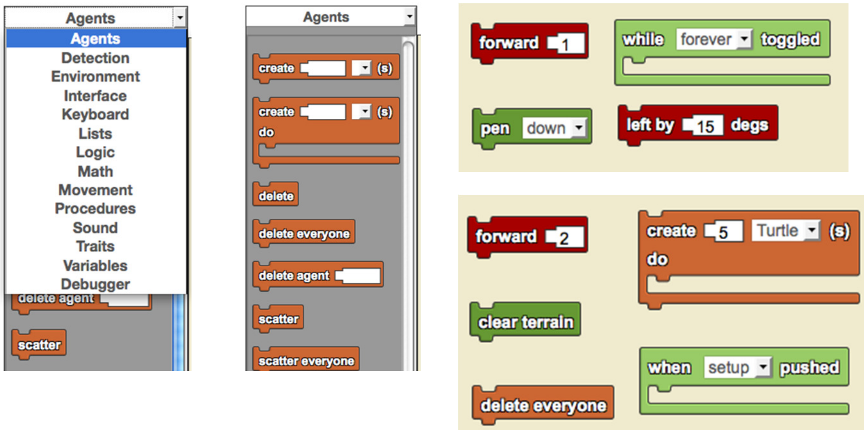
There can be many different types of agents within a model. Each different type of agent is called a breed. For example, in a model of rabbits and coyotes, the rabbits can be one breed of agents while the coyotes can be another breed of agents. "Everyone" refers to all of the agents except for "The World". "The World" is a special "super" agent that is responsible for setting up the world and creating the other agents.



Agents can be represented by 3D models from basic shapes to creatures.

Blocks and Drawers

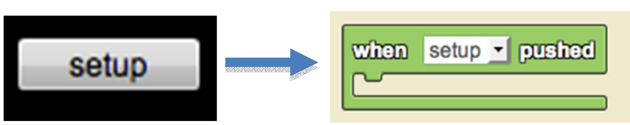
Blocks are the instructions that make up the program. There can be many different kinds of blocks that make up a program. Blocks are organized in drawers by function.

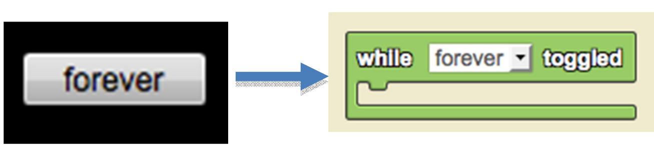


Pages and Procedures

Pages are areas where the user organizes blocks to control the different agents. There are initially three different pages: Turtle, Everyone, and the World. The blocks in the Turtle page are the instructions the turtle agents follow. When you create new breeds, new pages appear for them. Turtles are the starter breed of agents so there is a "Turtle" page by default.

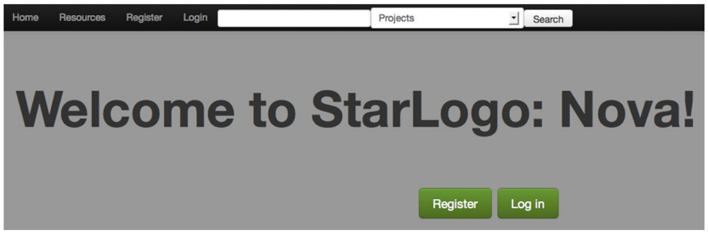
Procedures are stacks of blocks that are executed or "run" when either the user clicks a button, or when the program asks the agents to take their turn.

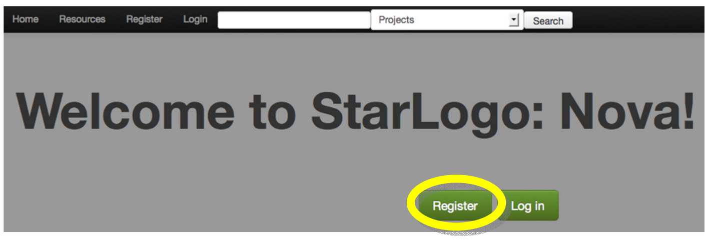


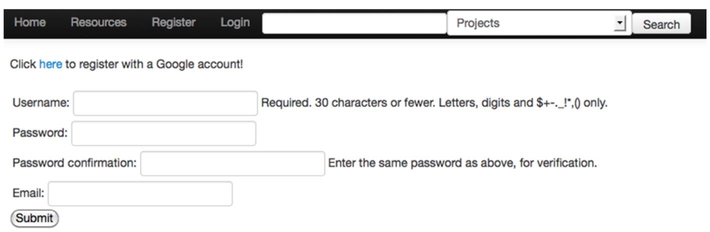


Now that you know the basics, let's get started on the Tutorial.

Part 1: Create a StarLogo NOVA account and log in

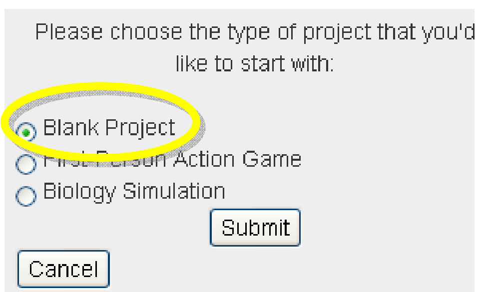
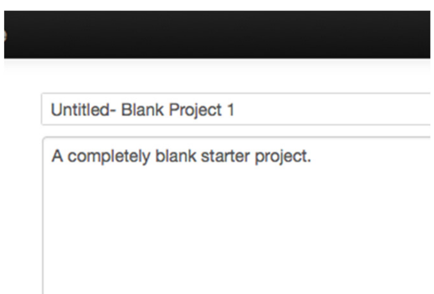
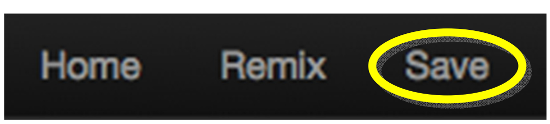
<table>
<tr>
<td>


</td>
<td>1) In a web browser with an internet connection, open a browser window and navigate to www.slnova.org the StarLogo Nova home page.</td>
</tr>
<tr>
<td>


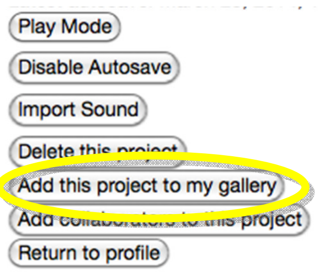
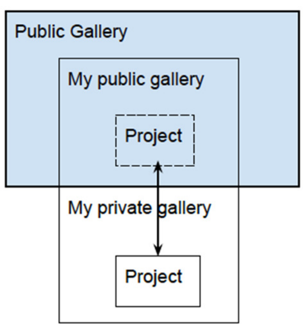
</td>
<td>2) If you don't already have a StarLogo Nova account, click the Register link and follow the instructions.</td>
</tr>
<tr>
<td>


</td>
<td>3) Enter a username, a password, and an email address, then click "Submit".</td>
</tr>
<tr>
<td colspan="2">Congratulations! You now have an account on StarLogo Nova! When you set up your account you get your own public and a private gallery. A gallery is a place to store and display your projects. You also get your own personal "profile" page. Through your profile, you can access the projects you make and projects that have been shared with you.</td>
</tr>
</table>

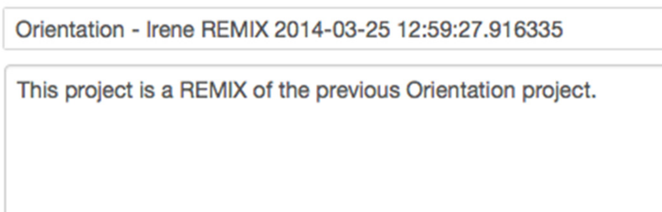
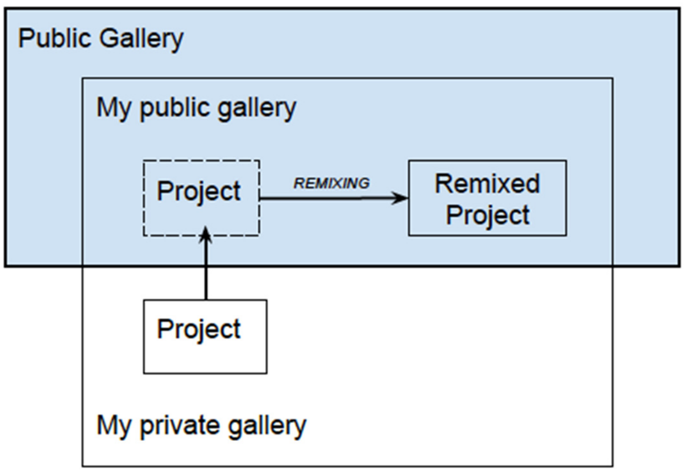
Part 2: Create a StarLogo NOVA project

	1) After logging in successfully, click on "My Profile" in the upper right hand corner of the information area. You will see options for editing user settings.
	2) Click the "Create a new project" button to open a new project.
	3) Choose "Blank Project" and click "Submit".
	4) You will see a new project appear with the title "Untitled-Blank Project 1". You can replace the title with anything you prefer. Then where it says "A completely blank starter project." type something descriptive into the text box. The titles and descriptions are searchable so it's a good idea to give good information in these areas.
	5) Hit "Save". This project is now saved in your Private Gallery. (All new projects get saved in the Private Gallery by default.)
Congratulations! You have now created and saved your first StarLogo Nova project.	

Part 3: Share your project

	1) Click on “Add this project to my gallery” and select your “public gallery” as the destination for this project. You will notice that your project is now shared between your public gallery and your private gallery. Once a project is in your public gallery, it can become a shared project where multiple collaborators can edit the project. Check that you can now see your project in your public gallery.
	2) Click on “My Profile” to get back to your profile page.
	3) Once there, you can see the project in your Public Gallery. Clicking on the project title will open the project.
	4) Let’s review what you just accomplished. You created a new project in your private gallery then you added the project to your public gallery. Your project can now be shared with others. AND you can see other user’s projects in their public galleries as well. Note that there is only one version of the project. It can be reached from both your public and private galleries.
Congratulations, you have shared your StarLogo Nova project through your public gallery!	

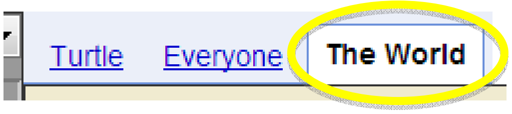
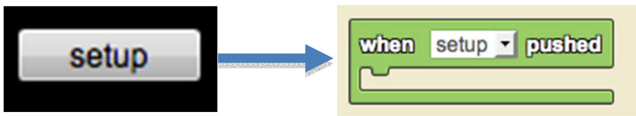
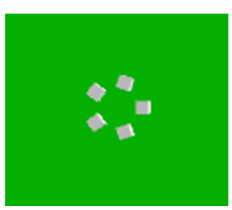
Part 4: Remix your project

<table>
<tr>
<td>
</td>
<td>1) Click “Remix” to create a new version of your project.</td>
</tr>
<tr>
<td>
</td>
<td>2) Remix is similar to “Save As” – it preserves your previous version and saves you a new version with the name “REMIX” and a timestamp at the end of the project name. You can change the name of the project and edit the info text as well.</td>
</tr>
<tr>
<td>
</td>
<td>3) Each time you remix a model, the remixed version appears in the same gallery where the original was located.

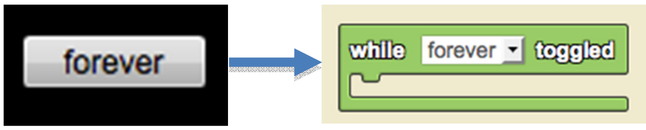
So if you remix a project in your public gallery, the remixed version is also in your public gallery. But if you remix a project in your private gallery, the remixed version is also in your private gallery.</td>
</tr>
<tr>
<td>
</td>
<td>4) Click on “My Profile” to get back to your profile page.</td>
</tr>
<tr>
<td colspan="2">Hooray, you’ve learned how to remix a project.</td>
</tr>
</table>

Flower Turtles Project

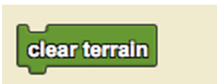
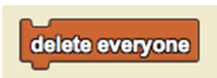
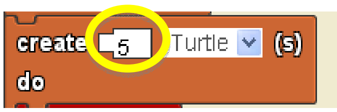
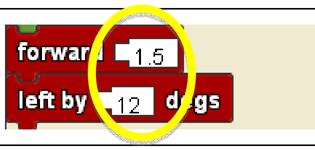
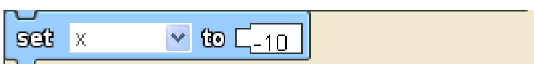
Create Agents

	1) Click on the page tab to switch to "The World" page.
	2) Bring out the following blocks to create a set of instructions for the Setup button.
	3) Here's what the blocks do: The "**when setup pushed**" block on the World Page tells the world what to do when the setup button is pushed. The "**create-do**" block allows users to create particular numbers of agents of certain type or breed, then have each of the newly created agents perform the commands within the "do" area right away. The "**clear terrain**" block erases any drawing on the terrain. The "**delete everyone**" block gets rid of any agents in Spaceland. The "**forward**" block moves the agent forward.
	4) Try combining the blocks so that when the setup button is pushed, five turtles are created and each of the turtles moves forward 2 steps away from the center of Spaceland. After making changes to your program, always click "Save" to save your changes, and always click "Run Code" before running your project.
 	5) Check Your Progress: Scroll/Swipe back up to Spaceland, and click the "setup" button. When you've successfully assembled these blocks, you should see a set of white blocks (the agents you created) in the center of Spaceland.
Congratulations! You've created your first agents. Notice that they were all "born" in the center of Spaceland at coordinate (0, 0) facing outward, then they took 2 steps forward just as you instructed them to.	

Making your turtles move

<table>
<tr><td></td><td>1) Click on the “Turtle” tab to switch to the “Turtle” page.
The turtle agents will run the blocks you assemble here.</td></tr>
<tr><td></td><td>2) Now it is your task to put the blocks together into a procedure so that the turtle agents will each draw a circular flower petal when the forever button is toggled on. (A toggle is like a light switch, it is either on or off.)</td></tr>
<tr><td></td><td>3) Let’s review what the blocks do:
The “when forever toggled” block on the Turtle Page tells the turtles what to do when the “forever” button is toggled to the ON position.
The “pen down” block tells each turtle agent to leave a trail wherever it goes.
The “forward” block moves the agent forward.
The “left by __degrees” block tells each turtle to turn left by some number of degrees.</td></tr>
<tr><td></td><td>4) Try combining the blocks so that when the forever button is pushed, each of the five turtles draws a petal of the flower.
Don’t forget to click on “Save” to save your changes. To test your changes, click “Run Code” and then use the user-interface buttons (setup and forever) in Spaceland.</td></tr>
<tr><td></td><td>5) Check Your Progress:
Scroll back down to Spaceland, and click the “forever” button. You should see a set of white blocks (the agents you created) drawing a flower.</td></tr>
<tr><td colspan="2">Congratulations! Your turtle agents drew a flower! If time, try the extensions.</td></tr>
</table>

Extensions (for those who want an additional challenge)

If you'd like to try these extensions, remix your Flower Turtles project and name it Painting Turtles	
	Use "clear terrain" to erase any existing drawing on the terrain between drawings.
	Use "delete everyone" to get rid of all existing agents between drawings.
	Extension #1: Try to change the number of flower petals.
	Extension #2: Draw a flower with square petals instead of round petals. [replace the number of steps and the degrees to turn]
	Extension #3: Change the color of the flowers.
	Extension #4: Change the starting location (x, y) of agents.
Define or identify the following terms: Workspace, SpaceLand, Information area, Terrain, Page, Drawer, Blocks, Buttons, Widgets, Agents.	

Lesson 2 - Student Activity #2 Guide

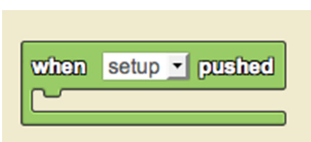
Flower Turtles: Have your turtles paint a masterpiece!
Your challenge is to make the turtles draw a flower pattern on Spaceland and to experiment with different kinds of turtle movement.

Note: Make sure to REMIX the project if you do any of the extensions.

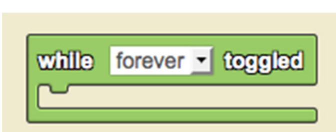
<u>Guidelines</u>: What your project needs to do

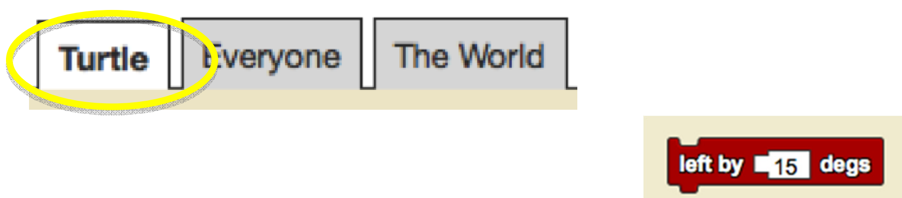
1. Start a new blank project.
2. Name it: Flower Turtles. If working in pairs, don't forget to put both partners' names in the project title.
3. **Create 5 turtles** that separate by 2 steps when the setup button is pressed.
4. **Have the turtles move and leave trails with their pens down** when the forever button is toggled.
5. When you are done, save and share your project.
6. If time, try some extensions.

In the World Page



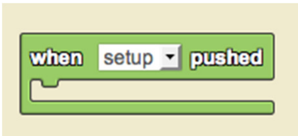
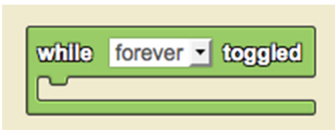
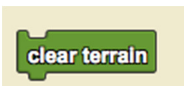
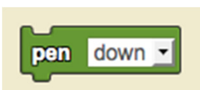
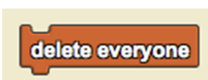
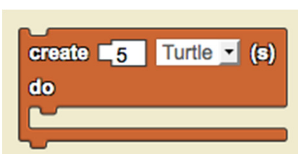
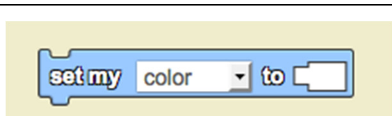
In the Turtle Page





Extensions:
1- Try changing the number of turtles created and scattering them.
2- Experiment with adding a slight wiggle to the turtle's walk using the random command block. The random block can be used in place of a number anywhere a number could fit.

StarLogo Nova Blocks introduced in Module 1 Lesson 2

	Executes commands when the push button widget is pressed. Widgets can be created using the *Edit Widgets* feature.
	Executes commands when the toggle button widget is turned on. When the toggle button widget is turned off, nothing occurs. Widgets can be created using the *Edit Widgets* feature.
	Removes all stamping or drawing modifications done to the terrain.
	Adjusts the pen tool. If the pen is down, the agent stamps the terrain at each position as it moves along the terrain. If the pen is up, the agent does not stamp the terrain.
	Deletes all agents.
	Creates a specific number of agents of the specific breed. Attach other blocks to specify traits and properties of these agents. Additional breeds are created in the interface.
	Moves an agent forward by a certain number of steps.
	Moves an agent backwards by a certain number of steps.
	Rotates an agent left by a certain number of degrees.
	Rotates an agent right by a certain number of degrees.
	Sets an agent's trait to a particular value.

scatter	Places agents in random positions on the terrain.
random	Returns a random integer from 0 to the input but NOT including the number entered (non-inclusive).
left by random degs	Random can be used in place of a number anywhere a number would fit. In this example instead of having a constant turn angle, an agent following this command would turn different amounts each time this command was executed.

1

Lesson 3

Conditionals with Trailblazer and Bumper Turtles

50 minutes (1 day)

Lesson Overview

In this lesson students will participate in two activities. In the first they will learn about conditionals, logic, and Boolean expressions as they guide an agent through a puzzle. They also consider the best path / solution and the degree of universality of their solution. In the second activity, students will learn a few simple commands and then starting with a basic project, implement a Bumper Turtles program in which agents respond to their environment.

Teaching Summary

Getting Started – 5 minutes (Review)

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

Activity #1: Trailblazer – 20 minutes (Guided Practice)

2. Blazing a Trail and Comparing solutions
3. New Concepts: conditionals and Booleans

Activity #2: Bumper Turtles – 20 minutes (Discovery / Creative)

4. Introduce new StarLogo Nova commands
5. The Challenge

Wrap-Up – 5 minutes (Reflection)

6. What does Bumper Turtles have to do with Modeling and Simulation?
7. What does Bumper Turtles have to do with complex adaptive systems?

Lesson Objectives

The student will:

- ✓ Learn that in complex adaptive systems one type of common interaction is that agents react to their environment (LO14)
- ✓ Create a model in which agents react to their environment (LO15)
- ✓ Trace a program's execution (LO16)
- ✓ Experiment with adding conditionals to their agents' behavior (LO17)
- ✓ Learn computer science concepts of Booleans, logic, and conditionals (LO18)
- ✓ Practice Pair Programming and Iterative design, implement, test cycle (LO19)
- ✓ Compare solutions to a problem using number of steps or number of instructions used (LO20)

Teaching Guide

Materials, Resources and Preparation

For the Students

- Student Activity Sheets (Trailblazer and Bumper Turtles)
- Three colors of pens (black, red and blue)
- Pencils and erasers
- Computers
- Module 1 Lesson 3 CS Concepts reference
- Module 1 Lesson 3 Blocks reference

For the Teacher

- Computer and projector
- Slide presentation

Getting Started - 5 min

1. Review of previous day's lesson and link to where we are going today.

- What commands enabled turtles to impact their environment?
  [pen down, delete everyone, clear terrain]
- What could an agent leaving trails represent in a real world scenario?
- Next we are going to learn how turtles can **react** to their environment.

Activity #1: Trailblazer - 20 min

Learning how to build a StarLogo Nova model requires students to learn how to translate an initial idea of what the turtles should do into specific instructions of how they should do it. These sets of instructions in computer science are called Algorithms. In this activity, participants will specify directions to help others recreate the safe path through a tangled maze without ever seeing it. Later we will draw a direct analogy to the conditional instruction used in programming the same behavior.

2. Blaze a trail (see student activity worksheet for details)

- Pass out Student Activity #1 handout.
- Assign partners to work together.
- Have students start at the designated start arrow position and heading.
- Have students draw the path in order to pick up all the gold while avoiding the hazards.
- Instruct the students that it is important that they use a pencil and that they draw the path in the middle of the squares.
- Have students draw landmarks as necessary to "pick up" gold while avoiding the "hazards."
- Players should create colored landmarks on the paper telling the other player where to go according to the following rules:
  - **Take a step forward.**
  - **If you are standing on a RED square, then turn right by 90 degrees**
  - **If you are standing on a BLUE square, then turn left by 90 degrees**
  - **If you are standing on a BLACK square, then turn right by 180 degrees**

  The goal is to place enough landmarks so that the turtle will follow the entire path from beginning to end.
- When a student has completed laying down landmarks, have him/her trade with the partner.
- The partner's task is to follow the trail and make it to the exit, picking up all the gold and avoiding the hazards. If not, what went wrong?
- When all participants have finished, ask them to compare their results.
- Conclude by asking: How many people were able to accurately follow their partner's path? Were there any mistakes made? (Did some people forget certain color blocks or use the wrong colors?)
- What strategies resulted in the most successful path followings?
- Is there more than one right solution?
- How would you decide which solution is the best?
- Trailblazers and Algorithms: You can think of the colored marks in Trailblazers as forming a set of instructions, just like a computer program. In computer science, a set of instructions that perform a function is called an "Algorithm." An algorithm is sort of like a recipe that tells you how to do something.
  - Is there only 1 correct algorithm for the Trailblazer map?
  - Some algorithms will only work under certain conditions. For instance if there was a different map of gold, the location of the blue, red and black squares will not be effective.

  Teaching Tip *This activity can be demonstrated on a large tiled floor using cans and objects as landmarks.*

3. New concepts: conditionals and Booleans

- Introduce a new CS construct called conditionals.
- Introduce the commands IF/THEN and IF/THEN/ELSE.
- Introduce Booleans as statements that evaluate to TRUE or FALSE.
- Demonstrate how Booleans and conditionals work together to enable branching.

- Have students come up with example IF/THEN statements from everyday life.

  BRANCHING WITH CONDITIONALS
  In addition to simple stacks of commands as we did in the Drawing a Flower and Painting Turtles projects, we can instruct a computer to execute different stacks of commands depending on the circumstance or condition. For example, we might want to write different behaviors for a coyote agent based on a condition. If it runs into a rabbit then chase the rabbit BUT if it runs into a mountain lion, run away from the mountain lion.

  To do this, we use a statement called a CONDITIONAL statement. It looks like this:

  > IF (something is true) THEN (do this)

  So using our example, our conditional statements would look like this:

  > IF (Rabbit nearby) THEN (Chase the Rabbit)
  > IF (Mountain Lion nearby) THEN (Run away from Mountain Lion)

  The (something is true) part is called a BOOLEAN expression or an expression that evaluates to TRUE or FALSE.

  > (Rabbit nearby) could evaluate to TRUE or FALSE.
  > (Mountain Lion nearby) could evaluate to TRUE or FALSE.

  CONDITIONAL STATEMENTS and BOOLEAN expressions work together. The THEN part of the CONDITIONAL STATEMENT only gets executed if its BOOLEAN expression evaluates to TRUE.

  Another type of CONDITIONAL STATEMENT is the IF/THEN/ELSE STATEMENT. With this statement the THEN part gets executed if the BOOLEAN expression evaluates to TRUE. The ELSE part gets executed if the BOOLEAN expression evaluates to FALSE.

  Think about when this might come in handy: What if you were the coyote and had a rabbit and a mountain lion in front of you at the same time. How would you use the IF/THEN/ELSE command to make sure you take the right action?

Activity #2: Bumper Turtles - 20 min

4. Introduce new commands

- Show new StarLogo Nova command blocks (slide presentation).
- Review commands used during last class.

5. The Bumper Turtles Challenge

- Open up the Bumper Turtles Starter program. (look for it in the Project GUTS Module 1 gallery)
- Remix and change title.
- Don't forget to put both partners' names in the project title.
- See that there is already code for the Paint Landmarks button. This should not be changed.
- Setup button already has code to create 4 turtles.

- Use conditionals to have the turtles react to the colored squares.
- Trace through code and talk about the order in which commands are executed.
- Does execution order matter?

Wrap-Up - 5 min

6. **What does Bumper Turtles have to do with Modeling and Simulation?**
   - What could these trails and bumpers represent?
   - Review the new terms used in this activity: conditional, Boolean, branching.

7. **What does Bumper Turtles have to do with complex systems?**
8. **Give an example of algorithms that are in Bumper Turtles.**

Assessment Questions

- Is Bumper Turtles a model of a complex adaptive system? Why or why not?
- How would you assess the "best" solution? [time taken, steps taken, fewest instructions]
- What is the difference between if/then blocks in a row vs. nested if/then/else statements?
- In your own worlds, how can the if/then logic block be used in a computer model to give an agent a behavior?
- Is the path taken by turtles repeatable? If I run the program again, will it produce the same drawing? Why or why not?

Standards Addressed

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.

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.
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 4: Analyzing and interpreting data
4B: Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
4E: Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.

Practice 5: Using mathematics and computational thinking
5A: Use digital tools (e.g., computers) to analyze data sets for patterns and trends.
5C: Create algorithms (a series of ordered steps) to solve a problem.

NRC Crosscutting Concepts

1. 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.

2. Cause and Effect:
2A: Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
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	Algorithms	1:6-2	Develop a simple understanding of algorithms using computer-free exercises.
CT	Algorithms	2-4	Evaluate ways that different algorithms may be used to solve the same problem.
CT	Algorithms	3A-3	Explain how sequence, selection, iteration and recursion are the building blocks of algorithms.
CT	Data representation	2-8	Use visual representation of problem state, structure and data.
CT	Modeling & simulation	2-9	Interact with content-specific models and simulations to support learning and research.
CPP	Data collection & analysis	2-9	Collect and analyze data that are output from multiple runs of a computer program.
CPP	Programming	2-5	Implement a problem solution in a programming environment using looping behavior, conditional statements, logic, expressions,
CPP	Programming	3A-3	Use various debugging and testing methods to ensure program correctness.

Responsiveness to Varied Student Learning Needs

In Project GUTS, we integrate teaching strategies found to be effective with learners with various backgrounds and characteristics such as economically disadvantaged students (EDS), students from groups that are underrepresented in STEM (URG), students with disabilities (DIS), English Language learners (ELL), girls and young women (FEM), students in alternative education (ALT), and gifted and talented students (GAT).

In each lesson we describe the accommodations and differentiation strategies that are integrated in the activities to support a wide range of learners.

Module 1 Lesson 3: Trailblazer and Bumper Turtles

(URG) *We involve students in working in small groups for the Trailblazer table-top game/activity, a strategy that uses a multi-modal experience to increase student engagement.*

(DIS) *Across both Trailblazer and Bumper Turtles, we provide multiple means of action, expression, representation and engagement by introducing a game and a design and build programming activity that build on the same underlying concepts. These are all principles of Universal Design for Learning.*

(URG)(DIS) *We use technology to present information in multiple modes of representations. In the StarLogo Nova modeling and simulation environment students can present information as code blocks, text, visual imagery, and as data in tables and graphs.*

(FEM) *We recommend careful planning of partners for pair programming in the Bumper Turtles activity, a practice that encourages participation for the girls in science.*

Lesson 3 - Student Activity #1 Guide

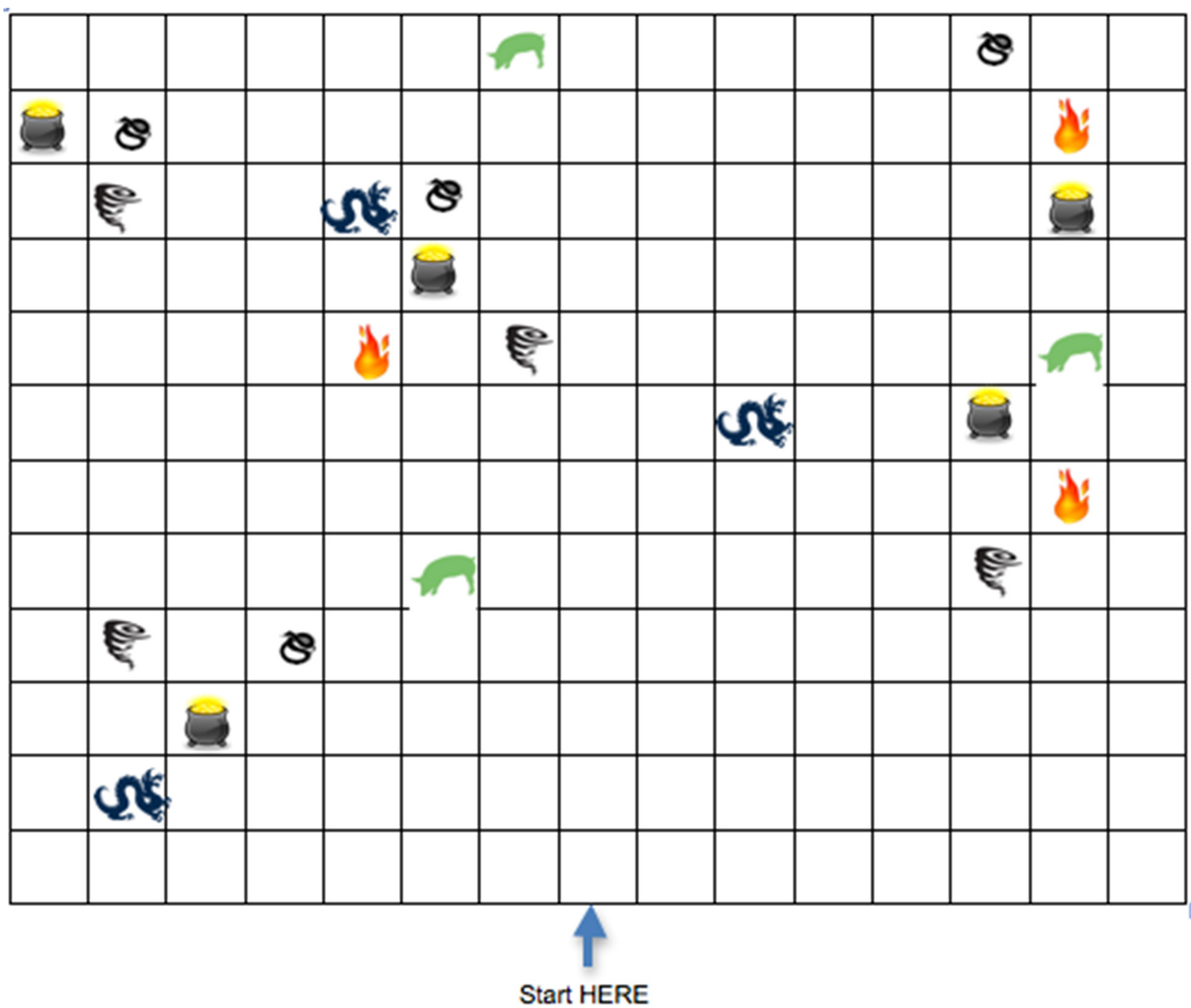
Trailblazer

Instructions and playing board

How to play: On the map, START at the designated position and heading in the direction of the arrow. Using a pencil, draw the path in the CENTER of squares. Pick up ALL the gold while avoiding the hazards, ending at START. Color the squares as necessary according to the following rules:

- **Take a step forward.**
- **If you are standing on a RED square, then turn right by 90 degrees**
- **If you are standing on a BLUE square, then turn left by 90 degrees**
- **If you are standing on a BLACK square, then turn right by 180 degrees**

Trade your map with a partner and figure out if following the landmarks leads you along the path to collect all of the gold while avoiding the hazards.



Lesson 3 - Student Activity #2 Guide

Bumper Turtles

- Start with the model "Bumper Turtles starter". (Teacher provides the link.)
- This starter model already has a button called "Paint Landmarks" and some coding associated with it.
- Click on the "Paint Landmarks" push button and see the program execute the code provided.

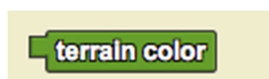
Your challenge is to make the turtles react to the landmarks created by the "Paint Landmarks" procedure, following the rules laid out in the Trailblazer activity.

Note: DO NOT make changes to the "Paint Landmarks" procedure.

<u>Guidelines</u>: Have the turtles check the terrain color they are standing on

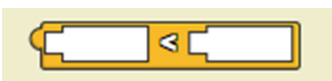
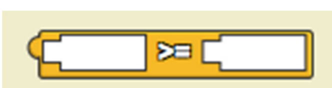
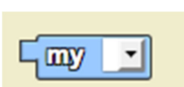
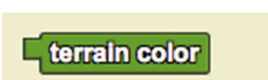
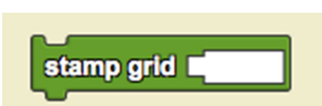
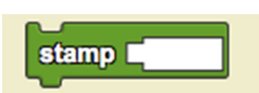
1. Remix the "Bumper Turtles starter" model, add your name(s) to the title of the project.
    a. If working in pairs, don't forget to put both partners' names in the project title.
2. In the World Page, instruct your turtles to react to the landmarks according to the rules in the Trailblazer activity
    a. Use logic blocks that evaluate the color of the terrain and tells the turtle how to turn.
3. When you are done, save and share your project.

The new command blocks to be used in addition to the blocks you used in Lesson 1 and 2 are:



Extensions:
Change how the turtles react to the colors (not just a turn, but a new shape or color for the agent).
Change the colors of the terrain stamps and make your turtle instructions match this new information.

StarLogo Nova Blocks introduced in Module 1 Lesson 3

	Carries out the specific procedures if the condition is true. This conditional block ONLY runs the main block IF the condition after the “if” is met.
	Carries out the specific procedures if the condition is true. Otherwise (if the condition is false) carry out procedures in the second block.
	Determines whether the two inputs are equivalent and returns true or false. Usually used after an “if” in a conditional block.
	Determines whether the two inputs are unequal and returns true or false. Usually used after an “if” in a conditional block.
	Determines if the first input is less than the second input and returns true or false. Usually used after an “if” in a conditional block.
	Determines if the first input is greater than the second input and returns true or false. Usually used after an “if” in a conditional block.
	Determines if the first input is less than or equal to the second input and returns true or false. Usually used after an “if” in a conditional block.
	Determines if the first input is greater than or equal to the second input and returns true or false. Usually used after an “if” in a conditional block.
	Returns an agent’s trait.
	Returns the color of the terrain the agent is currently on.
	Colors a grid square on the terrain in the agent’s current position.
	Colors a circle on the terrain in the agent’s current position.

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Lesson 4

Probability with Dice and Data and Colliding Turtles

50 minutes (1 day)

Lesson Overview

In this lesson students will participate in two activities. In the first activity, students will learn about probability, how it is implemented in StarLogo Nova, and use probability to implement chance behavior in agent movement. In the second activity, students will create a Colliding Turtles project in which turtles react to other turtles upon collision. The wrap-up discussion covers what probability is used for in computer modeling and simulation.

Teaching Summary

Getting Started – 5 minutes (Review)

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

Activity #1: Dice and Data – 20 minutes (Guided Practice)

2. Chances Are – one die
3. Wiggle Walk – two dice

Activity #2: Colliding Turtles – 20 minutes (Discovery / Creative)

4. New Concepts: Agent-agent interactions
5. Add a behavior that takes place upon collision

Wrap-Up – 5 minutes (Reflection)

6. What could turtles colliding represent in the real world?
7. How does probability play a role in modeling and simulation?

Lesson Objectives

The student will:

- ✓ Learn that in complex adaptive systems one type of common interaction is of agents interacting with other agents (LO21)
- ✓ Create a simple program with agents interacting with other agents (LO22)
- ✓ Use the random function to implement probabilistic outcomes / behaviors (LO23)
- ✓ Learn computer science concepts of random numbers (LO24)
- ✓ Understand the concept of collisions (LO25)
- ✓ Learn mathematical concepts of probability and distributions (LO26)

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- New StarLogo Nova project or Colliding Turtles Starter model
- Two dice and a paper cup for each group of 2-3 students

For the Teacher

- Computer and projector
- Slide presentation with simple commands
- Teacher sample code
- Graph paper or Excel spreadsheet projected on a screen

Getting Started - 5 min

1. Review of previous day's lesson and link to where we are going today

- What commands enabled agents to react to their environments?
  [See slide presentation: if/then and if/then/else commands; example of using and if/then to react to the environment.]

Activity #1: Dice and Data - 20 min

2. Chances Are

- Introduce the topic: Probability plays a large role in models of complex adaptive systems. We've programmed our agents to mimic the movement of creatures in the real world. There are also chance events that occur upon when agents interact, such as the passing of a contagion from one person to the other.
- Form small groups of 2-3 students.
- Hand out two dice and one cup per small group. Hand out activity sheet.
- Instruct the students to roll 1 die 50 times while a partner marks down the results for all 50 rolls using the chart provided with the possible rolls (1 through 6).

Roll	Area for recording marks with example	
1	I I I	Sum: 3
2		Sum:
3		Sum:
4	~~I I I I~~	Sum: 5
5		Sum:
6		Sum:

- Ask each group “What was the distribution of the results? Was one number more common? Why might that be?”
- If time allows, pool all of the data from the class and see what the sums are across groups. Graph this data as a bar chart. Ask what the graph look like.
- As the groups report their data, put the class information together as a bar graph.
- Discussion: What do the numbers look like now? What’s different about this data compared to the data of just one group?
- Note: the distribution should be even, theoretically – the chances of rolling each of the sides is equal.

3. Wiggle Walk- using random numbers to determine the angle turned

- Next we are going to roll two die. Do you predict we will have the same flat distribution?
- Each group should designate a Student 1 and a Student 2, each with their own die.
- This time, ask the students to roll 2 dice simultaneously and collect the data from 50 rolls.
- Students are to SUBTRACT the Student 1 die number from the Student 2 die number.
- Record the outcome on the activity sheet with a mark next to the sum of the dice rolled (some will be negative numbers). After 50 rolls, sum up each row of tic marks and record the sum in the column on the right.

Area for recording tic marks of subtracted numbers

5		Sum:
4		Sum:
3		Sum:
2		Sum:
1		Sum:
0		Sum:
-1		Sum:
-2		Sum:
-3		Sum:
-4		Sum:
-5		Sum:

- What number gets created most often from the rolling and subtraction? Why?
- Ask “How many ways are there to make 2?”, “How many ways can you roll a 0?” What about other configurations?
- Given this chart, what should be the most commonly created number? Why?

- If time allows, graph this data as a bar chart; what shape does the graph look like? (Draw it.)
- To help students understand this phenomenon, describe the underlying statistics: We know that with one die we have equal probability of rolling a 1, 2, 3, 4, 5, or 6.
- Have students fill in the chart in their activity sheet that shows the outcome of rolling two dice. The numbers down the column represent the number rolled on one die; the numbers rolled across the top represent the numbers rolled on the other die. Subtract the second number from the first number that was rolled.

Student 2

Student 1

--	1	2	3	4	5	6
1	0					
2						
3						
4						
5						
6						

Notice that the most common number in the matrix is a 0 [because there are many different combinations that subtract to form 0].

- Next relate this to our wiggle walk. Fill in the result of a left turn of random 6 followed by a right turn of random 6. (Note, we use subtraction.)

Right turn

Left turn

--	1	2	3	4	5	6
1	0					
2						
3						
4						
5						
6						

Notice the most common number in the matrix is now a 0. A 0 represents no change in heading. So whereas it is common to stay going straight, there is a smaller chance of turning at a large angle.

- In the wiggle walk we use this left turn random and right turn random to make an agent walk mostly in a straight line but sometimes wander a bit off.

- Using the PowerPoint presentation, walk through the execution of the wiggle code.

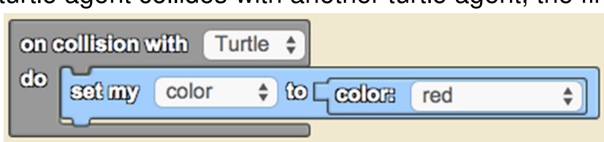
Activity #2: Colliding Turtles - 20 min

In this activity students will start a new project OR use the Colliding Turtles Starter model to create a model with colliding turtles.

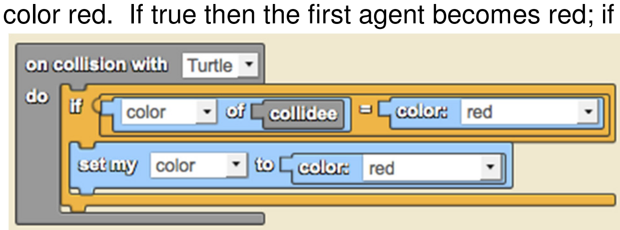
4. **Agent-agent interactions**
   - Introduce collisions: In this activity we are going to implement agents interacting with other agents upon collision. Collisions occur when two agents bump into one another. (They do not need to be centered on the same patch, just touching.) This is different from bumper turtles – In bumper turtles, agents were responding to colored patches in their environment, not other agents.
   - We will use a collision block that looks like this. Use the pull down arrow to select what type of object to collide with. Then put the commands that should run or execute when the collision occurs in the area below the notch.

Select the object to collide with

5. **Adding a behavior that takes place upon collision with another turtle**
   - Here's an example of programming a reaction to a collision. In this example, when the turtle agent collides with another turtle agent, the first agent's color turns red.



   - Below is another example showing the use of a collision block with a conditional instruction. The set color command only executes if the condition is true. The condition asks whether or not the turtle agent that the first turtle collides with (the 'collidee') is the color red. If true then the first agent becomes red; if not, nothing happens.



Teaching Tip *If time allows, have students show their projects to each other.*

Wrap-Up – 5 min

6. **What does Colliding Turtles have to do with Modeling and Simulation?**
   What could these collisions represent?
7. **How do we use probability in models?**

Assessment Questions

- Which characteristics of complex adaptive systems can you identify in Colliding Turtles?
- Give an example of how agents interacting with other agents may be used to represent something in the real world.
- How does using probability impact the outcome when running simulations?
- What variables were used in Colliding Turtles?
- What is the difference between "right turn random 90" and "right turn random 90 left turn random 90"?

Standards Addressed

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.
1B: Ask question to identify and/or clarify evidence and/or the premise(s) of an argument.
1E: Ask questions that require sufficient and appropriate empirical evidence to answer.
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
2C: Use and/or develop a model of simple systems with uncertain and less predictable factors.
2E: Develop and/or use a model to predict and/or describe phenomena.

Practice 3: Planning and carrying out investigations
3D: Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

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.
4E: Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.
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
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
6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.

NRC Crosscutting Concepts

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

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

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.

CSTA K-12 Computer Science Standards

CT	Algorithms	1:6-2	Develop a simple understanding of algorithms using computer-free exercises.
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	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.
CPP	Programming	2-5	Implement a problem solution in a programming environment using looping behavior, conditional statements, logic, expressions,

Responsiveness to Varied Student Learning Needs

In Project GUTS, we integrate teaching strategies found to be effective with learners with various backgrounds and characteristics, such as economically disadvantaged students (EDS), students from groups that are underrepresented in STEM (URG), students with disabilities (DIS), English Language learners (ELL), girls and young women (FEM), students in alternative education (ALT), and gifted and talented students (GAT).

In each lesson we describe the accommodations and differentiation strategies that are integrated in the activities to support a wide range of learners.

Module 1 Lesson 4 Activity #1: Dice and Data

(URG) *In Dice and Data, we use a class modeling activity that involved student movement and interaction, a strategy that uses a multi-modal experience to increase student engagement.*

(DIS) *Across both the Chances Are and Wiggle Walk activities, we provide multiple means of action, expression, representation and engagement by introducing a game and a design-and-build programming activity that build on the same underlying concepts. These are all principles of Universal Design for Learning.*

Module 1 Lesson 4 Activity #2: Colliding Turtles

(URG)(DIS) *We use technology to present information in multiple modes of representations. In the StarLogo Nova modeling and simulation environment, students can present information as code blocks, text, visual imagery, and as data in tables and graphs.*

(FEM) *We recommend careful planning of partners for pair programing in the Colliding Turtles activity, a practice that encourages participation for the girls in science.*

Lesson 4 - Student Activity #1 Guide

Name ___________________

Dice and Data: Chances Are and Wiggle Walk

Introduction
Probability plays a large role in models of complex adaptive systems. We'll be programming our agents to mimic the movement of creatures in the real world. There are also chance events that occur upon when agents interact such as the passing of a contagion from one person to the other.

PART 1: "Chances Are"

Directions

- In your group, roll 1 die 50 times in a cup, while the partner marks down the results for all 50 rolls using the chart provided with the possible rolls (1 through 6).

For each roll of the die, record the outcome with a tic mark below next to the number rolled. After 50 rolls, sum up each row and record the sum in the column on the right.

1		Sum:
2		Sum:
3		Sum:
4		Sum:
5		Sum:
6		Sum:

Discussion:
What was the distribution of the results?
Was one number more common?
Why might that be?

Extension:
If time allows, pool all of the data from the class and see what the sums are across groups.
If you graphed this data as a bar chart, what would the graph look like? (Draw it below.)

PART 2: Wiggle Walk

Next imagine that you were going to roll two dice instead of one die and you will subtract the second number from the first number. Do you think we will still get a flat distribution (in which the probability of rolling each outcome would be the same)?

Directions

- Each group should designate a Student 1 and a Student 2, each with their own die.
- This time, roll 2 dice simultaneously and collect the data from 50 rolls.
- Students are to SUBTRACT the Student 1 die number from the Student 2 die number.
- Record the outcome on the activity sheet with a mark next to the sum of the dice rolled (some will be negative numbers). After 50 rolls, sum up each row of tic marks and record the sum in the column on the right.
- For instance, if student 1 rolls a three and student 2 rolls a six, 3 - 6 = -3, so you would put a tic mark in the -3 row.

Area for recording tic marks of subtracted numbers

5		Sum:
4		Sum:
3		Sum:
2		Sum:
1		Sum:
0		Sum:
-1		Sum:
-2		Sum:
-3		Sum:
-4		Sum:
-5		Sum:

Discussion:

What number gets created most often from the rolling and subtraction? Why?
Given this chart, what should be the most commonly created number? Why?

Extension:

If time allows, graph this data as a bar chart, what shape does the graph look like? (Draw it below.)

To understand this phenomenon, let's look at the underlying statistics:
We know that with one die we have equal probability of rolling a 1, 2, 3, 4, 5, or a 6.

Fill in the chart below that shows the outcome of rolling two dice. The numbers down the column represent the number rolled by Student 1, the numbers rolled across the top represent the numbers rolled on the other die, rolled by Student 2. Subtract the second number from the first number rolled.

Student 2

Student 1

--	1	2	3	4	5	6
1	0					
2						
3						
4						
5						
6						

Discussion:
How many ways are there to make 2?
How many ways can you create a 0?
What about other numbers?
What is the most often seen number in the matrix?
How many times is it seen?

Next, fill in the result of a left turn of random 6 followed by a right turn of random 6.

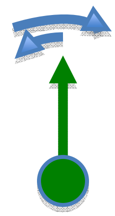
Right turn

Left turn

--	1	2	3	4	5	6
1	0					
2						
3						
4						
5						
6						

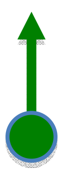
Discussion:
How many ways are there to make 0?
How many ways can you roll a +2?
How many ways can you roll a -2?
What about other numbers?
What is the most often seen number in the matrix?
How many times is it seen?

Finally, consider rolling two dice where one represents the degrees to turn to the left and the other die represents the degrees to turn to the right. That's similar to using a left turn random 6 followed by a right turn random 6, then taking a step forward.

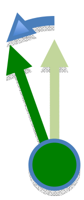


Turtle seen from above with initial heading.

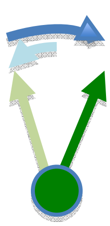
What is actually going on?



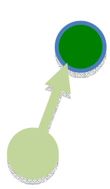
1. Agent has an initial heading.



2. Agent turns left by some random number of degrees between 1 and 6. In this case, it is 2 degrees. (Image not to scale)

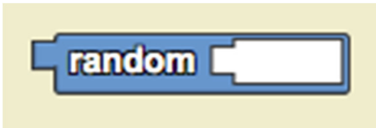


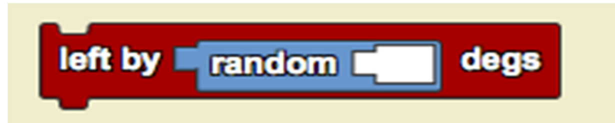
3. Agent turns right by some random number of degrees between 0 and 5. In this case, it is 5 degrees, so the final heading is 3 degrees to the right of the original heading. (Image not to scale)



4. Agent takes one step forward at new heading. (Image not to scale)

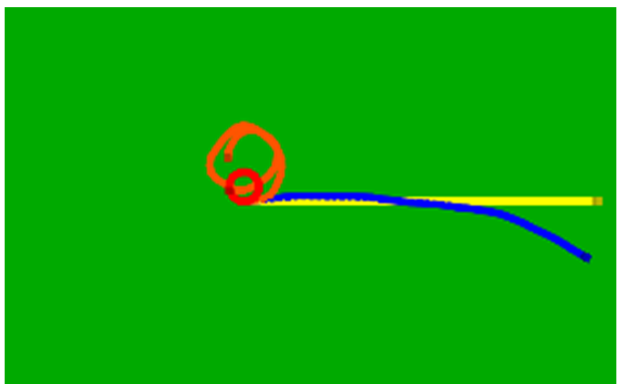
In StarLogo Nova:





In StarLogo Nova, we use the random command to simulate the roll of a die. Random 6 would give me the result of rolling a 60-sided die with numbers 1 through 6 on the sides. Random functions can also be used within other commands to implement random behavior.

Self-test:



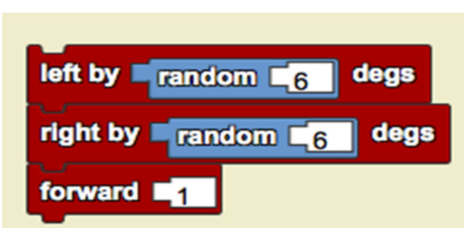
Match the command blocks a, b, c, and d with the path created by an agent following those blocks.

a. 

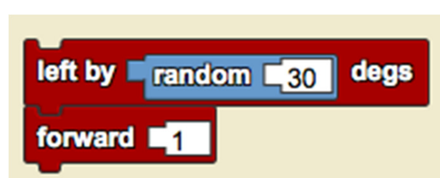
color: __________

c. 

color: __________

b. 

color: __________

d. 

color: __________

Lesson 4 - Student Activity #2 Guide

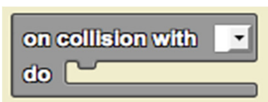
Name ________________

Colliding Turtles

Introduction

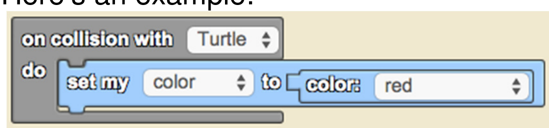
In this activity we are going to implement agents interacting with other agents upon colliding. Collisions occur when two agents bump into one another. (They do not need to be centered on the same patch, just touching.) This is different from Bumper Turtles; in Bumper Turtles, *agents were responding to colored patches in their environment*, not other agents.

We will use a collision block that looks like this. Use the pull down arrow to select what to type of object to collide with. Then put the commands that should run or execute when the collision occurs in the area below the notch.

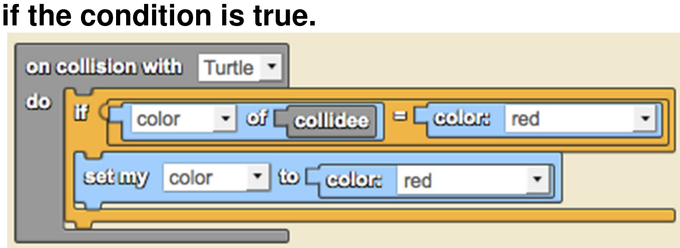


Select the object to collide with

Here's an example:



Here's another example with a conditional instruction. **The set color command only executes if the condition is true.**

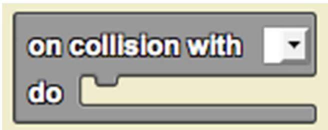
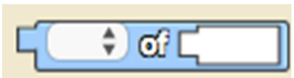
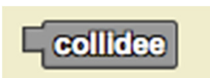


Your challenge is to make the turtles react to another agent upon collision.

<u>Guidelines:</u>

1. Start from a new blank project or remix the "Colliding Turtles starter" model in the Project GUTS gallery.
2. Don't forget to put both partners' names in the project title.
3. Create 50 blue turtles (Refer to Lesson 2) and 5 red turtles. (Will need 2 'create do' blocks.)
4. Have the turtles move around with a wiggle walk. (Work in the turtle page with a forever block.)
5. Use a collision block and have the turtles change a trait like color after colliding with another turtle.
6. When you are done, save and share your project.

StarLogo Nova Blocks introduced in Module 1 Lesson 4

	Specifies a series of actions to be executed after a collision between two breeds. If the two breeds are the same, each agent in the collision must perform the same action after the collision. If the two breeds are different, each agent in the collision can be given different commands.
	'Trait of' block is used to specify which trait of the agent it should check for (X, Y, Z, color, size, heading, shape or a trait that you have added)
	Specifies the other agent in the collision.
	Counts the number of agents of a specific breed in a given radius with a specific trait. This can be used to detect other agents that are nearby and have specific traits.

1

Lesson 5

Modeling the Spread of Disease

50 minutes (1 day)

Lesson Overview

In this lesson students will convert their Colliding Turtles model into a simple Epidemic model by adding slider widgets for transmission and recovery. The Contagion model represents a very simplified version of an epidemic or spread of a disease. Two variables will be created: transmission rate and recovery rate. Students will later use this model to run experiments to determine if disease will spread throughout a virtual population in different scenarios.

Teaching Summary

Getting Started – 5 minutes (Review)

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

Activity #1: Introduction to Epidemiology – 25 minutes (New Learning)

2. Epidemiology and the spread of disease

Activity #2: Modeling the Spread of Disease – 25 minutes (Guided Practice and Discovery)

3. New concepts and commands
4. Altering Colliding Turtles to an Epidemic Model and adding widgets
5. Customizing your model [adding transmission and recovery]
6. Test your model

Wrap-Up – 5 minutes (Reflection)

7. What does this model tell you? Can it be trusted?
8. What other things move through a population like a disease? [Rumors, ideas, etc.]

Lesson Objectives

The student will:

- ✓ Learn about epidemiology and how it can be modeled as a complex system (LO27)
- ✓ Create a simple model in which agents pass a contagion from one to another (LO28)
- ✓ Learn the CS concepts of procedures and variables (LO29)
- ✓ Create and use sliders to set variables and initial conditions (LO30)
- ✓ Create procedures and call procedures (LO31)
- ✓ Use the random function to simulate probabilistic outcomes (LO32)

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- StarLogo Nova model of Colliding Turtles

For the Teacher

- Computer and projector
- Slide presentation with new commands and concepts

Getting Started - 5 min

1. Review of previous day's lesson and link to where we are going today

- What does the Colliding Turtles model you built last time remind you of? What could the blue and red represent?
- Thinking about the wiggle walk, what would be the result if the left and right turn were given a different range for the random function?

Activity #1: Introduction to Epidemiology - 10 min

2. Epidemiology and spread of disease

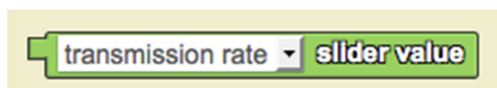
- "Scientists who study epidemics are called epidemiologists. Epidemiologists study the spread of disease such as the swine flu. Epidemics are hard to study because they are made up of many connected and inter-related parts interacting in different ways. They can be hard to predict and sometimes the way a disease spreads creates patterns that cannot be predicted even if you know something about the people involved. These are characteristics of what we call "complex systems." (Many interacting parts, hard to predict, patterns emerge that are not predictable even if you know about individuals)"
- "One way epidemiologists try to understand epidemics is to run computer simulations of how diseases spread and test different measures that could be taken to stop an epidemic."
- Introduce the example of MRSA (Methicillin-resistant Staphylococcus aureus) using the slide presentation. Discuss how agents go from one state to another, such as from healthy to infected.

Activity #2: Modeling the Spread of Disease - 30 min

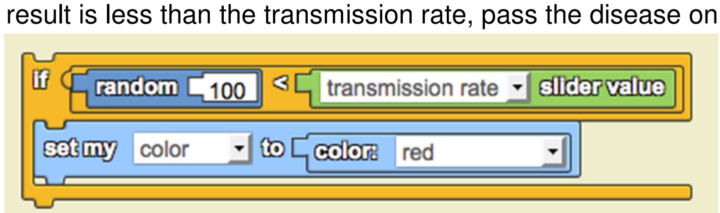
3. New CS Concept and Commands (see slides on Variables and Procedures)

4. Altering Colliding Turtles to create an Epidemic Model
(See student activity handout.)

- What we have already is a model in which there are agents and collisions between agents have an outcome.
- Now we are going to remix our Colliding Turtles to make it into a model of an epidemic.
- To do this, we are going to create two variables: transmission rate and recovery rate. Transmission rate is the probability that an agent will get sick upon colliding with a sick agent. Recovery rate is the probability that a sick agent gets healthy at any turn. Ask if these are independent or dependent variables.
- We will learn how to create widgets called "sliders." These sliders are variables that hold values. These values are inputs into our model.
- In the colliding turtles model, turtles always reacted to a collision. In our epidemic model, we will incorporate a transmission rate so only some of the time a disease is passed from one agent to another.
- Demonstrate how to create a widget or show students using the slide presentation. [Edit Widget, New Widget, Create Widget by specifying name and type.]
- Change the max value of the "Transmission rate" to 100 by typing in 100 next to max and hitting the return key.



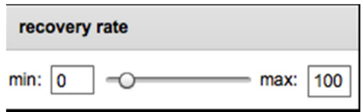
- Click on "Edit Widgets" again to get out into editing mode and back into play mode.
- We now have a way to set the transmission rate through the user interface with a slider.
- We can get the value of transmission rate in code using the slider value command.
- How do we "pass the disease to the healthy agent 40% of the time after a collision?" (Hint: remember the dice rolls.)
- We can use the random function to roll a 100-sided die.
- If the result is less than the transmission rate, pass the disease on.



- Have students save and test their models.

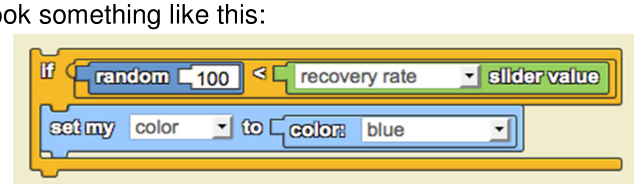
5. Customizing your model. (Add in recovery.)
As it currently exists, every agent who collides with a sick agent gets sick and no one recovers. Is that realistic?

- Introduce new command blocks: the “procedure” block and “call” procedure block.
- Creating and calling the recovery procedure.
- Next, ask students to add the recovery rate slider in the same way they added the transmission rate slider.



- Then guide them in creating a recovery procedure.   At each step, a sick person has a chance of recovering so we will need recovery to be called when the forever button is toggled.

- Note: the “call recovery block” needs to be within the “when forever toggled” loop.
- Within the recovery procedure, students will need to use the random function to mimic rolling the 100-sided die, as we did in the transmission case.
- It could look something like this:



6. Testing your model

- Have the students save and test their models.
- Try changing the recovery rate. Did you see any new outcomes or patterns?

Wrap-Up – 5 min

7. What does your model tell you?

- What assumptions are made in your model? Was there any key factor that was left out that might be important in the real world?

8. What other things move through a population like a disease?

Assessment Questions

- Is the epidemic model a model of a complex adaptive system? Why or why not?
- What variables were used in your epidemic model?
- How would you test whether the spread of disease is impacted by an agent’s frequency of travel?
- How many times do I need to run each experiment at each setting?

Standards Addressed

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.
1C: Ask questions to determine relationships between independent and dependent variables and relationships in models.

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
3D: Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.
3E: Collect data about the performance of a proposed object, tool, process or system under a range of conditions.

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.

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
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.
6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
6F: Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.
6G: Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

NRC Crosscutting Concepts

1. 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.

2. Cause and Effect:
2A: Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
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.

3. 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.
3B: The observed function of natural and designed systems may change with scale.
3D: Scientific relationships can be represented through the use of algebraic expressions and equations.
3E: Phenomena that can be observed at one scale may not be observable at another scale.

4. 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.

CSTA K-12 Computer Science Standards

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

Responsiveness to Varied Student Learning Needs

In Project GUTS, we integrate teaching strategies found to be effective with learners with various backgrounds and characteristics such as economically disadvantaged students (EDS), students from groups that are underrepresented in STEM (URG), students with disabilities (DIS), English Language learners (ELL), girls and young women (FEM), students in alternative education (ALT), and gifted and talented students (GAT).

In each lesson we describe the accommodations and differentiation strategies that are integrated in the activities to support a wide range of learners.

Module 1 Lesson 5 Activity #1: Introduction to Epidemiology

(EDS) *In the Introduction to Epidemiology we elicit students' prior knowledge of getting a communicable disease and build on their funds of knowledge as a resource for further questioning and investigating.*

(EDS) *We validate the sense of place [aspects of the neighborhood and school] to keep the students engaged and make a connection of science and neighborhood by using the example of Community Associated MRSA. We refer to the cultural context of school and community, neighborhoods, when discussing the model of CA-MRSA and what was included in the model.*

(URG)(DIS) *We use technology to present information in multiple modes of representations. In the StarLogo Nova modeling and simulation environment, students can present information as code blocks, text, graphical display of the simulation, and as data in tables and graphs.*

(FEM) *We chose a curriculum topic, epidemiology, which had relevancy and real-world application, a strategy to interest and engage girls and students from groups that are underrepresented in STEM.*

(ALT) *We focus on career connections, the work of epidemiologists, a life-skills strategy that is promoted in alternative education.*

Module 1 Lesson 5 Activity #2: Modeling the Spread of Disease (Contagion model)

(EDS)(URG)(ELL) *We ask students to apply what they know, specific to their cultural and/or socio-economic context, when addressing issues related to the spread of disease and the realism of models. We can ask what is assumed in this model, what is realistic to the students, and what is not. This practice can also highlight home culture connection to science by capitalizing on funds of knowledge from the students' homes and communities.*

(URG)(DIS) *We use technology to present information in multiple modes of representations. In the StarLogo Nova modeling and simulation environment students can present information as code blocks, text, graphical display of the simulation, and as data in tables and graphs.*

(URG) *We can connect science to locally meaningful issues that could promote community involvement and social activism. When discussing what else spreads like a disease, note that other trends and phenomena are studied as contagions. Examples include gossip, gun violence, fads and fashions, etc.*

(ELL) *The "place-based" nature of this lesson establishes connections between school science and the students' community and lives.*

(FEM) *We chose a curriculum topic, epidemiology, which had relevancy and real-world application, a strategy to interest and engage girls and students from groups that are underrepresented in STEM. Careful planning of partners for the on-computer activity is a strategy that encourages participation for the girls in science.*

Lesson 5 - Student Activity #2 Guide

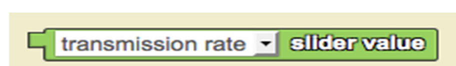
Model the Spread of Disease

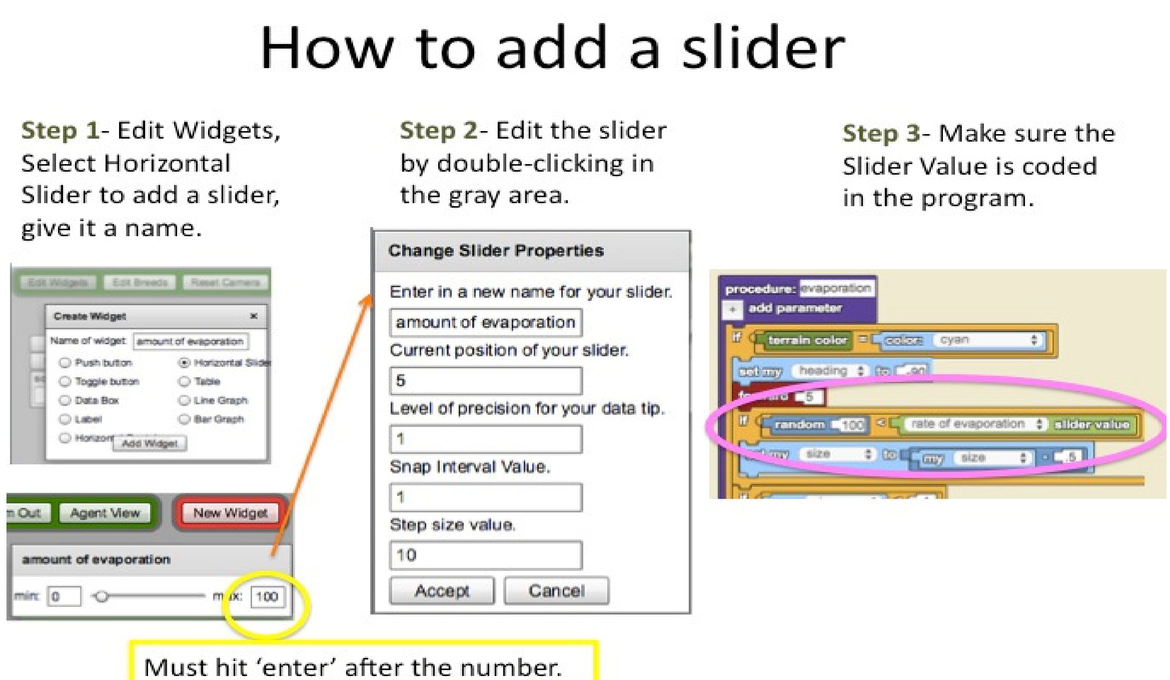
Part 1: Altering Colliding Turtles to create an Epidemic Model

Your challenge is to make the turtles spread disease to one another when they collide. You will learn how to use sliders to change a variable in a computer model.

Guidelines:

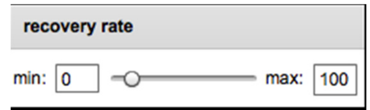
1. Remix your Colliding Turtles project or use the 'Epidemic Starter' model in Project GUTS gallery.
2. Name it 'Epidemic Model: *your name(s)*' *Don't forget to put both partners' names in the project title.*
3. Create 300 blue turtles and 5 red turtles.
4. Create a transmission rate slider; set the maximum to 100.
5. Use the value in the transmission rate slider as the probability of passing on the disease.
   Note: you will need to use the random function to mimic rolling the 100-sided die.
6. Save and test your model.





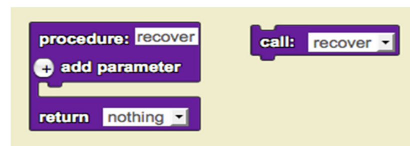
Part 2: Customizing your model [adding in recovery]

Your challenge is to make the turtles recover from the disease.



1. Create a recovery rate slider.
2. Create a recovery procedure.
3. Use the value in the recovery rate slider as the probability that recovering from the disease at each step.

Recovery Procedure: At each step, a sick person has a chance of recovering so we will need recovery to be called when the forever button is toggled. You will need to use the random function to mimic rolling the 100-sided die as we did in the transmission case.



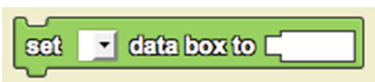
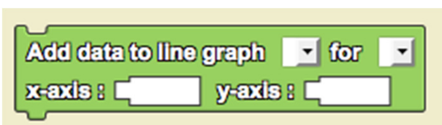
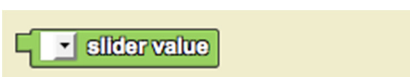
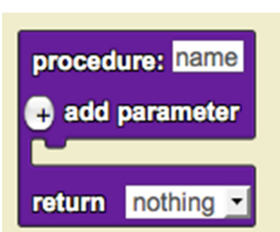
Note: the “call recovery block” needs to be within the “when forever toggled” loop.

Testing your model

- Save and test your model.
- Try changing the recovery rate. Did you see any new outcomes or patterns?
- Notice that even when the recovery rate is really low, the disease goes away. Why do you think that is? Is this realistic?

When you are done, save and share your project.

StarLogo Nova Blocks introduced in Module 1 Lesson 5

	Push this button to get access to the widgets. Widgets are user-input and output elements like buttons, data output, tables and graphs.
	This button appears AFTER clicking "Edit Widgets". Select the type of widget you'd like to add. Give the widget a name. "Push button" – a button that runs once or pops up after being pushed "Toggle button" – a button that stays on until turned off "Data Box" – a data display box "Label" – a place for the user to enter descriptive text "Horizontal Slider" – a slider to control the value of a variable "Table" – a configurable data table with rows and columns "Line Graph" – a configurable line graph with one or more lines "Bar Graph" – a configurable bar graph with one or more bars
	After creating a data box, use this block to set its value to a number or a color.
	After creating a line graph widget and naming a series (on the interface), this block adds data to the line graph. It will plot the point x, y based on the blocks that you provide. Usually these values are variables that you have defined.
	After setting up a slider widget, you can use the value of the slider in your code using this block.
	Returns the current value of the clock. This can be used when you plot data vs. time.
	Changes the value of the clock. This block is particularly useful for resetting the clock on setup.
	Creates a procedure with a name and a list of commands. Procedures are useful for organizing code into reusable modules. Some procedures just make changes to the agents and the world and return nothing. Other procedures calculate values and return the result.
	Calls the procedure selected.

1

Lesson 6

Adding Instrumentation to your Model and Running Experiments

50 minutes (1 day)

Lesson Overview

In this lesson students will add instrumentation to their model so they can collect quantitative data on the spread of disease. Students will use this model to run experiments to determine if disease will spread throughout a virtual population under different initial conditions and different scenarios.

Teaching Summary

Getting Started – 5 minutes

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

Activity 1: Instrumenting Your Model – 10 minutes

2. Review qualitative vs. quantitative data
3. Add a line graph
4. Test your model

Activity 2: Designing and Running Experiments – 30 minutes

5. Designing experiments
6. Running experiments
7. Collecting and analyzing data

Wrap-Up – 5 minutes

8. What patterns did you uncover? What conditions or settings led to each pattern?
9. When you run the model with the same input setting (for transmission rate and recovery rate) do you always get the same result or outcome? Why or why not?

Lesson Objectives

The student will:
- ✓ Learn the difference between qualitative vs. quantitative results (LO33)
- ✓ Learn how to instrument a model with a line graph (LO34)
- ✓ Learn experimental design using a computer model (LO35)
- ✓ Conduct experiments using a model as an experimental test bed (LO36)
- ✓ Record and analyze results (LO37)
- ✓ Ask questions that arise from observations of your model's behavior (LO38)

Teaching Guide

Materials, Resources and Prep

For the Students
- Computers
- StarLogo Nova Epidemic model
- Experimental Design handout

For the Teacher
- Computer and projector
- Slide presentation with new commands and concepts

Getting Started - 5 min

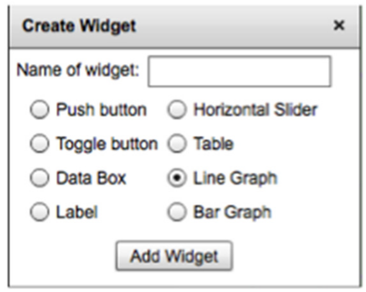
1. Review of previous day's lesson and link to where we are going today
- What are variables and procedures?
- How are they used in models?

Activity #1: Instrumenting Your Model - 10 min

2. Qualitative vs. quantitative data
- Using the epidemic model, students can make qualitative observations of the changes that occur as we change the transmission rate. But sometimes, we need quantitative data to get a better sense of change over time.
- Definitions: <u>Qualitative</u> means relating to, measuring, or measured by the *quality* of something (its size, appearance, value, etc.) rather than its quantity. <u>Quantitative</u> means relating to, measuring, or measured by the *quantity* of something rather than its quality.
- In order to collect and visualize quantitative data we need to add a line graph in StarLogo Nova. The graph will collect data on the time elapsed since the model started running and the cumulative number of healthy and sick individuals over time.
- Then we can compare patterns in the collected data.

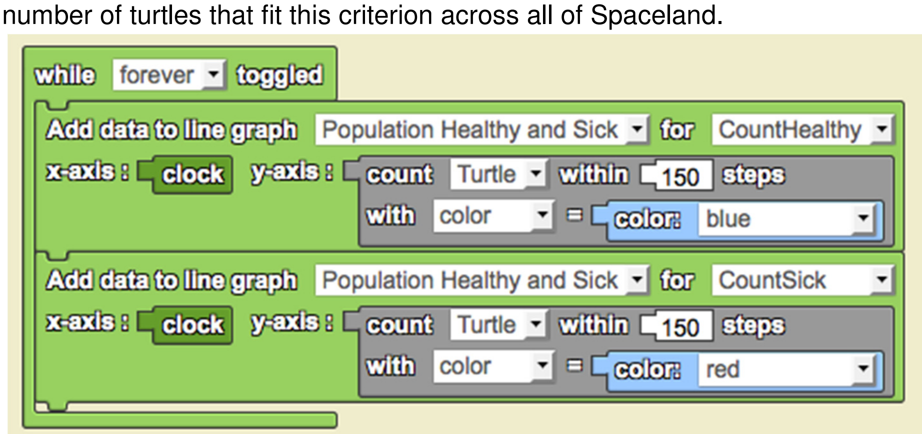
3. Adding a line graph
- We need some way of tracking the spread of disease; what data should we collect?
- What do you want to find out using the model? [Does everyone get sick? If so, how fast? For example, if we are interested in seeing how fast the disease spreads, we will need to know when everyone is sick.]

- If we want to know if anyone remained healthy throughout the epidemic, we need to keep track of the number of healthy people.
- Let's create a new line graph called "Population Healthy and Sick"
- How can we track the sick and healthy people? What is different about how they are displayed? [healthy are blue and sick are red]
- Demonstrate how to create a line graph using the slide presentation or StarLogo Nova.
- In the Colliding Turtles model, turtles always reacted to a collision. In our epidemic model, we will incorporate a transmission rate so only some of the time a disease is passed from one agent to another.
- Demonstrate how to create a widget or show students using the slide presentation.



[Edit Widget, New Widget, Create Widget by specifying name and select Line Graph, click on Add Widget. You can reposition the Line Graph in Edit Widgets mode.]

- Drag the line graph off to the side of Spaceland but still inside the browser window.
- Double click on New Series and change its name to "Count Healthy" then select blue as its line color.
- Add another Series and change its name to "Count Sick" then select red as its line color.
- Finally, click "Edit Widgets" to leave editing mode and return to play mode.
- Next, we want "The World" to update the line graph each time through the forever loop, so we need to add a while forever toggled command to the page labeled "The World."
- Notice that we need the "clock" along the x-axis and the count of blue turtles on the y-axis. We can get the count of turtles that are blue using the count command. Since the whole Spaceland is less than 150 steps square, saying "within 150 steps" will get us the number of turtles that fit this criterion across all of Spaceland.



- **Add 2 new blocks to your <u>Setup</u> procedure- clear line graph and set clock (to 0).**
- **We recommend that you save and refresh the browser window.**
- **If the graph and other widgets disappear, try resizing the browser window by grabbing a lower corner to make it bigger and smaller. The widgets will likely reappear.**

4. Test your model
- Does your line graph work?
- What patterns can you now see that were difficult to see without a line graph?

Activity #2: Designing and Running Experiments - 30 min

5. Design your experiment
- Assign students to work in small groups.
- Hand out the experimental design form and review its contents.
- Give students time to plan and describe their experiment using the form.
- Ask, “What are the variables that already exist in this model?” [#initially sick, density of population, transmission rate, population movement, recovery rate.] Choose one variable to experiment with, then use the “Experimental Design handout” to describe your experiments and record data from your experiments.
- Ask, “What are the dependent and independent variables?” [Independent variables include number of initially sick agents, transmission and recovery rates. Dependent variables would include the time it takes for all to get sick, the number that are ‘sick’ after a specified amount of time.]
- Ask, “How many trials do you need to run at each setting of the variable?” “Why are many trials necessary?”

6. Run your experiment
- Students are to run the experiment they described in the form and collect data.
- What is the range of values for the variable you chose?
- How many trials will you run at each setting?
- How will you capture the data?
- Currently the “data output to file” function is not available in StarLogo Nova. An alternative is to grab screen shots of the graph and label them with the settings.
- Show students how to do a screen grab and name their file.
- Another alternative is to keep the line graph recording all experiments without clearing the line graph.
- Or students can add data boxes (similar steps to how a graph was added) that will count the number of blue or red agents.

7. Analyzing data and describing the results of your experiment
- Ask, “What patterns do you see in the collected data?”
- Ask, “What correlations do you think exist between the variable setting and the outcomes?”

Wrap-Up – 5 min

8. What does your model tell you?
- What assumptions are made in your model? Was there any key factor that was left out that might be important in the real world?

Assessment Questions

- Is the epidemic model a model of a complex adaptive system? Why or why not?
- What variables were included in your epidemic model?
- What was included and what was missing from your model? Name two things that happen in real life that are not included in this model.
- How would you change the model to one in which sick agents get healthy again after colliding into a healthy agent?
- How would you modify the model to help you study a real-world disease?

Standards Addressed

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.
1B: Ask question to identify and/or clarify evidence and/or the premise(s) of an argument.
1C: Ask questions to determine relationships between independent and dependent variables and relationships in models.
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
2C: Use and/or develop a model of simple systems with uncertain and less predictable factors.
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 design solutions under a range of conditions.

Practice 4: Analyzing and interpreting data
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.
4E: Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.
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
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.
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
6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
6E: Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.

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
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

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

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

3. 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.

4. 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.

CSTA K-12 Computer Science Standards

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	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	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	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.

Responsiveness to Varied Student Learning Needs

In Project GUTS, we integrate teaching strategies found to be effective with learners with various backgrounds and characteristics such as economically disadvantaged students (EDS), students from groups that are underrepresented in STEM (URG), students with disabilities (DIS), English Language learners (ELL), girls and young women (FEM), students in alternative education (ALT), and gifted and talented students (GAT).

In each lesson we describe the accommodations and differentiation strategies that are integrated in the activities to support a wide range of learners.

Module 1 Lesson 6: Instrumenting Your Model and Designing and Running Experiments

(URG) *Students are given "agency" as the creators of their own models, and as researchers seeking to answer a question or understand a phenomenon. The models that students build are their own creations.*

(FEM) *Careful planning of partners for the on-computer activity is a strategy that encourages participation for the girls in science.*

(DIS)(GAT) *There is ample opportunity to extend level of content and time for practice by compacting areas already mastered and to allow more time for students to complete previous experiments and customizations. This differentiation strategy of pacing can benefit a wide range of students, including those with learning disabilities and/or gifted and talented students.*

(GAT) *The teacher can promote autonomy and the forging of authentic connections to the epidemiology content and to the practice of computer modeling.*

(GAT) *Grouping students of similar interests and ability, incorporating standards from a higher grade, and providing opportunities for self-directed projects are successful strategies for gifted and talented students.*

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?
Prediction
What effect do you think the changes you make will have on the model?
Data Collection
What data will you collect?
Data Analysis
How will you analyze your data? (i.e. look for patterns, compare final values, look at the graph)
Interpretation
What is the answer to your question? How does the analysis of your data help you answer your question?

MODULE 2 (EARTH SCIENCE) INTRODUCTION

Module Name: Water as a Shared Resource

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 considers how humans are impacting the environment and how resources are being used and managed (or not managed) for the future. In particular, the module explores ground water as a shared resource and factors that affect how a resource is shared among stakeholders. Students investigate the movement of water through the hydrological cycle. The base model for this unit simulates the part of the hydrological cycle in which water falls as rain, seeps into an aquifer, and is pumped out by a single pump. Students walk through each part of the model, run experiments to better understand the model, and then modify the base model to add additional pumps and/or add variable rates for rainfall, pumping, and infiltration (soil types).

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 the hydrological cycle, watersheds, surface water, ground water, precipitation, percolation, aquifers, porosity, and infiltration are reviewed, but in order to achieve deeper learning it is advisable that the students will have covered these concepts beforehand. A recommended video resource that provides coverage of these concepts is available at: https://www.youtube.com/watch?v=R8NQUQDZ3N0. An alternate video is available at: https://www.youtube.com/watch?v=al-do-HGuIk.

It is necessary to have completed Module 1 prior to commencing this module, in order to have the necessary skills to complete the activities in this module.

3. Standards covered by the Module

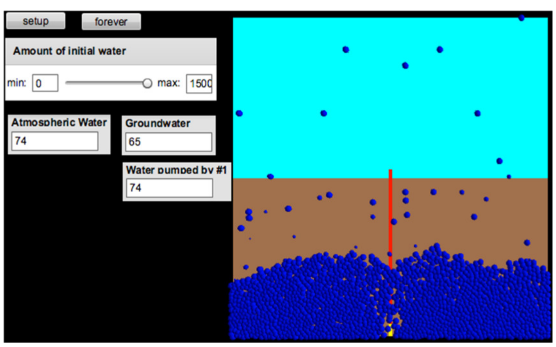
Please see the Standards Document for a detailed description of Standards covered by this Module, Lesson by Lesson.

4. Materials needed for this Module

You will need the following materials to teach this module:
- Computer and projector
- Water Resources background videos [for reference]
  "Water and You" https://www.youtube.com/watch?v=R8NQUQDZ3N0.

"The Water Cycle" https://www.youtube.com/watch?v=al-do-HGulk.

- Link to the Water for Life – Jay-Z video [http://www.mtv.com/artists/jay-z/playlist/1688080/]
- Large bucket of water for lesson 1 activity #2 (on day 1)
- 10 to 12 plastic cups for lesson 1 activity #2 (on day 1)
- Water source for lesson 1 activity (on day 1)
- Water pump base StarLogo Nova models
- Guided Introduction to StarLogo Nova document [for reference]
- 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]
- Scientific Practices with Computer Modeling & Simulation 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
- Slide presentation 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 Water as a Shared Resource

Pacing Guide

Getting Started	Introduce the Water as a Shared Resource module and sharing resources / cooperation as a complex system phenomenon.	5 mins
Activity 1	Watch & discuss Diary of Jay-Z in Africa: Water for Life.	15 mins
Activity 2	Shared Water hands-on activity; experience the sharing of water resources from the perspective of various stakeholders.	25 mins
Wrap-Up	How can computer modeling help us understand resource limitations and sharing?	5 mins

Learning Objectives: Students will…

Complex Adaptive Systems	Be able to describe how a community of water users can be studied as a complex system phenomenon: there are many agents interacting following simple rules, there is no leader, there are emergent patterns and the system may be unpredictable [**LO2**].
Disciplinary Core Ideas	Learn of limitations of and threats to fresh water supplies [**LO1**]. Consider the importance of water for our survival [**LO3**].
Modeling and Simulation	Learn that models can be used to investigate water sharing scenarios and or policies. [**LO4**].

Assessments of Understanding:

Complex Adaptive Systems	List two characteristics of water resources that show it is a complex system [**LO2**].
Disciplinary Core Ideas	List two threats to fresh water supplies [**LO1**]. List three ways humans are dependent on water for survival [**LO3**].
Modeling and Simulation	Why are modeling and simulation useful in understanding water resource management? [**LO4**]

DAY 2: Math Basics for Modeling and the Water Pumping Base Model

Pacing Guide

Getting Started	Review of the previous day's lesson and concepts. Connection to today's lesson.	5 mins
Activity 1	Review math basics for modeling: coordinate space, relative vs. absolute position, agent heading, and angles of rotation.	20 mins
Activity 2	Under the Hood: Inspecting the Water Pumping model. Find commands that are familiar and ones that are new. Decode model by procedures. Run the model multiple times.	20 mins
Wrap-Up	Is anything unexpected happening in the model?	5 mins

Learning Objectives: Students will…

Complex Adaptive Systems	Make observations of water being pumped out of the ground in the model. Identify an emergent pattern in the water pump model [**LO5**].
Disciplinary Core Ideas	Learn that water continually cycles among land, ocean, and atmosphere [**LO6**].
Modeling and Simulation	Identify abstractions made and limitations of the model [**LO7**]. Use the Water Pumping base model to conduct a repeated experiment and make observations (drawing simple correlations) [**LO8**].
Computer Science	Decode a model. [**LO9**] Trace a program's execution [**LO10**].

Assessments of Understanding:

Complex Adaptive Systems	What is an emergent pattern being formed when we run the model? [**LO5**]
Disciplinary Core Ideas	Identify which part(s) of the water cycle is represented in the Water Pumping model? [**LO6**]
Modeling and Simulation	What are some of the abstractions or simplifications made in the model? [**LO7**] What were some of the observations you made as you ran the model? [**LO8**]
Computer Science	Name three blocks of code you recognized and what each one does [**LO9**]. List the steps the program executes in order in the forever loop [**LO10**].

DAY 3: Adding More Water Pumps and Running Experiments

Pacing Guide

Getting Started	Review of the previous day's lesson and concepts and connection to today's lesson.	5 mins
Activity 1	Add another pump to the Water Pumping base model and add monitors and graphs that collect data on the amount of water pumped by each pump.	20 mins
Activity 2	Design and run an experiment to see the effect of the modification. What is the impact of multiple users? What factors determine which user gets more water?	20 mins
Wrap-Up	What does the computer model enable us to do that would be difficult to do in the real world? How could a model like this one be used to manage water resources?	5 mins

Learning Objectives: Students will…

Disciplinary Core Ideas	Learn that typically as human populations and consumption of natural resources increase, so do the negative impacts on Earth [**LO11**].
Modeling and Simulation	Ask a question that can be answered using the model as an experimental test bed [**LO12**]. Design and conduct an experiment [**LO13**]. Collect and analyze data to look for patterns [**LO14**].
Computer Science	Modify a simple computer model and display output data using widgets [**LO15**]. Practice Pair Programming and Iterative design, implement, and test cycle [**LO16**].

Assessments of Understanding:

Disciplinary Core Ideas	Describe potential negative impacts of adding additional water wells in a community with limited water resources [**LO11**].
Modeling and Simulation	See student Model Design Form and Experimental Design Form [**LO12, LO13,** and **LO14**].
Computer Science	Describe a procedure you added to the model [**LO15**]. In your own words, describe how you tested and, if necessary, refined your procedure [**LO16**].

DAY 4: Customizing Your Water Pumping Model

Pacing Guide

Getting Started	Review of the previous day's lesson and concepts and connection to today's lesson.	5 mins
Activity 1	Introduce key elements of the computational science process. Discuss other factors that impact water availability. Discuss local or regional issues affecting water supply or quality. Then define your computational science project.	20 mins
Activity 2	Design and develop your customized model in teams. Ideas for topics to investigate include variable rainfall, soil types, pollution, and/or regulations that impact water use.	20 mins
Wrap-Up	What research is necessary to ground your model in reality? How will you check to see if your model is realistic?	5 mins

Learning Objectives: Students will…

Disciplinary Core Ideas	Learn that resources are distributed unevenly around the planet as a result of past geologic processes [**LO17**]. Humans depend on water resources and many of these resources are not renewable or replaceable over human lifetimes [**LO18**].
Modeling and Simulation	Use the key stages of computational science and project design form to develop a question, create a model, and design an experiment [**LO19**].
Computer Science	Implement problem solutions using looping behavior, conditional statements, logic, expressions, variables and functions [**LO20**].

Assessments of Understanding:

Disciplinary Core Ideas	Give three examples of how local conditions affect water supply or quality [**LO17**]. Describe why some water is not renewable or replaceable; where does the water go? **[LO18]**
Modeling and Simulation	See student Project Design Form. (Did student choose a question appropriate for answering with the model? Could student explain why it was chosen? Did student describe the aspects of the real world to be included in the model and why they were selected? etc.) [**LO19**]
Computer Science	Describe procedures in the model that you built. Choose one and describe how it works in detail [**LO20**].

DAY 5: Experiment with Your New Water Pumping Model

Pacing Guide

Getting Started	Review of previous day's lesson and concepts and connection to today's lesson.	5 mins
Activity 1	Complete and debug code.	15 mins
Activity 2	Run experiments, analyze results and discuss conclusions. Relate the results back to the bigger issue of shared resources and ground water. Prepare your model and results for presentation.	25 mins
Wrap-Up	How would you know if your model reflects reality? What research is necessary to check if your model reflects the real-world?	10 mins

Learning Objectives: Students will…

Complex Adaptive Systems	Revisit complex systems concepts and learn how they relate to understanding resource management [**LO21**].
Disciplinary Core Ideas	Gain a deeper understanding of impacts on ground water resources through experience creating and experimenting with a water pump model [**LO22**].
Modeling and Simulation	Use customized model as an experimental test bed to run experiments [**LO23**]. Learn that multiple runs of the experiment are needed at each variable setting due to inherent randomness in the model [**LO24**].
Computer Science	Use iterative refinement and apply debugging techniques to isolate and fix errors in code [**LO25**].

Assessments of Understanding:

Complex Adaptive Systems	Describe four characteristics of a complex system and how they relate to a resource management situation [**LO21**].
Disciplinary Core Ideas	What local or regional issue impacting water resources was included in your model? What are some of the potential impacts of that factor or condition? [**LO22**].
Modeling and Simulation	See student Experimental Design Form [**LO23, LO24**].
Computer Science	Give an example of how you were able to find and fix an error you had in your code [**LO25**].

2

Lesson 1

Introduction to Water as a Shared Resource

50 minutes (1 day)

Lesson Overview (New Learning – guided by teacher)

In this lesson students will engage in discussion about water resources and group decision-making, stimulated by a video and a participatory simulation that serve to highlight group decision-making dynamics. The video will serve to get students thinking about water resources and the difficulties some people their age face in obtaining safe drinking water. The two activities will provide background on how communities make decisions, especially when dealing with a shared resource like water.

Teaching Summary

Getting Started – 5 minutes

1. Water as a Shared Resource Overview

Activity #1: Water for Life – 15 minutes

2. Watch and discuss "Water for Life: Diary of Jay-Z in Africa" video
3. Sources of fresh water: ground water vs. surface water

Activity #2: Water Sharing – 25 minutes

4. Participatory Simulation: "Some for All or All for One"
5. Debrief the participatory simulation

Wrap-Up – 5 minutes

6. How can computer modeling help us understand resource management?

Lesson Objectives

The student will:

- ✓ Learn of limitations of and threats to fresh water supplies [LO1]
- ✓ Be able to describe how a community of water users can be studied as a complex system [LO2]
- ✓ Consider the importance of water for our survival [LO3]
- ✓ Learn that models can be used to investigate water sharing scenarios and or policies [LO4]

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- Paper cups

For the Teacher

- Computer and projector
- Water Resources background document
- Link to the "Water for Life: Diary of Jay-Z in Africa" video
- Water jug
- White board or large flip chart and markers

Getting Started - 5 min

1. Water as a Shared Resource overview

Start with a quick overview of relevant earth science concepts using direct instruction. (It is expected that the students have learned these concepts prior to encountering them in this module.)

- [ESS3.A: Natural Resources] Living things need water, air, and resources from the land, and they live in places that have the things they need. Humans use natural resources for everything they do.
- [ESS3.C: Human Impacts on Earth Systems] Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other 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.
- [MS-ESS2.C: The Roles of Water in Earth's Surface Processes] Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. Nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and form underground formations.
- [MS-ESS2.C: The Roles of Water in Earth's Surface Processes] Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. Global movements of water and its changes in form are propelled by sunlight and gravity.
- [MS-ESS3.A: Natural Resources] Humans depend on Earth's land, ocean, atmosphere,

and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.

Activity #1: Water for Life - 15 min

In this activity, students will watch a compelling video then review the sources of fresh water and the difference between ground water and surface water.

2. Watch and discuss "Water for Life: Diary of Jay-Z in Africa" video

- Link to the "Water for Life: Jay-Z in Africa" video found at http://www.mtv.com/artists/jay-z/playlist/1688080/
- Watch from 00:00 to 07:37 on the video.
- What was the most surprising thing you learned in this video?

3. Discuss the sources of fresh water and the difference between ground water and surface water

- Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere.
- Which sources are ground water [aquifers, subglacial lakes] and which are surface water [streams, lakes, wetlands]?
- Even though the amount of water locked up in glaciers and ice caps is a small percentage of all water on (and in) the Earth, it represents a large percentage of the world's total freshwater. The majority of freshwater on Earth, about 68.7 percent, is held in ice caps and glaciers. (Source: water.usgs.gov/edu/watercycleice.html)

Teaching Tip *It is important to be sensitive to the fact that students in some regions of the country also live without readily-available sources of fresh water.*

Activity #2: Water Sharing - 25 min

4. Participatory Simulation: "Some for All or All for One"

This activity is designed to highlight some of the interesting dynamics that come about when a group of individuals has to make decisions regarding a shared resource. In this "participatory simulation" students will act as stakeholders in a water-sharing scenario. When considering a shared resource like a water well, it is important to understand that each member in a community that uses this well has an impact on every other well user. An individual has the ability to choose what amount of the resource they will take based on some simple rules.

- Before running the participatory simulation, fill the water bucket with the equivalent of 6 drinking cups of water. (Use the plastic cups that will be distributed to the stakeholders.)
- Select 10 to 12 students to play the roles of stakeholders in a community. The remaining students are observers who should quietly observe the game in progress.
- Have the stakeholders form a circle then face out from the center.
- Give each stakeholder an empty cup.
- Tell the stakeholders that they will have the opportunity to take the water they need.
- Tell the stakeholders that whatever is left in the bucket at the end of the round, the teacher will double and redistribute to everyone equally.

- Note that since the stakeholders are facing away from the center of the circle; they cannot see each other's action.
- Play three rounds as follows.

  Round 1: (Do group discussion prior to playing the round.)
  - Explain the rules then play one round as specified above. Each stakeholder has the opportunity to take the water he or she needs, up to a full cup's worth.
  - Remember that players are facing out and shouldn't see what the others stakeholders are taking.
  - Example scenario - there are 10 stakeholders; you start with the equivalent of 6 cups of water. Each stakeholder takes the equivalent of ½ a cup. At the end of round 1, there are now 5 cups distributed among stakeholders, plus 1 cup remaining in the bucket. The teacher now doubles that to 2 cups. Each player now gets an additional 2/10 of a cup. Note that if some stakeholders take full cups worth of water, others will be left with none!
  - When all stakeholders have had a turn, have the stakeholders turn so that they are facing into the circle and compare what choices the other stakeholders made. When some stakeholders see what has happened, they might think it 'isn't fair.'
  - Remind the stakeholders that everyone made their choices individually.
  - Allow students to have a short discussion before the next round.
  - Teacher note: If all 10 players decided to take 0 cups of water, then the amount of water would be doubled to 12 cups and everyone would have more than enough to fill their cups at the end of the round. Students should not be told this but will likely figure it out on their own.

  Round 2: (Do group discussion prior to water distribution.)
  - Reset the game to the original configuration with 6 cups of water in the bucket and none in the stakeholders' cups.
  - In this round, stakeholders are allowed to have a group discussion before the water gets distributed. The group can discuss the strategies beforehand but then they must go back to facing out so they cannot see what the other stakeholders actually do.
  - Follow the same rules – the limit is 1 cup for each player, then the remaining amount gets doubled after the round and redistributed.
  - Again allow time to have a short discussion of what happened before the next round.

  Round 3: 'The Punishment' round
  - This time, do not reset the game to the original configuration!
  - In this round, each stakeholder can 'pay' the teacher 1/3 of a cup of water to take away 1 cup of water from someone else in the group.

5. **Debrief the Participatory Simulation**

   Making decisions as an individual or as a group have can often lead to unexpected results. If you were to study the 'average' decision that individuals make, it will not always be a good predictor of what the group as a whole will decide. Individuals may act differently when they are cooperating. In small groups, humans will often cooperate because they are related or friends with the others in the groups. Cooperation and sharing resources was necessary for our human ancestors' early survival, yet cooperation still exists today. There aren't many that are 'free loaders.' People in these groups tend to help out and eventually get rewarded by receiving help from others. There are many examples of where cooperation is seen in humans - a group of hunters going after a large prey, cooperating on the playing field to win a game, community gardens and farms, volunteering to help pass out papers in the classroom, etc. However, even if cooperation is still very common in humans, it doesn't mean that everyone in a group will cooperate with a group decision. In this case, an individual could ‘defect’ from the cooperation yet still benefit from the resources that are in the community. In a group of cooperative people, it is often beneficial for a person to act in a selfish way.

Debrief the participatory simulation:

- Ask the stakeholders: How did you decide how much water to take? Did you change your ‘strategy’ after the first round? Did you consider the options for how much water to take from an individual perspective or from a group perspective?
- Most likely there are a few that are ‘defectors’ and act in a more selfish way. Ask “Do you think it is typical for a group of people that share a resource to have a few that act in a selfish way?”
- Ask observing (non-stakeholder) students “Can you think of any real-world situations that are similar to this game?”
- If an individual acts out of self-interest but the action ultimately proves to be self-defeating, how might they act in the future?
- Ask “What do you think would happen if there was no punishment round?”
- Relate to students that scientists study the “evolution of cooperation” using computer models and simulations of simple scenarios like the one they just played.
- Resources and further reading:
  http://www.sciencedaily.com/releases/2010/05/100501013529.htm
  http://www.beinghuman.org/article/evolutionary-benefits-cooperation

Wrap-Up - 5 min

6. **How can computer modeling help us understand resource management?**
   - If we were to model the game we just played, what would the agents represent? What rules would the agents follow? What kinds of questions could we try to answer using the model?
   - What are other resources that we need to manage in our community?

Assessment Questions

- List two threats to fresh water supplies [LO1].
- List two characteristics of water resources that show it is a complex system [LO2].
- List three ways humans are dependent on water for survival [LO3].
- Describe how modeling and simulation can be used in water resource management? [LO4]

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.

NRC Disciplinary Core Ideas

ESS3.A: **Natural Resources** Humans depend on Earth’s land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.

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.
ESS2.C: **The Roles of Water in Earth's Surface Processes**
Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. Nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and form underground formations. Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. Global movements of water and its changes in form are propelled by sunlight and gravity.

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.
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	2-10	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.

2

Lesson 2

Math Basics for Modeling and the Water Pumping Base Model

50 minutes (1 day)

Lesson Overview (New Learning and Exploration)

In this lesson, students will become familiar with the Water Pumping base model. In the first activity students will review math basics necessary for understanding the model. In the second activity students will decode the base model and run simple experiments, make observations, and identify a complex systems characteristic of the model. In the third activity, students will add an evaporation slider, and then will run an experiment, using the slider. Finally, students will be asked to think of ways to improve the model, based on what they know about the hydrologic cycle and water as a resource.

Teaching Summary

Getting Started – 5 minutes

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

Activity #1: Math Basics for Modeling – 15 minutes

2. Review coordinates on a graph; connect coordinate system to Spaceland.
3. Create turtles in different quadrants of Spaceland and use new blocks to make turtles move in a specific direction.

Activity #2: Inspecting the Water Pumping Model – 10 minutes

4. Identify familiar coding blocks
5. Decode model in pairs.

Activity #3: Adding a Slider for Evaporation Rate – 15 minutes

6. Add a slider for evaporation rate.
7. Run an experiment using the evaporation slider.
8. Discuss the results and relate them to the hydrologic cycle.

Wrap-Up – 5 minutes

9. Discuss limitations of the model and think of ways of improving it.

Lesson Objectives

The student will:

✓ Identify an emergent pattern in the water pump model [LO5].
✓ Learn that water continually cycles among land, ocean, and atmosphere [LO6].
✓ Identify abstractions made and limitations of the model [LO7].
✓ Use the Water Pumping base model to conduct a repeated experiment and make observations (drawing simple correlations) [LO8].
✓ Decode a model [LO9].
✓ Trace a program's execution [LO10].

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- Water Pumping StarLogo Nova base model
- Coordinates and Headings in StarLogo Nova [student handout]
- Model Observation Form [student handout]
- Scientific Practices with Computer Modeling & Simulation [student handout]
- Experimental Design Form document [student handout]
- New commands and concepts sheet [student handout]

For the Teacher

- Computer and projector
- Water Pumping StarLogo Nova models: base model, base model plus evaporation.
- 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**
   - What do you remember from the video? [Refer to Lesson 1.] (DCI: The Role of Water in Earth's Surface Processes) (DCI: Human Impacts on Earth Systems)
   - Can anyone summarize what happened during our game sharing water? [Refer to Lesson 1.] (Practice: Constructing Explanations and Designing Solutions)
   - What do you remember from the Water Pumping model? What elements were modeled in it? [Have the students open the Water Pumping model in pairs and identify elements; refer to Lesson 1.] (Practice: Developing and using models)

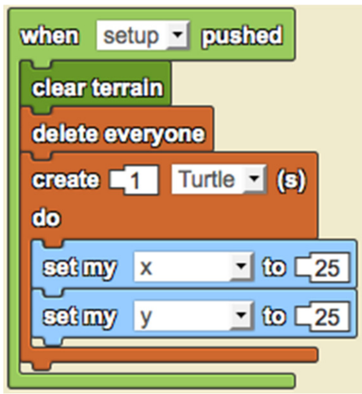
Activity #1: Math Basics for Modeling - 15 mins

In this activity, the students will connect their prior understanding of graphing to the green Spaceland of StarLogo Nova. The coordinate system of Spaceland has (0,0) in the center and expands 50 blocks in all directions. Students will practice placing their turtles in specific quadrants of Spaceland using set traits block called 'set my…' Students will then use the 'set my heading to' block to explore having turtles move in specific directions in Spaceland. These commands were used to make the water molecules move as if responding to gravity. (Practice:

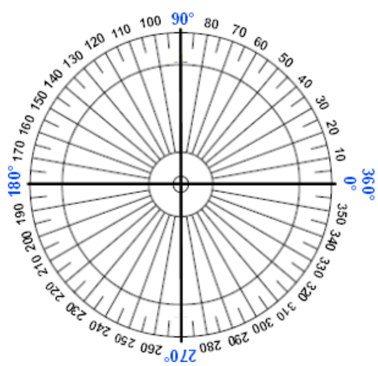
Using Mathematics and Computational Thinking)

2. **Review coordinates on a graph; connect coordinate system to Spaceland.**
   - Review X and Y axes as horizontal and vertical and review where (0,0) is in Spaceland.
   - Demonstrate to students how to set an agent at (0,0)

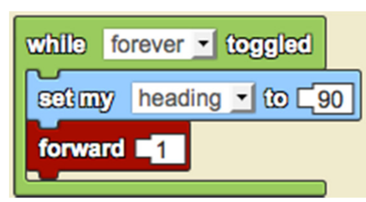
3. **Create turtles in different quadrants of Spaceland and add new blocks to have the turtles move in a specific direction.**



- Have students add code to the 'when setup pushed' block. First they must clear everything that was there before and then add a turtle with specific X and Y coordinates.
- Next, students should add to the setup code by adding 3 more 'create 1 turtle' with new X and Y coordinates.
- Students should be able to put a turtle in each of the 4 quadrants using the 'set my' blocks.



- Now students will use the 'when forever toggled' block to get their turtles moving in a specific direction on Spaceland. The directions follow 360 degrees like a protractor.
- Have students get their turtles to all move towards the top of Spaceland. To do this they will need the code as seen below.



Activity #2: Inspecting the Water Pumping Model - 10 mins

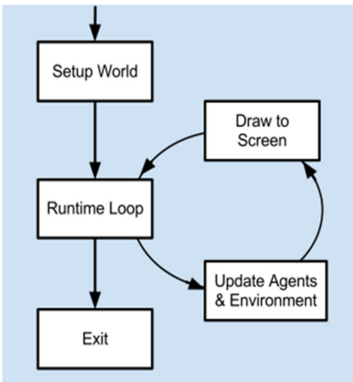
4. **Review familiar and new command blocks.**
   - Keep track of familiar command blocks. Students can refer to their StarLogo Nova Command Blocks and CS Concepts reference sheets from Module 1.
   - Review what the new command blocks do [New commands and concepts sheet].
   - As a group, look at the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

5. **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: Pump, Evaporation, Make Sky, Make Pump, Make Earth, Position Groundwater, Groundwater Movement. The detailed

description of what an agent's procedures are can be added to the Model Observation Form.

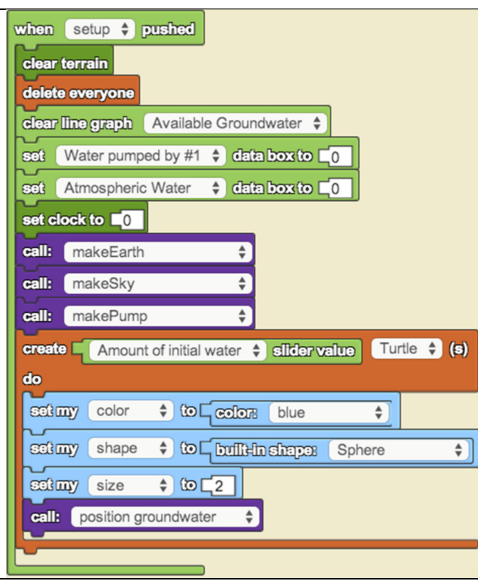
- Give the students 5 minutes to decode, then ask students to share out.

[Note to teachers:] 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.



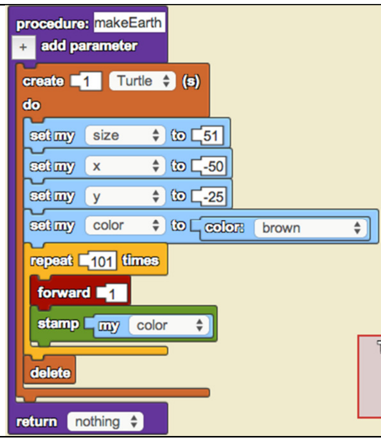
Time is harder to see; instead it can be thought of as a series of time slices or "clock ticks." At each tick, all of the agents have a chance to update their position or state. Ticks or time slices are not the same as seconds because it may take more or less than one second to update all of the agents. 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?"



When the setup button is pressed, Spaceland is cleared of everything and everyone then clears the parts relating to the graph and data boxes to set them at zero.

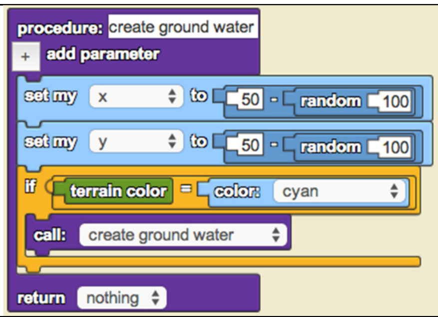
Next, the three procedures are done (MakeEarth, MakeSky and MakePump). The water molecules are created and spread out using a procedure called 'position groundwater.'



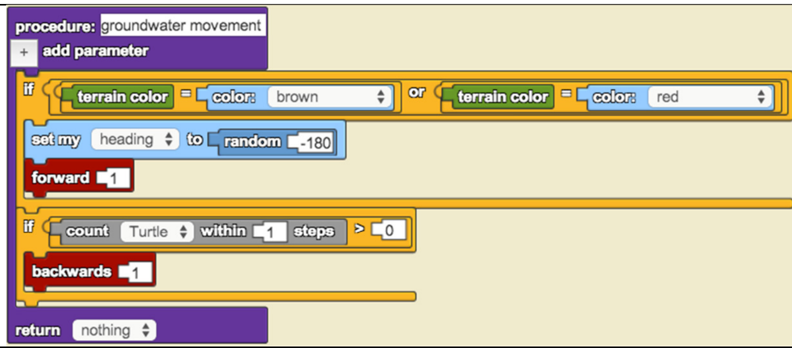
The procedure ‘makeEarth’ has the computer repeat creating a turtle and stamping a brown color on Spaceland. This covers the bottom half of Spaceland with a brown area called Earth.

The procedure ‘makeSky’ has the computer repeat creating a turtle and stamping a cyan blue color on Spaceland. This covers the top half of Spaceland with a cyan blue area called Sky.

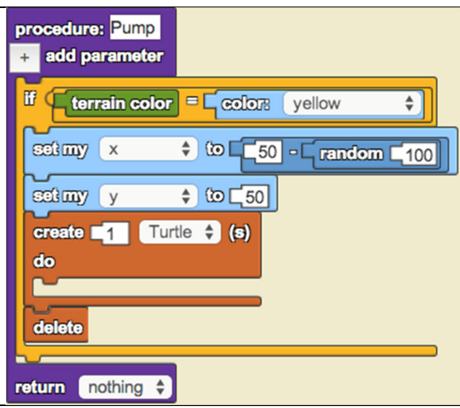
In order to make a red pump with a yellow end, the computer sets its traits to be a certain size, color, facing a certain way, as well as a location on Spaceland. The pump is 50 grid blocks tall plus a 5-block tall area that is yellow. Once the pump is made, the turtle is deleted.



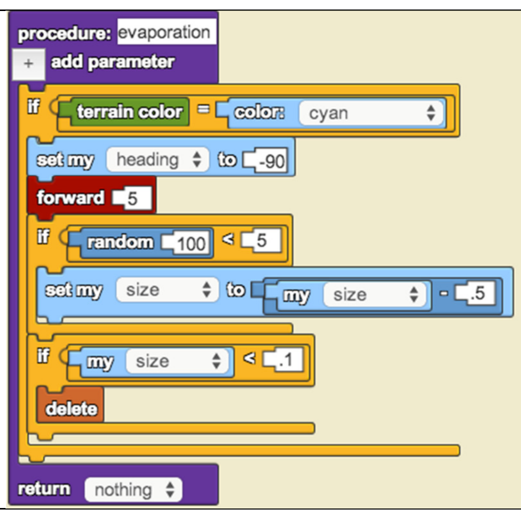
Blue groundwater is created by using a random X and Y coordinate. Groundwater can only be created in the brown Earth area, not in the cyan sky area. If it lands in the cyan sky area it has to do the procedure over again.



Groundwater will move through the brown Earth area by having a random heading downward, and if it lands on top of another water agent, it will jump back one and keep moving



The water will get 'pumped' when the water hits the yellow part of the pump. This means that the water leaves the Earth and goes into the atmosphere. The water is put up at the top of Spaceland and a new water turtle is created, while the original one is deleted.



In the turtle page, water falls from the sky by having its heading down (-90) and it has a 5% chance of getting smaller. If it gets so small, it will disappear.

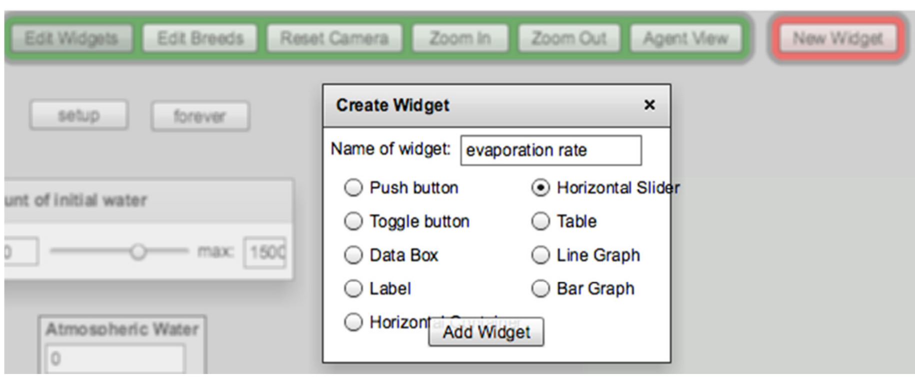
Teaching Tip *The program execution loop can be diagrammed on the board to give visual clues as to what is happening as time advances in the simulation.*

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).*

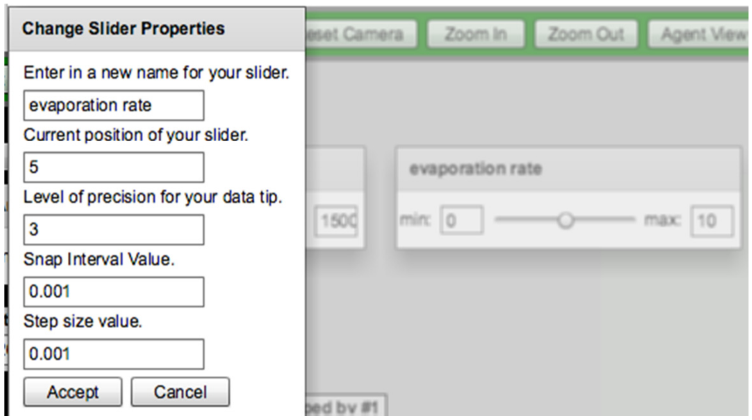
Activity #3: Adding a Slider for Evaporation Rate - 15 mins

In this activity students will add a slider that controls the evaporation rate of water. With the slider, they will be able to will run experiments more efficiently. They should propose questions about the effect of evaporation on the water cycle as modeled here, and they should reflect on the real-world implications of their discoveries. (Practice 1: Asking questions and defining problems) (Practice 2: Developing and using models) (CCC: Patterns)

6. **Add a slider for evaporation.**
   - Have the students remix the model and rename it by adding "mod 1."
   - Review the part of the code that controls evaporation.
   - Ask the students if they can think of a way of changing the evaporation 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.

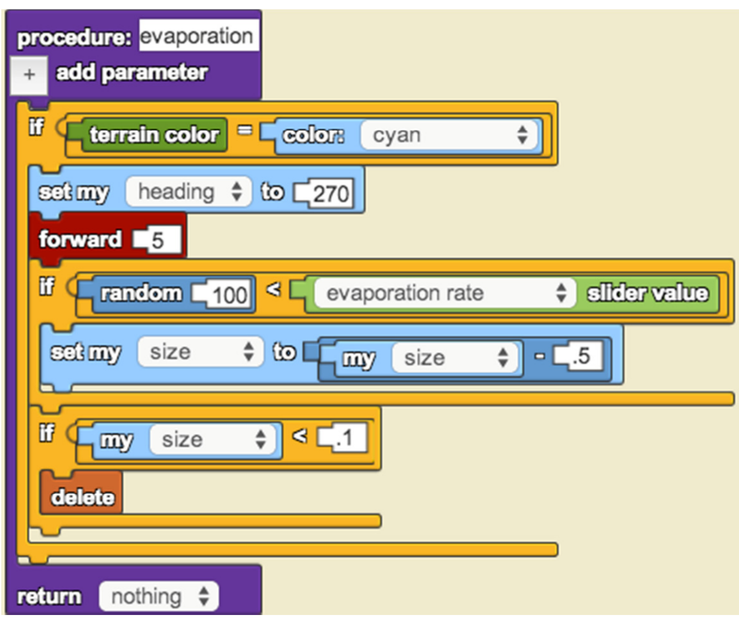


Ask the students if they could use this for changing the evaporation WHILE running the model, WITHOUT going to the code.



Change the maximum and minimum and step size for the evaporation, a rate of 100 is usually good. (Double click on the slider.) Click “edit widgets” again to get out of the editing widgets mode.

- Ask the students to run the code.
  Does it work? Why not? Check the code for the evaporation procedure. 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 evaporation on the slider. Has anything happened?

7. Run an experiment using the evaporation slider.

- Now that it’s easy to change the evaporation we can run an experiment! We can observe the system from the global perspective to see the relationship between evaporation rate and the availability of water, as well as some of the dynamics of the hydrologic cycle.

(CCC: Scale, proportion, and quantity)
- Use the “Experimental Design” form as a guide and guide students as they develop a scientific question while working in pairs. Emphasize the need to use multiple trials at each setting and to clearly identify the variables, as well as the difference between a question and a *testable* question.
- 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 the amount of groundwater 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)

8. **Discuss the results and relate them to the hydrologic cycle.**
   - Share out your experimental results.
   - Did the experiment work as you expected?
   - What do you think will happen if we run out of groundwater? (Practice 1: Asking questions and defining problems)

Wrap-Up - 5 mins

9. **Discuss limitations of the model and ask students to think of ways of improving it as homework.**
   - What’s missing from this Water Pumping model? (Practice 2: Developing and using models)
   - How do humans influence the hydrologic cycle?
   - How can we add water sharing and infiltration to our model? (Practice 1: Asking questions and defining problems) Discuss adding more pumps as well as changing how the water moves through the earth.

Assessment Questions

- What is an emergent pattern being formed when we run the model? [LO5]
- Identify which part(s) of the water cycle is represented in the Water Pumping model? [LO6]
- What are some of the abstractions or simplifications made in the model? [LO7]
- What were some of the observations you made as you ran the model? [LO8]
- Name three blocks of code you recognized and what each one does [LO9].
- List the steps the program executes in order in the forever loop [LO10].

Standards Addressed

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.

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.
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.

Lesson 2 - Student Activity #2 Guide

Inspecting the Water Pumping Model

Look 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 Water Pumping 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 is a tip:

- 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? *How much time does the main forever loop represent? (minutes? days? months?)* *What are the variables of interest?*
Automation
What happens each time through the forever (or main) loop?
Assumption(s)
What real life elements or behaviors were left out of this model?
Analysis
What patterns did you observe? Do these patterns occur in real-life?

Lesson 2 - Student Activity #3 Guide

Adding a Slider for Evaporation Rate

Adding a Slider
In Activity 2 you edited the code to change the evaporation rate. In this activity you will learn a better way to change the evaporation rate.

1) **REMIX** your model and edit the name to “Water Pumping base model **your name your partner’s name mod1**”
2) Add a slider for the evaporation rate and all necessary code.
3) Write down the slider settings you set.
4) Run an experiment using the evaporation rate slider. Use the **Experimental Design Form** to design your experiment first.
5) Record the data from your experiment and summarize your results.

Here is a tip:

- 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.
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?
Prediction
What effect do you think the changes you make will have on the model?
Data Collection
What data will you collect?
Data Analysis
How will you analyze your data? (i.e. look for patterns, compare final values, look at the graph)
Interpretation
What is the answer to your question? 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:	
Ask questions and define 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 More Water Pumps and Running Experiments

50 minutes (1 day)

Lesson Overview (New Learning and Exploration)

In this lesson, the students will modify the base Water Pumping model to include additional water pumps. In the first activity, the students will add a second water pump that pulls water from the aquifer. Next, students will add monitors and a line graph that collects and displays the cumulative amount of water pumped by each pump. In the second activity, the new model can then be used as an experimental test bed. Students develop a hypothesis, run an experiment, and analyze the results to see what effect the modification had on the system.

Teaching Summary

Getting Started – 5 minutes

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

Activity #1: Adding a Water Pump – 20 minutes

2. CS review: find and decode the procedure that creates the initial pump.
3. Duplicate and alter the procedure to create a new pump.
4. Add monitors and line graphs to display and visualize data.
5. Test your model.

Activity #2: Running an Experiment – 20 minutes

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

Wrap-Up – 5 minutes

9. What does the computer model enable us to do that would be difficult in the real world?
10. How could a computer model like the Water Pumping model be used to manage water resources?

Lesson Objectives

The student will:

- ✓ Learn that typically as human populations and consumption of natural resources increase, so do the negative impacts on Earth [LO11].
- ✓ Ask a question that can be answered using the model as an experimental test bed [LO12]. Design and conduct an experiment [LO13].
- ✓ Collect and analyze data to look for patterns [LO14].
- ✓ Modify a simple computer model and display output data using widgets [LO15].
- ✓ Practice Pair Programming and Iterative Design-Implement-Test cycle [LO16].

Teaching Guide

Materials, Resources and Preparation

For the Students

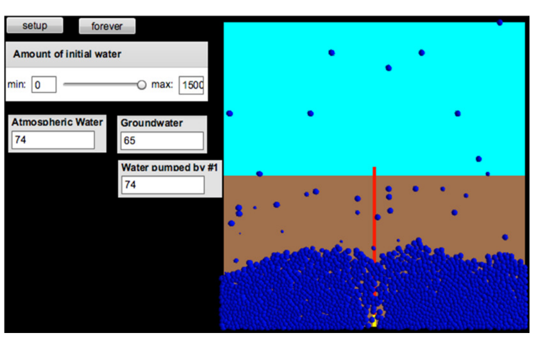
- Computers
- Water Pumping StarLogo Nova base model
- New commands and concepts sheet [student handout]
- Model Design Form document [student handout]
- Experimental Design Form document [student handout]

For the Teacher

- Computer and projector
- Water Pumping StarLogo Nova models: base model, base model plus new pumps
- Water Resources background videos [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

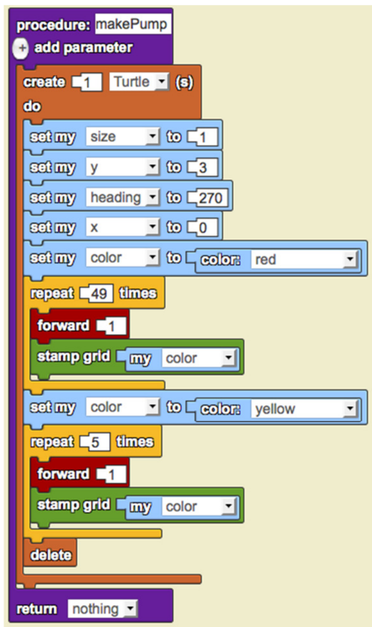
1. **Review of the previous lesson and make connection to today's lesson** – 5 mins
   - Last time we learned about the base model, the abstractions included, and the mechanisms that are executed to make the simulation run. Today we are going to add another pump to the model, then add output widgets so we can assess the impact of the new pump when we run experiments. What do you predict will happen when we add a new pump? (Practice 1: Asking questions and defining problems) (Practice 2: Developing and using models) (CCC: Cause and Effect)
   - Review concepts of infiltration and aquifers.



Activity #1: Adding a Water Pump - 20 mins

We'll be adding a new pump that pulls water from the aquifer. Ask the students to review what we know about how the first pump was created. Remember to remix the project before making any changes.

2. **CS Review: code and concepts useful for the modification**
    - Use Think-Pair-Share to have students discuss the existing code and report out.

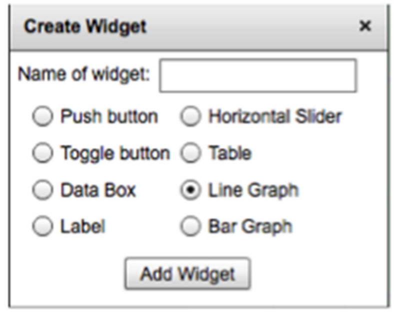


- [Teacher notes:] Remember that in this model we are using a 2D view of Spaceland, rather than the 3D view.
- In the "makePump" procedure a red turtle is created at (0, 3) and is set to head towards the bottom edge of Spaceland.
- Then the turtle takes 49 steps forward while stamping the grid beneath it red at each step.
- Then the turtle sets its color to yellow and continues 5 more steps forward while stamping the grid beneath it yellow at each step.
- Finally, the turtle is no longer needed so we delete it.

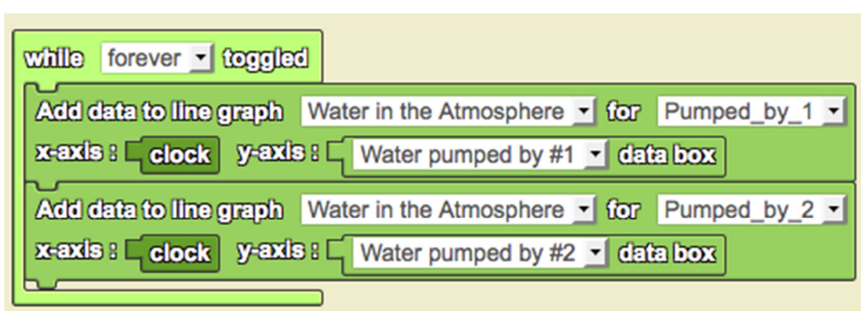
3. **Duplicate and alter the procedure to create a new pump**
    - Ask students for suggestions on how to make a new pump.
    - Suggest that we start by making a copy of the existing code for creating a water pump! (n.b. this is a perfect opportunity to talk about remixing on a procedural level.)
    - Demonstrate how to use the rectangular lasso to select, copy, and paste a whole code block.
    - Give the students the challenge of repositioning the second pump at a distance from the first pump.
    - Have the students show their neighbors their solutions to this challenge.
    - Next, if time allows, tell the students that we will want to be able to distinguish the number of water particles drawn up by each pump so we will need to be able to tell whether a water molecule is pulled up by one pump or another.
    - Have students brainstorm and attempt a solution to this challenge.

4. **Add monitors and line graphs to display and visualize data**
    - Demonstrate to the students how to use the Edit Widgets tool to add two output data boxes and a line graph (or, alternatively, have a student who knows this technique demonstrate it).
    - [Notes for the teacher:] Let's add some instrumentation so we can detect how fast the water is being pumped from each pump head.
    - We will start with by adding two monitors, one for the water pumped by the first pump head and one from the new pump head.

- Click the "Edit Widgets" tool in the Spaceland window then click on "Create Widget."



- Select "Data Box" and then name the widget "Water pumped by #1" and click "Add Widget." Reposition the widget where it is clearly visible and does not overlap any existing user interface element. Do the same steps to create a widget called "Water pumped by #2."
- Note: these data boxes can now be used as global variables. The value held in the data box can be updated by any agent.
- Next, add the code that will initialize the values of these data boxes, then increment (or increase) the value anytime an agent interacts with the pump.
- Where do we initialize the values? [in the setup]
- Where do we increment the values? [in the "pump" procedure]
- In order to collect and visualize quantitative data we need to add a line graph in StarLogo Nova. With this information we will be able to compare patterns in the collected data.
- For this model, what products do we want to monitor? [We'd like the graph to collect data on the time elapsed since the model started running and the cumulative number of water molecules pumped by each pump over time.]
- Let's create a new line graph called "Water Pumped over Time."
- Demonstrate how to create a line graph in StarLogo Nova using Edit Widgets. Drag the line graph off to the side of Spaceland. Add new series to the graph by double clicking on New Series and changing the name and line color.
- For example,
    - Create a new series called "Pumped_by_1" then select red as its line color.
    - Create a new series called "Pumped_by_2" then select black as its line color.
- Finally, click "Edit Widgets" to leave editing mode and return to play mode.
- Next, we want "The World" to update the line graph each time through the forever loop, so we need to add a "while forever toggled" loop on the page labeled "The World."



- Notice that we need the "clock" along the x-axis and the cumulative number of water pumped on the y-axis. Where can we get a count of water agents pumped? [The value is held in the "Water pumped by #1" data box already, so use it.]

- Add in similar "Add data to line graph" command blocks to the "while forever toggled" loop for each of the other products you would like to monitor in the line graph.

5. **Test your model**
   - Test your model: Click the "setup" button. Did the value in the "Water pumped by #1" and "Water pumped by #2" data boxes get reset to zero? Click on "forever." Does the model behave as expected? Is the line graph displaying data? Are the water molecules getting sucked up by the pumps? (Practice 3: Planning and carrying out investigations)

     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 experiment with additional modifications.*

Additional modifications: (optional)
- Change the pump depth
- Change the pump head surface area
- Add even more pumps

Activity #2: Running an Experiment - 20 mins

In this activity students will run an experiment using the model they have modified by adding another pump. 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 multiple trials at each setting and to clearly identify the variables, as well as the difference between a question and a *testable* question. (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 will be conducted 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 the cumulative number of water molecules pumped over time under the different conditions 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 2400 ticks with a second pump located with x = 25. Hit forever to pause it every 100 ticks. Write down the count of water molecules pumped from each of the data boxes. 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. Compare the amounts pumped to the results from the same experiment, when run with just one pump.
     Note: This experiment is just an example among many possible experiments.

8. **Collecting and analyzing data.**
   - Graph your data points. Do you notice any trend? Did the amount of water pumped increase, decrease or stay the same over time with the modification added? 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. **What does the computer model enable us to do that would be difficult to do in the real world?**
9. **How could a computer model like this one be used to manage water resources?**

Assessment Questions

- Describe potential negative impacts of adding additional water wells in a community with limited water resources [LO11].
- Assess student responses on the Model Design Form and Experimental Design Form [LO12, LO13, and LO14].
- Describe a procedure you added to the model [LO15].
- In your own words, describe how you tested and, if necessary, refined your procedure [LO16].

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. **Earth's Systems** MS-ESS2-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

NRC Disciplinary Core Ideas

ESS2.C: **The Roles of Water in Earth's Surface Processes** Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. Global movements of water and its changes in form are propelled by sunlight and gravity. 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.

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	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.

Lesson 3 - Student Activity #1 Guide

Adding a Water Pump

In this activity, you will be adding a new pump that pulls water from the aquifer. Review what you know about how the first pump was created.

1. Open up your version of the base model. **REMIX** and rename the project with ***your name your partner's name*** **mod3**"

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.

Lesson 3 - Student Activity #2 Guide

Running 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 is a tip:

- 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?
Prediction
What effect do you think the changes you make will have on the model?
Data Collection
What data will you collect?
Data Analysis
How will you analyze your data? (i.e. look for patterns, compare final values, look at the graph)
Interpretation
What is the answer to your question? 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?
What do the agents represent? *What does the space or environment represent?* *What are the Interactions?* *How much time does the main forever loop represent? (minutes? days? months? years?)* *What are the assumptions made? What real life elements or behaviors were left out of this model?*
How will it be modeled?
What happens when simulated time advances?

2

Lesson 4

Customize your Water Pumping Model

50 minutes (1 day)

Lesson Overview (New Learning and Exploration)

In this lesson, students design their own Water Pumping 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 Water Pumping 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 Designing Your Project – 20 minutes

2. Introduce key components of the computational science process
3. Define your computational science project

Activity #2: Designing and Developing 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:

- ✓ Learn that resources are distributed unevenly around the planet as a result of past geologic processes [LO17].
- ✓ Learn that Humans depend on water resources and many of these resources are not renewable or replaceable over human lifetimes [LO18].
- ✓ Use the key stages of computational science and Project Design Form to develop a question,

create a model, and design an experiment [LO19].
- ✓ Implement problem solutions using looping behavior, conditional statements, logic, expressions, variables and functions [LO20].

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- Water Pumping StarLogo Nova model
- New commands and concepts sheet [student handout]
- Project Design Form [student handout]
- Experimental Design Form document [student handout]
- Scientific Practices with Computer Modeling & Simulation document [student handout]

For the Teacher

- Computer and projector
- Water Pumping StarLogo Nova models: base model, base model plus pumps.
- Water Resources background videos [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**
   - Last time we added another pump to the Water Pumping base model, and used the model as an experimental test bed to see the impact of additional water consumers on the aquifer. What did we learn? (DCI: Human impacts on Earth Systems)
   - Today, using what you've learned in the first three lessons on water resources and computational science, you'll come up with your own modifications in teams.

Activity #1: Computational Science and Design Your Project - 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 a local condition impacting water supply or quality.

2. **Introduce key components of the computational science process**
   - 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-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, refer to the Water Pumping model 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 local/regional factors such as rainfall, soil types, pollution, or regulations that may affect water supply or water quality. (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.

  [As an example, we might add regions with soil of different porosity (clay, dirt, gravel, etc.) to the model. Have water move through different regions at different speeds.]
  [As an example, we might add restrictions on water pumping such that after a limit is reached by a pump, the pumping turns off thereby allowing other pumps to continue unabated.]

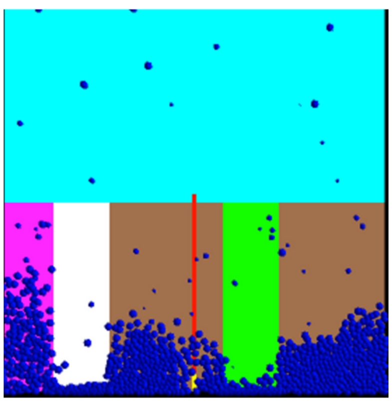
  Teaching Tip *Students should be encouraged to develop their own Water resource questions they would like to address with their models. The teacher should help them* *simplify their questions to ensure they will be able to create an appropriate model.*

Activity #2: Designing and Developing 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. [The example provided below shows how to regions of different soil types.]

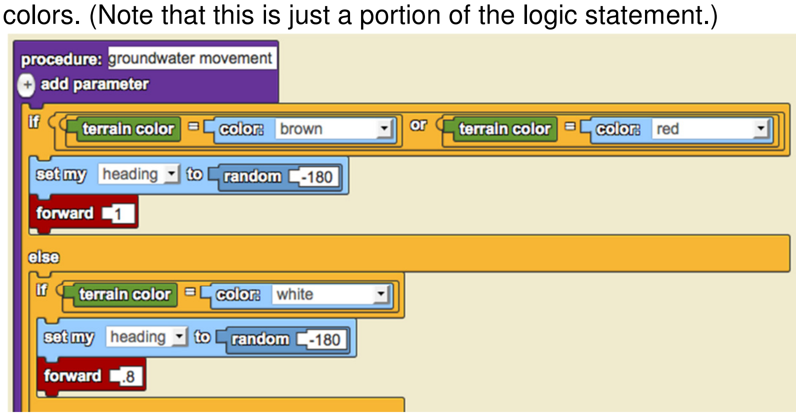
4. Agents and Environment

- The students should first create code that adds in their agents and any modifications to the environment they want. The setup code in “The World” page is usually used for setting up the environment and populating the environment with agents. In the example of creating regions of different porosity, the following steps would be necessary:
  - Create an agent who will stamp a region of a different color.
  - Create a procedure (called from within the “when setup pushed” procedure) that instructs the agent to walk with pen down to change the terrain color in places. When the area is colored then the agent can be deleted.



5. Interactions

- The students should then create code that instructs an agent what to do when it interacts with other elements in the environment or with other agents. Below is an example of instructing agents how to interact when they are stading on terrain patches of different colors. (Note that this is just a portion of the logic statement.)



  - Run the code and test it. Do the elements of the model behave how you think they should? Be sure to test the range of values for each variable (such as evaporation rate and number of water agents).

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. adding two types of soils with different porosity, changing the rates at which water is recharging the aquifer, adding some element that partially blocks the flow of the water in the ground, create areas on the surface of the ground that are not permeable to water (example is asphalt or concrete), adding plants that use water before the water enters the aquifer. Students need to understand how to test and experiment with these models as well as how to code them. Less advanced learners should at least achieve adding additional pumps at various depths 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?**
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 local conditions affect water supply or quality [LO17].
- Describe why some water is not renewable or replaceable; where does the water go? [LO18]
- See student Project Design Form. (Did student choose a question appropriate for answering with the model? Could student explain why it was chosen? Did student describe the aspects of the real world to be included in the model and why they were selected? etc.) [LO19]
- Describe procedures in the model that you built. Choose one and describe how it works in detail [LO20].

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.

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.

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	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.

Lesson 4 - Student Activity #1 Guide

Computational Science and Designing Your Project

Design your project
In this activity you and your programming partner will come up with your own model based on the Water Pumping base model.

5. Open up your version of the base model. **REMIX** and rename to “Water Pumping ***your name your partner’s name*** **NEW**”

6. Use the **Project Design Form** to plan your modeling.

Here is a tip:

- 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.

Lesson 4 - Student Activity #2 Guide

Designing and Developing Your Model

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 ("Water Pumping ***your name your partner's name*** **NEW**")
2. Use the **Project Design Form** to guide you as you take turns **driving** and **navigating**.

Here is a tip:

- You can copy and paste code from other models to help you work more quickly.

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?
Prediction
What effect do you think the changes you make will have on the model?
Data Collection
What data will you collect?
Data Analysis
How will you analyze your data? (i.e. look for patterns, compare final values, look at the graph)
Interpretation
What is the answer to your question? How does the analysis of your data help you answer your question?

Project Design Form

Name(s): ____ Date: _____________

Model name: ____

As you create a computer model of a scientific phenomenon, use this form to help you organize your thoughts and develop the model from start to finish.

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?
What question do you seek to answer?
How will it be modeled? What abstractions are used?
Who are the Agents? What is the Environment? What are the Interactions? *How much time will the main forever loop represent? (minutes? days? months? years?)* *What are the parameters of interest?*

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?
Prediction
What effect do you think your variables will have on the model?

Data Analysis
How will you analyze your data?
Interpretation
How does the analysis of your data help you answer your question?
Going further
If you had more time, what further changes would you make to your model?

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:	
Ask questions and define 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 Water Pumping 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 repeated trials at each variable setting. Students will critically analyze their results, as well as their model, and relate it back to the bigger picture – Water as a Shared Resource. Students will reflect on what modeling water as a shared resource has taught them about resource management and their own actions as water users. 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 complex adaptive systems concepts

Activity #1: Completing and Debugging Your Code – 15 minutes

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

Activity #2: Running 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 sharing resources
10. Share your model and experimental results with the class

Lesson Objectives

The student will:

- ✓ Revisit complex adaptive systems concepts and learn how they relate to understanding resource management [LO21].
- ✓ Gain a deeper understanding of impacts on ground water resources through experience creating and experimenting with a water pump model [LO22].
- ✓ Use customized model as an experimental test bed to run experiments [LO23]. Learn that multiple runs of the experiment are needed at each variable setting due to inherent randomness in the model [LO24].
- ✓ Use iterative refinement and apply debugging techniques to isolate and fix errors in code [LO25].

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- Water Pumping with customizations StarLogo Nova model
- Scientific Practices with Computer Modeling & Simulation document [student handout]
- Project Design Form [student handout from Lesson 4]
- New commands and concepts sheet [student handout]

For the Teacher

- Computer and projector.
- Water resources background videos [for reference].
- Water pumping StarLogo Nova models: base model plus sample customizations
- 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 water pumping. 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 complex adaptive systems**
   - Before starting, briefly revisit the complex adaptive systems concepts of leaderlessness, many agents following simple rules, emergent pattern formation, and unpredictability. Relate these concepts to features of the water pumping model and patterns generated by running our simple model. (CCC: Patterns) (CCC: Cause and Effect) (CCC: Systems and systems models) (CCC: Stability and change)

Activity #1: Completing and Debugging Your 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 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**
   - Each time you finish making a change to your code, test that you have not introduced new bugs and that the elements of the model are behaving as expected.
     Did the elements you created in your setup procedure appear? Did the model behave the way you expected it to?
   - Test your forever loop. Are all of the behaviors you created that you want to run when you toggle forever working as you had hoped?
   - Test your model. Did you create other widgets such as buttons, sliders, graphs and other monitors? Check each of these to make sure they are working correctly.
   - Observe 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: Running 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 sharing resources**
   - Now think about the bigger picture. What do your results tell you about sharing resources? 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 four characteristics of a complex system and how they relate to a resource management situation [LO21].
- What local or regional issue impacting water resources was included in your model? What are some of the potential impacts of that factor or condition? [LO22].
- See student Experimental Design Form [LO23, LO24].
- Give an example of how you were able to find and fix an error you had in your code [LO25].

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.

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.

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	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.

Lesson 5 - Student Activity #1 Guide

Completing and Debugging Your Code

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

3. Open up your model ("Water Pumping ***your name your partner's name*** **NEW**")

4. Test your model out and fix any issues you find.

Here is a tip:

- 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.

Lesson 5 - Student Activity #2 Guide

Running Experiments

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

1. Open up your model ("Water Pumping ***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 is a tip:

- 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

Preparing 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 questions and answers.

Here is a tip:

- 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: ____

As you create a computer model of a scientific phenomenon, use this form to help you organize your thoughts and develop the model from start to finish.

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?
What question do you seek to answer?
How will it be modeled? What abstractions are used?
Who are the <u>Agents</u>? What is the <u>Environment</u>? What are the <u>Interactions</u>? *How much time will the main forever loop represent? (minutes? days? months? years?)* *What are the parameters of interest?*

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?
Prediction
What effect do you think your variables will have on the model?

Data Analysis
How will you analyze your data?
Interpretation
How does the analysis of your data help you answer your question?
Going further
If you had more time, what further changes would you make to your model?

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:	
Ask questions and define 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	

MODULE 3 (LIFE SCIENCE) INTRODUCTION

Module Name: Ecosystems as Complex Systems

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 Life Science module begins with an exploration of a simple predator-prey model to consider who eats whom—and what happens when one population grows faster than another. After learning more about ecosystem dynamics, producers and consumers, and interdependent relationships within an ecosystem, students develop their own model of a local ecosystem.

The primary goal of this unit is to engage students in simple interactive activities to explore ecosystems concepts, and in the use, modification, and creation of an agent-based model of a simple virtual ecosystem.

2. Prerequisite knowledge and assumptions encompassed by the Module

This lesson assumes that the teacher has already introduced ecosystems concepts such as a) the definition of an ecosystem, b) indirect interactions within ecosystems, c) direct interactions between organisms in ecosystems, d) food chains and food webs, e) energy flows in ecosystems, f) trophic levels and g) biomass in ecosystems. [See the document “Ecosystems as Complex Systems” for background information.]

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
- Ecosystems as Complex Systems background document [for reference]
- Rabbits and Grass base StarLogo Nova model
- Guided Introduction to StarLogo Nova document [for reference]

- CS Concepts guide document [for reference & student handout]
- StarLogo Nova Blocks Reference Guide [for reference & student handout]
- StarLogo Nova Blocks Reference Guide Module 3 [for reference & student handout]
- Scientific Practices with Computer Modeling & Simulation 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
- 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: Ecosystems as Complex Adaptive Systems

Pacing Guide

Getting Started	Introduction to Ecosystems: What are ecosystems, how is energy involved? (Different trophic levels, energy moves through the food web)	10 min
Activity 1 (New Learning)	Papercatchers Activity: population growth patterns, limits to growth, and carrying capacity	25 min
Activity 2 (New Learning)	Previewing the Rabbits and Grass Model (teacher-led demonstration) and challenge (Can you balance the ecosystem? What is a healthy ecosystem?)	10 min
Wrap-Up (Reflection)	If you were to study a real-world ecosystem, what kind of data would you want to collect?	5 min

Learning Objectives: Students will…

Complex Adaptive Systems	Gain a basic understanding of ecosystems as complex adaptive systems.
Disciplinary Core Ideas	Experience population growth and limits to growth through a simulation. Graph different patterns of growth and learn to distinguish them. Learn the ecosystem concept of carrying capacity.
Modeling and Simulation	Setup and run experiments using a computer model. Investigate the parts of a computer model. Speculate as to why computer models can be valuable scientific tools.

Assessments of understanding:

Complex Adaptive Systems	Name two characteristics of a complex adaptive system that exist in ecosystems.
Disciplinary Core Ideas	Describe two patterns you saw in Papercatchers. How would you determine the “carrying capacity” of an environment?
Modeling and Simulation	How many trophic levels were represented in the model?

DAY 2: Rabbits and Grass Model

Pacing Guide

Getting Started (Review)	Review of the previous day's lesson and concepts. Connection to today's lesson.	5 min
Activity 1 (Discovery)	Under the Hood: inspecting the Rabbits and Grass model, variables, looping and execution order.	20 min
Activity 2 (Guided Practice)	Designing and running experiments: specify your question, write up your experimental design and run your experiments. (Review how to change a parameter, add a slider, a graph, etc).	20 min
Wrap-Up (Reflection)	How does experimental design with computer models differ from experimental design without computers? What does the computer model enable us to do that would be difficult to do in the real world?	5 min

Learning Objectives: Students will…

Complex Adaptive Systems	Make observations of ecosystems dynamics and change in population sizes over time.
Disciplinary Core Ideas	Growth of organisms and population increases are limited by access to resources. Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.
Modeling and Simulation	Ask a question and design an experiment. Conduct an experiment. Make observations (drawing simple correlations).
Computer Science	Decode a simple model. Trace a program's execution.

Assessments of understanding:

Complex Adaptive Systems	Is the Rabbits and Grass ecosystem a complex adaptive system? Why or why not?
Disciplinary Core Ideas	What are the three different outcomes seen in the rabbits and grass model?
Modeling and Simulation	What variables were we able to manipulate in Rabbits and Grass? Give a good explanation of what happens when a simulation is run. What does it mean if a model produces different outcomes each time I run it?
Computer Science	Diagram an execution loop showing what calls what in the Rabbits and Grass model.

DAY 3: Adding a Predator

Pacing Guide

Getting Started (Review)	Review of the previous day's lessons and concepts; connection to today's lesson.	5 min
Activity 1 (Guided Practice)	Adding a predator, and running an experiment. What is the impact of adding a top predator on the ecosystem?	20 min
Activity 2 (Guided Practice)	Running an experiment. What is the impact of adding a top predator on the ecosystem?	20 min
Wrap-Up (Reflection)	In the real world, what might impact how animals use and gain energy? How can computer models be useful in understanding ecosystems?	5 min

Learning Objectives: Students will…

Disciplinary Core Ideas	Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.
Modeling and Simulation	Design and conduct and experiment. Collect and analyze data to look for patterns.
Computer Science	Modify a simple computer model. Practice Pair Programming and Iterative design, implement and test cycle. Learn CS concepts of user-defined variables and subclasses or breeds.

Assessments of understanding:

Disciplinary Core Ideas	How would you compare the health of the ecosystem with and without a predator?
Modeling and Simulation	What was the impact of adding a predator? How would you describe the distribution of different outcomes?
Computer Science	What is an example of how an IF/THEN was used in this model?

DAY 4: Create Your Own Ecosystem Model

Pacing Guide

Getting Started (Review)	Review of the previous day's lessons and concepts; connection to today's lesson.	5 mins
Activity 1 (New Learning)	Computational Science cycle: Introduction to the Computational Science cycle and defining your computational science project.	20 mins
Activity 2 (Creative / Discovery)	Design and develop your model: Agents and environment, interactions.	20 mins
Wrap-Up (Reflection)	How would you know if your model reflects reality? What research is necessary to ground your model in reality? How will you check to see if your model is realistic?	5 mins

Learning Objectives: Students will…

Disciplinary Core Ideas	Students will learn that organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.
Modeling and Simulation	Develop a scientific question that can be answered with data output from running a model. Use abstraction to develop an idea for a model.
Computer Science	Develop a design for a computational science project. Practice Pair Programming and Iterative design, implement, test cycle.

Assessments of understanding:

Disciplinary Core Ideas	Give an example of a three trophic level ecosystem where growth of populations is limited by access to resources.
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?
Computer Science	What procedures in the model have you built? Choose one and describe how it works.

DAY 5: Designing and Running an Experiment and Sharing Your Findings

Pacing Guide

Getting Started	Review of the previous day's lessons and concepts; connection to today's lesson	5 mins
Activity 1	Finish implementing your model	20 mins
Activity 2	Running experiments with your model	20 mins
Wrap-Up	Analyze the results of your experiments and discuss your conclusions. Relate the results back to the bigger issue of Ecosystems as Complex Systems. Prepare your model and results for presentation.	5 mins

Learning Objectives: Students will…

Complex Adaptive Systems	Revisit the concept of population growth and feedback loops and come up with a possible feedback loop related to ecosystems. [The more fish there are, the more baby fish they will produce.]
Disciplinary Core Ideas	Gain a deeper understanding of ecosystem dynamics. They will learn that organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. Ecosystems are dynamic in nature; their characteristics can vary over time.
Modeling and Simulation	Use their new model as a test bed to run experiments. Learn that the results of their experiments can inform them of ways to further improve their model.
Computer Science	Follow the correct execution of their models and apply debugging techniques to fix their code.

Assessments of understanding:

Complex Adaptive Systems	Describe a feedback loop in ecosystems.
Disciplinary Core Ideas	Describe how adding a predator can impact an ecosystem.
Modeling and Simulation	What experiments did you run in the model and why? What real world information could help you to improve the model? Complete the "Scientific Practices with Computer Modeling & Simulation" document.
Computer Science	Define debugging and give an example of some debugging you had to do in your code [LO6].

3

Lesson 1

Ecosystems as Complex Adaptive Systems

50 minutes (1 day)

Lesson Overview

In this lesson students will be introduced to ecosystems concepts through an activity called "Papercatchers." Papercatchers is a participatory simulation in which students play the part of agents in a simulation. After playing the "game" that illustrates population dynamics and carry capacity, students will view a computer model of a simple ecosystem projected from the instructor's computer. Through the model, students will review concepts of population growth, producers and consumers, and the movement of energy through an ecosystem.

Prerequisites and Assumptions

This lesson assumes that the teacher has already introduced ecosystems concepts such as a) the definition of an ecosystem, b) indirect interactions within ecosystems, c) direct interactions between organisms in ecosystems, d) food chains and food webs, e) energy flows in ecosystems, f) trophic levels and g) biomass in ecosystems.

Teaching Summary

Getting Started – 10 minutes

1. Ecosystems as Complex Adaptive Systems introduction

Activity #1: Papercatchers – 25 minutes (New Learning)

2. Participatory Simulation
3. Population Growth and Carrying Capacity

Activity #2: Previewing the Rabbits and Grass Model – 10 minutes (New Learning / Discovery)

4. Preview of the model,
5. Make observations, ask questions

Wrap-Up – 5 minutes

6. If you were to study a real-world ecosystem, what kind of data would you want to collect?

Lesson Objectives

The student will:

- ✓ Learn characteristics of complex systems that relate to ecosystems [LO1]
- ✓ Experience population growth and limits to growth through a simulation [LO2]
- ✓ Graph different patterns of growth and learn to distinguish them [LO3]
- ✓ Learn the concept of a carrying capacity [LO4]
- ✓ Make observations of the behavior of a system using a computer model [LO5]
- ✓ Speculate as to why computer models can be valuable scientific tools [LO6]

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- Rabbits and Grass StarLogo Nova model
- Recycled printing paper

For the Teacher

- Large open space
- Computer and projector
- Rabbits and Grass StarLogo Nova model
- Large chart paper for collecting and graphing data and markers
- Piece of newspaper

Getting Started - 10 min

1. Ecosystems as Complex Adaptive Systems
(excerpt from the document "Ecosystems as Complex Adaptive Systems")

Start with a 10-minute review of ecosystems concepts using direct instruction

- An ecosystem consists of a specific area and all of the organisms in that area.
- All organisms take up some space, take in nourishment from the environment, and excrete waste, these are indirect interactions between organisms.
- Direct interactions between organisms include predation, competition, symbiosis,
- Whether direct or indirect, these interactions allow changes to ripple through the organisms and environment of an ecosystem, to affect many others types of organisms.
- The difference between food chains and food webs.
- Energy flows in an ecosystem from producers to consumers
- Trophic levels and biomass. At each step along the chain of producers and consumers, less energy is available – and the biomass that is available gets smaller and smaller.

Then move on characteristics of complex adaptive systems seen in ecosystems:
(CCC: Systems and Systems models)

- One of the characteristics of a complex system is that the behavior of some aspect of the system, seen as a whole, doesn't necessarily follow directly from an understanding of how the individual "parts" of the system work. In other words, "the sum of the parts is greater than the whole." (We saw this in the Walk & Turn activity in Module 1.)

- Another characteristic of most complex adaptive systems is feedback. Feedback is a circular process in which a system's output is returned or "fed back" into the system as input. For example, if we look at the ecosystem of fish in a pond, where the fish are not being consumed by predators we see that as the population approaches the carrying capacity of the pond, the rate of population growth decreases. This happens via limits in required resources (e.g. oxygen in the water). So the increase in the fish population leads to a reduction in the necessary resources available to each member of the population, which in turn leads to moderation in the rate of increase in the population. We will see this type of pattern in the participatory simulation and models that accompany this module. (This type of feedback is called negative, or damping feedback.)
- Possibly most important, ecosystems often demonstrate emergent behavior. This is related to the first point, where the overall behavior turns out not to be obvious from the component behavior. In a high desert ecosystem, simply knowing that rabbits eat grass, coyotes eat rabbits, and mountain lions eat rabbits and coyotes, doesn't tell us much (beyond giving us a general sense) about the patterns in the respective populations over time – we really need to study the ecosystem as a whole. From the above, we can see that ecosystems are usually complex adaptive systems, as well.

Activity #1: Papercatchers - 25 min

In this activity, students will learn about population growth and limits to growth (DCI: LS2.A). Students will play the part of members of a growing population and experience limits to the growth of populations when resources are limited. Students will analyze different patterns of population growth (Practice: Analyzing and Interpreting Data) including exponential and logistic growth (CCC: Patterns) and will learn the ecosystem concept of carrying capacity (DCI: LS2.A).

2. Participatory Simulation

- Gather materials and set up a table and graph on a whiteboard or chalkboard. Label the x-axis with generations #1-10 and the y-axis with population size 0-50. Tell students we are going to participate in a participatory simulation called "Papercatchers."
- In round 1 begin by asking all students to crumple up a piece of scrap paper then pick one person to represent the initial member of the population. In one color mark the table and graph with generation 0, population 1. When the instructor gives the next generation command, have the initial population member throw the piece of paper 2 feet overhead and attempt to catch it. If he/she succeeds, then he/she survives into the next generation and reproduces by selecting a student from the audience to join in the population. If he/she does not catch the paper ball, he/she does not survive and must sit down. Mark the table and graph with the new population at next generation. Repeat in this manner for several more generations while recording the population size and generation number after each throw. If the population crashes or becomes extinct, begin again, noting that sometimes populations will crash by chance when numbers are small. Once all members of the audience are standing, take a look at the graph and have student reflect on the pattern.
  ASK: What type of pattern do you see?
  ASK: What do you predict would happen if we could play with an unlimited number of people? (The result would be exponential growth / sometimes also called a "population explosion.") (Practice: Analyzing and Interpreting Data) (Practice: Use mathematics and Computational Thinking) (CCC: Patterns)
- In round 2, place a large piece of newspaper on the floor. Tell students they will follow the same rules (if they catch their paper ball, they stay in the population and reproduce; if they drop their paper ball, they die and must sit down) but this time, there is an added constraint. To

survive, they must throw and catch their paper ball while keeping one foot on the piece of newspaper.
ASK: How do you predict the pattern we saw before will change?
Using a different color marker, record the population size and generation number as before. After the population size stabilizes, ask students what pattern they observe in the data and what does the piece of newspaper relate to limited resources in nature. If necessary, help students make the connection between the piece of newspaper and a limited food supply. Calculate the maximum number of individuals that can be supported by the piece of newspaper, call this the "carrying capacity". (The S-curve in the data is known as Logistic Growth.) (Practice: Analyzing and Interpreting Data) (Practice: Use mathematics and Computational Thinking) (CCC: Patterns)

- In round 3, replace the piece of newspaper with a sheet of 9 by 11 printer paper. Again, ask students for a prediction of what will happen when they play again. Ask them what the shape of the population growth curve will be. Play again and record data using a different color marker. This time determine the carrying capacity of the smaller sheet of paper. In concluding the activity discuss the relationship between food supply and population growth and relate the exercise to ecosystems.
- Discuss what the different sized sheets of paper might represent in an ecosystem. (DCI: LS2.A). (CCC: Patterns)

3. Population Growth and Carrying Capacity

- Hand out student activity sheet "Patterns of Growth in Papercatchers". Give students 10 minutes to complete the form before discussing their answers.
- Review the growth patterns that were seen in Papercatchers.(CCC: Patterns)
- Discuss the concept of Carrying Capacity in terms of Papercatchers and the real world.

Teaching Tip *In a small class, it is possible to run this activity for a few rounds with students then postulate what might have happened if there were more students available to play additional rounds. Ask students what pattern they might expect and why.*

Teaching Tip *Assign one student as a data collector and another as a data recorder.*

Activity #2: Previewing the Rabbits and Grass Model - 5 min

In this teacher demonstration, students will get a first look at the base model they will be using and modifying in this module.

4. Preview the Rabbits and Grass model

- Open the Rabbits and Grass model in StarLogo Nova public folder.
- Discuss what abstractions exist in this model. Who are the agents, what is the environment, and what are the interactions between agents and environment? (Use the model observation form)
- Have students describe what they see when you run the model. Then have them provide suggestions on variables to change.

5. Learn about the model, make observations

- Run the model a few times and have students note the initial numbers of rabbits and grass.
- Categorize the outcomes seen. [All the rabbits die / grass continue; all the grass are eaten then all the rabbits die; both populations persist for a long time. (This type of oscillating pattern is called a dynamic equilibrium.)]
- Discuss what a controlled experiment might look like with this model.

Teaching Tip *Encourage students to think about what is missing from the model or what is inaccurate in the model. [example: Rabbits giving birth to just one rabbit at a time.]*

Wrap-Up - 5 min

6. **Patterns of Growth in ecosystems.**
    - What growth patterns did you see in the rabbits and grass populations?
    - Were there limits to growth? If so, what were they?
    - If you were to study a real-world ecosystem, what kind of data would you want to collect?

Assessment Questions

- Name a characteristic of complex systems that can be seen in ecosystems [LO1]
- Describe and draw two growth patterns you saw in Papercatchers. [LO2, LO3]
- Describe what limited growth in the Papercatchers activity [LO4]
- Describe two outcomes you witnessed in the demonstration of the rabbits and grass model [LO5]
- Discuss why a computer model might be helpful in studying ecosystems [LO6]

Standards Addressed

NGSS Performance Expectations

Ecosystems: Interactions, Energy, and Dynamics MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

NRC Disciplinary Core Ideas

Interdependent Relationships in Ecosystems DCI-LS2.A: Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Growth of organisms and population increases are limited by access to resources. **Ecosystem Dynamics, Functioning, and Resilience** DCI-LS2.C: Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

NRC Scientific and Engineering Practice Standards

Practice 3: Planning and carrying out investigations 3E: Collect data about the performance of a proposed object, tool, process or system under a range of conditions. **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. 4G: Analyze and interpret data to determine similarities and differences in findings. **Practice 5: Using mathematics and computational thinking** 5B: Use mathematical representations to describe and/or support scientific conclusions and design solutions.

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.
6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.

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.

NRC Scientific and Engineering Practice Standards

Practice 2: Developing and using models
2C: Use and/or develop a model of simple systems with uncertain and less predictable factors.
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
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 or produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

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.

Practice 5: Using mathematics and computational thinking
5B: Use mathematical representations to describe and/or support scientific conclusions and design solutions.
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.

NRC Crosscutting Concepts

1. 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.

3. 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.

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.

CSTA K-12 Computer Science Standards

CT	Abstraction	2-12	Use abstraction to decompose a problem into sub problems.
CT	Connections to other fields	2-15	Provide examples of interdisciplinary applications of computational thinking.
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	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.

Responsiveness to Varied Student Learning Needs

In Project GUTS, we integrate teaching strategies found to be effective with learners with various backgrounds and characteristics such as economically disadvantaged students (EDS), students from groups that are underrepresented in STEM (URG), students with disabilities (DIS), English Language learners (ELL), girls and young women (FEM), students in alternative education (ALT), and gifted and talented students (GAT).

In each lesson we describe the accommodations and differentiation strategies that are integrated in the activities to support a wide range of learners.

Module 3 Lesson 1: Ecosystems as Complex Adaptive Systems

(URG) *The in-class modeling activity, Papercatchers, involves student movement, a strategy that uses a multi-modal experience to increase student engagement.*

(DIS) *In the preview of the Rabbits and Grass model, we use technology to present information in multiple modes of representations. We provide multiple means of action, expression, representation and engagement. These are all principles of Universal Design for Learning.*

(EDS) *We elicit students' prior knowledge about local ecosystems and build on their funds of knowledge as a resource for further questioning and investigating.*

(EDS) *We validate the use of place [by situating the topic of ecosystems within the local environment] to keep the students engaged and make a connection of science and community.*

(FEM) (URG) *We choose a curriculum topic, Ecosystems, that has relevancy and real-world application, to interest and engage the girls and students from underrepresented groups in STEM in the class.*

Lesson 1 - Student Activity #1 Guide

Papercatchers

Name: Date:

Instructions:

1) Copy the data collected during the Papercatchers activity into the table below. Note that you may not be able to complete all 10 generations in class.

Generation	Round 1 – no paper		Round 2 - newspaper		Round 3 – sheet paper
	Population size		Population size		Population size
1	1		1		1
2					
3					
4					
5					
6					
7					
8					
9					
10					

2) In this simulation of an ecosystem, what were the independent and dependent variables?

3) Using different colored pens or markers for each Round, create line graphs of the populations over time in generations. Make note of any carrying capacity or limits on growth in each round.

Remember to label your axes.

.

4) Predict the population sizes in each round (no paper, newspaper, sheet paper) if we could continue for 10 generations. (Remember that each new generation occurred when the current population did the ball toss and either died or brought another person in.

Generation	Round 1 – no paper		Round 2 - newspaper		Round 3 – sheet paper
…	Population size		Population size		Population size
10					

5) Describe how you made the prediction using mathematical and scientific reasoning.

3

Lesson 2

Rabbits and Grass Model

50 minutes (1 day)

Lesson Overview (New Learning and Exploration)

In this lesson students will participate in two activities that USE the Rabbits and Grass model. The first activity is a look under the hood at the model to understand what was included and left out of the model (abstraction). In the second activity, students will learn to design and conduct systematic experiments using the model as an experimental test bed. They will instrument their model to collect data, then analyze data and report out on their findings.

Teaching Summary

Getting Started – 5 minutes

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

Activity #1: Looking under the Hood – 20 minutes (New Learning / Discovery)

2. Familiar and New Command Blocks
3. Decoding a model – looking for the parts and interactions between them
4. What calls what? – execution of the program loop

Activity #2: Designing and Running Experiments – 20 minutes (Guided Practice)

5. Experimental design
6. Running experiments
7. Collecting and analyzing data

Wrap-Up – 5 minutes

8. What does computer modeling and simulation allow us to do that would be difficult to do in the real world?

Lesson Objectives

The student will:

✓ Decode a simple model of a complex adaptive system [LO7]
✓ Trace a program's execution [LO8]

- ✓ Ask a question and design an experiment [LO9)]
- ✓ Conduct an experiment using a computer model [LO10]
- ✓ Make observations (drawing simple correlations) [LO11]

Teaching Guide

Materials, Resources and Preparation

For the Students

- Computers
- Rabbits and Grass base model
- Model Observation Form
- Scientific Practices with Computer Modeling & Simulation sheet
- Experimental Design Form
- New Commands and Concepts sheet

For the Teacher

- Computer and projector
- PPT with simple commands
- Rabbits and Grass base model

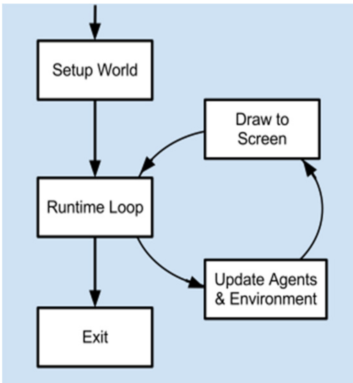
Getting Started - 5 min

1. Review of previous day's lesson and link to where we are going today

- What observations did you make while experimenting with the Rabbits and Grass model?
- What do you think is going on in the model? (before looking under the hood)

Activity #1: Looking under the Hood - 20 min

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:

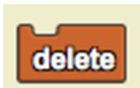
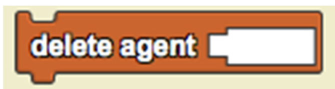
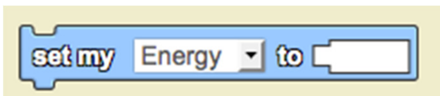
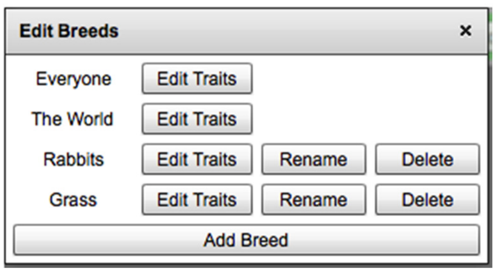
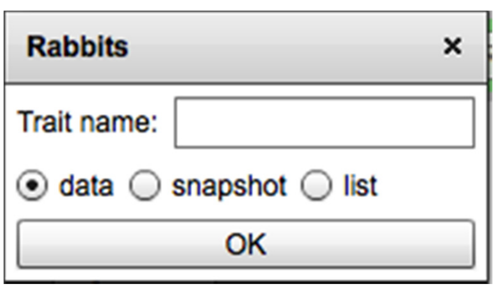
Model Observation Form

Model name: ______Rabbits and Grass____

Abstractions
Who are the <u>Agents</u>?   What is the <u>Environment</u>?   What are the <u>Interactions</u>? *How much time does the main forever loop represent? (minutes? days? months? years?)* The agents are rabbits and grass. The environment is a meadow. The rabbits move around. When eat the grass. The grass grows new clumps from time to time. The forever loop is likely to be a few days.
Automation
What happens each time through the forever (or main) loop? Grass grows. Rabbits move, reproduce and die. If rabbits collide with grass, the grass gets eaten.
Assumption(s)
What real life elements or behaviors were left out of this model? One assumption is that rabbits give birth to one offspring. I don't think this is realistic. Don't rabbits have many babies at a time?
Analysis
What patterns did you observe? Do these patterns occur in real-life? The population of rabbits grows quickly. Sometimes too quickly. The grass can get all eaten up. If there is not enough grass to feed all the new rabbits, the rabbits will all eventually die.

2. Review Familiar and New Command Blocks

- Keep track of familiar command blocks. Students can refer to their StarLogo Nova Command Blocks reference sheets from Module 1.
- Review what the new command blocks do.

	The delete block deletes the current agent.
	The delete agent block deletes the agent referenced.
	The set my (trait) to (value) block is used to set the current agent's trait to some value. In this case, Energy is a new trait created by the user.
 	The user created the Rabbits trait "Energy" using the Edit Breeds panel. Click on "Edit Breeds" in the Spaceland panel. Then click on the "Edit Traits" button next to Rabbits. From here you can give an agent a new trait by clicking on "Add Trait" Then specify a trait name and type. The type can either be "data", "snapshot", or "list". For Energy, we want to store a value or number, so choose "data" and click OK. In computer science, this is called declaring a variable. The variable in this case is a number variable called "Energy".

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

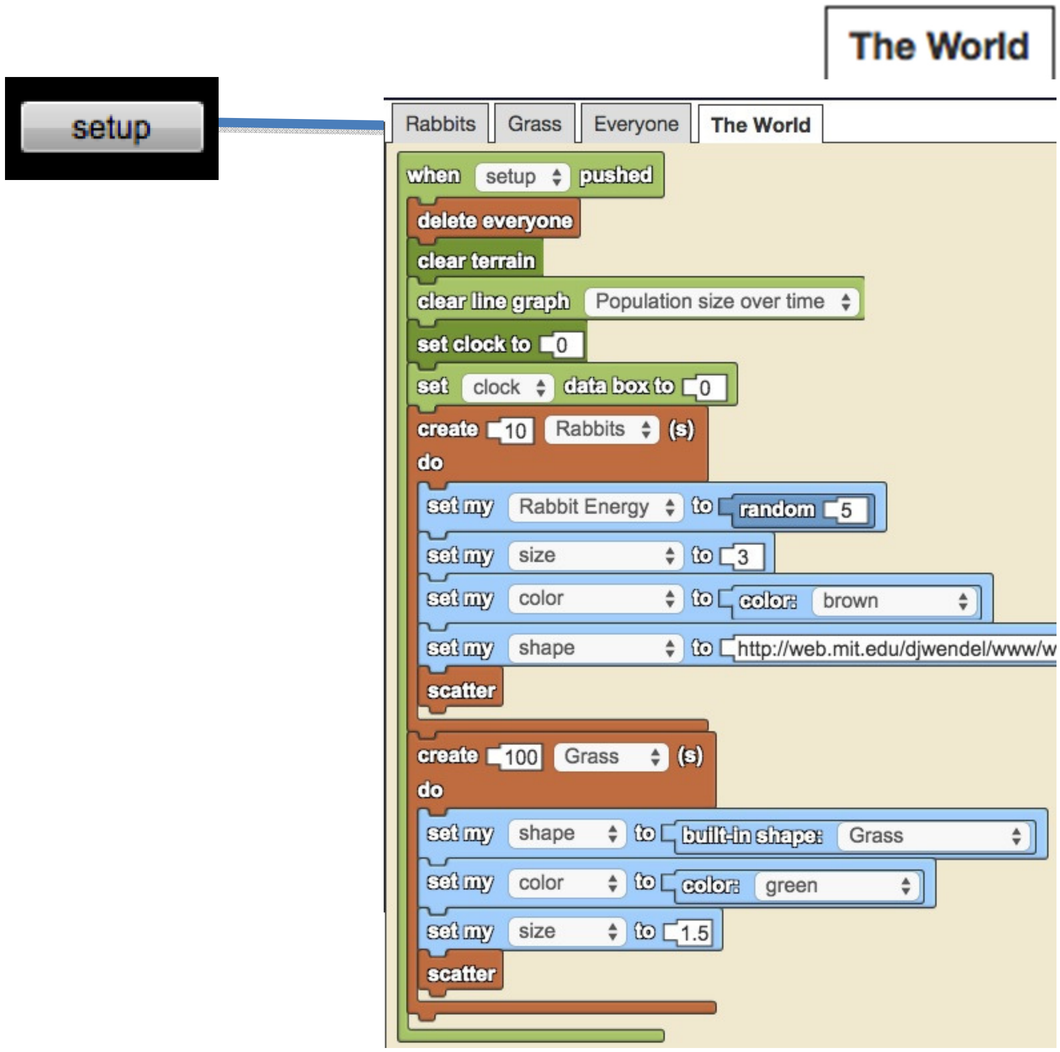
- Assign partners to share a computer
- Assign each pair a piece of the model to decode Rabbits, Grass, or World. The detailed description of what an agent's procedures can be added to the model observation form.
- Give the students 5 minutes to decode then ask students to share out

[Notes for the teacher: The base model for this module is a simple ecosystem that consists of rabbits and grass. The grass reproduces at a certain rate and the rabbits randomly move around the world eating the grass. If a rabbit stumbles across a grass, it will eat the grass and gain energy. If a rabbit gains enough energy, it will reproduce (asexually by hatching a baby like itself). If a rabbit wanders around too long without finding any grass to eat, it will die. The "world" agent simply sets up the world in the set up phase.]

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

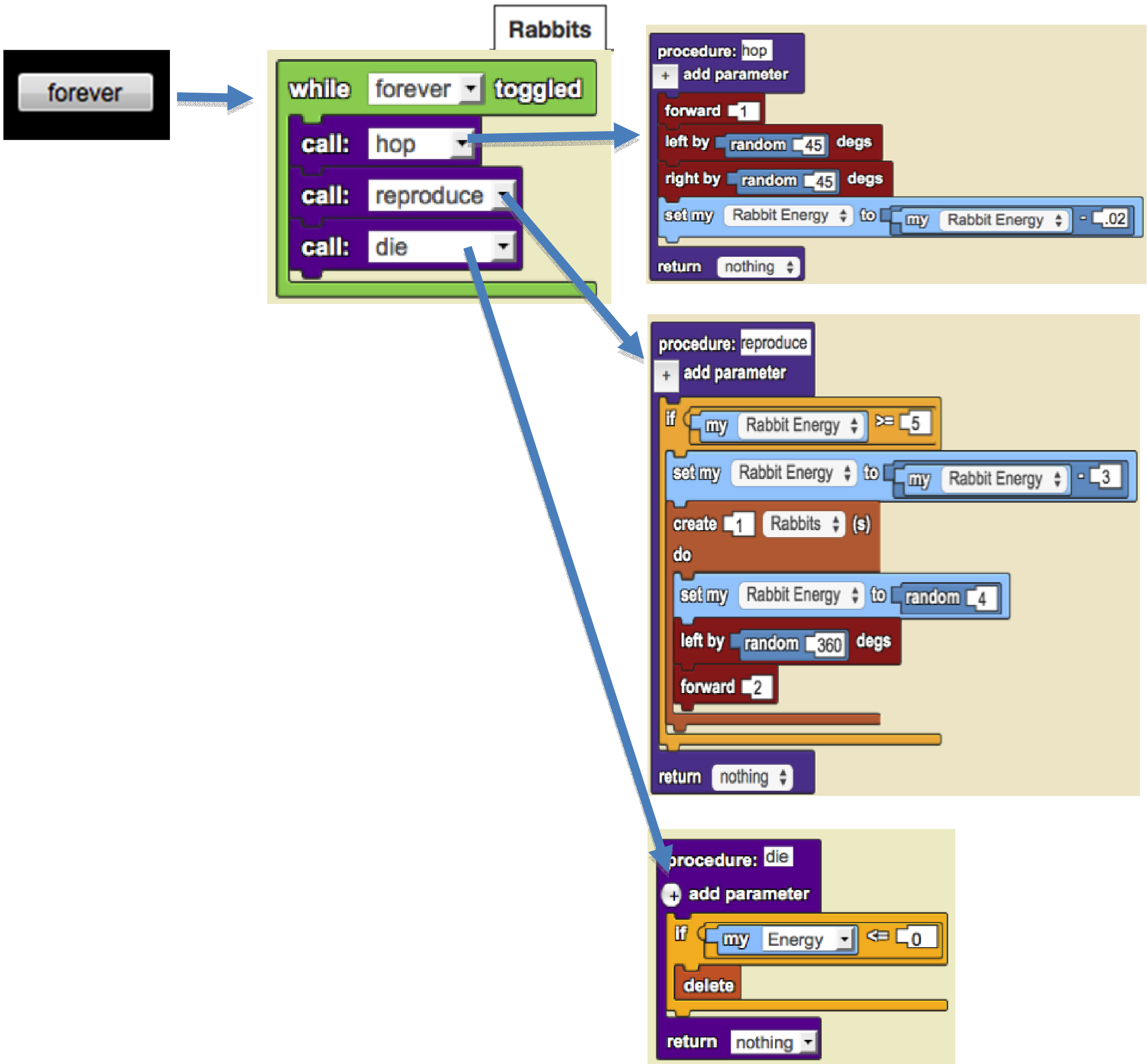
- Demonstrate how to trace execution of the program starting with Setup button
- As a group, trace execution of the program starting with Run button

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



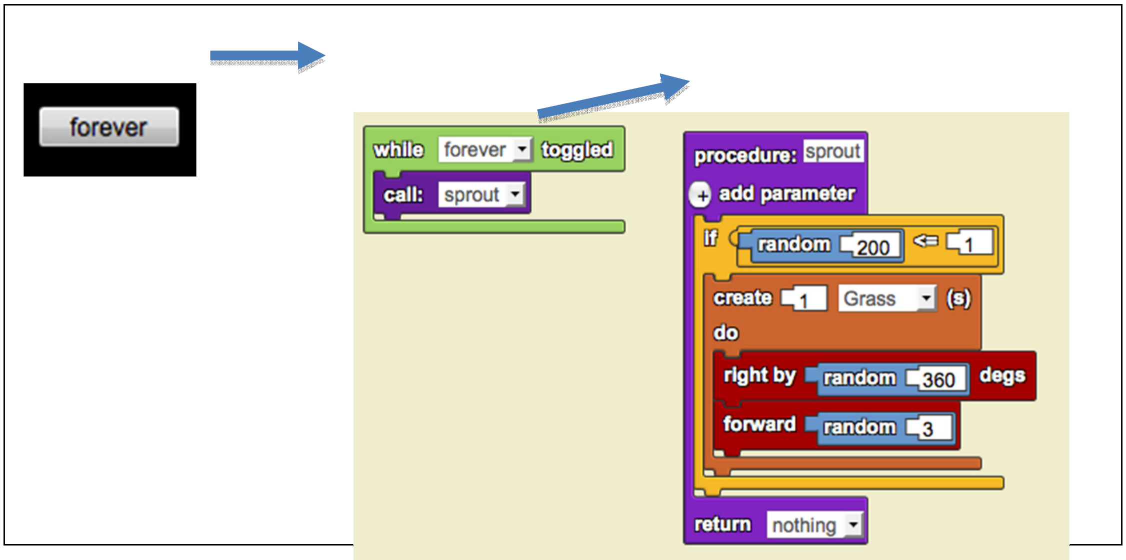
First everyone gets deleted and the terrain gets cleared. The 10 rabbits are created with their shape set to “rabbit-shape”, their energy set to a random value between 1 and 5, their size set at 3, and their color set to brown. The rabbits are scattered throughout Spaceland.

Next 100 grass agents are created, their shape set to grass-shape, their color set to green and their size set to 1.5. They too are scattered around Spaceland.

Toggling the forever button to its "ON" state in Spaceland causes the execution of this procedure in the Rabbit agents.


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.]



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 their 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 #2: Designing and Running Experiments - 20 min

With these simple agents and behaviors in place, we can observe the system from the global perspective to see the relationship between the amount of grass and the rabbit populations. We can also instrument the model to gain a quantitative understanding of the population dynamics.

5. Experimental Design

- Assign students to work in small groups.
- Hand out the experimental design form and review its contents.
- Give students time to plan and describe their experiment using the form.
- Ask, "What are the dependent and independent variables?"
- Ask, "What are the variables that already exist in this model?" [#initially rabbits, density of grass, energy gained from eating grass.] Choose one variable to experiment with, then use the "Experimental Design handout" to describe your experiments and record data from your experiments.
- Ask, "How many trials do you need to run at each setting of the variable?"

6. Run your experiment
- Students are to run the experiment they described in the form and collect data.
- What is the range of values for the variable you chose?
- How many trials will you run at each setting?
- How will you capture the data?
- Currently the “data output to file” function is not available in StarLogo Nova. An alternative is to grab screen shots of the graph and label them with the settings.
- Show students how to do a screen grab and name their file.
- Another alternative is to keep the line graph recording all experiments without clearing the line graph.

7. Analyzing data and describing the results of your experiment
- Ask, “What patterns do you see in the collected data?”
- Ask, “What correlations do you think exist between the variable setting and the outcomes?”

Wrap-Up – 5 min
8. How does experimental design with computer models differ from experimental design without computers?
- What does a computer model enable us to do that would have been difficult or impossible in the real world?
- What might be a danger of trusting a computer model?

Assessment Questions
- Is the Rabbits and Grass ecosystem a complex adaptive system? Why or why not? [LO7]
- What rabbit procedures were called when the forever button was toggled on? [LO8]
- What were the independent and dependent variables in your experimental design [LO9]
- How many times did you have to run your model at each setting? Why? [LO10]
- Give an example of a correlation you observed after running experiments with the model [LO11]

Background Information
Document: Ecosystems as Complex Adaptive Systems
Document: Feedback loops
Video: Using computer models in scientific inquiry

Standards Addressed
NGSS Performance Expectations

Ecosystems: Interactions, Energy, and Dynamics MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

NRC Disciplinary Core Ideas

Interdependent Relationships in Ecosystems DCI-LS2.A: Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. In any ecosystem, organisms and populations with similar requirements

for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Growth of organisms and population increases are limited by access to resources.

Ecosystem Dynamics, Functioning, and Resilience
DCI-LS2.C: Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

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.
1B: Ask question to identify and/or clarify evidence and/or the premise(s) of an argument.
1C: Ask questions to determine relationships between independent and dependent variables and relationships in models.

Practice 2: Developing and using models
2A: Evaluate limitations of a model for a proposed object or tool.
2C: Use and/or develop a model of simple systems with uncertain and less predictable factors.
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 design solutions under a range of conditions.

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.

Practice 5: Using mathematics and computational thinking
5B: Use mathematical representations to describe and/or support scientific conclusions and design solutions.
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.
6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.

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
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

1. Patterns:
1B: Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.
1D: Graphs, charts, and images can be used to identify patterns in data.

3. 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.

4. 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.

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

7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.
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	Abstraction	2-12	Use abstraction to decompose a problem into sub problems.
CT	Algorithms	3A-3	Explain how sequence, selection, iteration and recursion are the building blocks of algorithms.
CT	Connections to other fields	2-15	Provide examples of interdisciplinary applications of computational thinking.
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	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.

Responsiveness to Varied Student Learning Needs

In Project GUTS, we integrate teaching strategies found to be effective with learners with various backgrounds and characteristics such as economically disadvantaged students (EDS), students from underrepresented groups in STEM (URG), students with disabilities (DIS), English Language learners (ELL), girls and young women (FEM), students in alternative education (ALT), and gifted and talented students (GAT).

In each lesson we describe the accommodations and differentiation strategies that are integrated in the activities to support a wide range of learners.

Module 3 Lesson 2: Rabbits and Grass model

> **(EDS)(URG)(ELL)** *We ask students to apply what they know, specific to their cultural and/or socio-economic context, when addressing issues related to ecosystems and the realism of models. We can ask what is assumed in this model, what is realistic to the students, and what is not.*
>
> **(URG)(DIS)** *We use technology to present information in multiple modes of representations. In the StarLogo Nova modeling and simulation environment students can present information as code blocks, text, graphical display of the simulation, and as data in tables and graphs.*
>
> **(ELL)** *The "place-based" nature of this lesson establishes connections between school science and the students' community and lives.*
>
> **(FEM)** *Careful planning of partners for the on-computer activity is a strategy that encourages participation for the girls in science.*
>
> **(FEM) (URG)** *We choose a curriculum topic, Ecosystems, that has relevancy and real-world application, to interest and engage the girls and students from underrepresented groups in STEM in the class.*

Lesson 2 - Student Activity #1 Guide

Looking 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 Rabbits and Grass 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.

Lesson 2 - Student Activity #2 Guide

Designing and Running Experiments

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.

Model Observation Form

Name(s): ____Date: __________

Model name: ____

Abstractions
Who are the <u>Agents</u>? What is the <u>Environment</u>? What are the <u>Interactions</u>? *How much time does the main forever loop represent? (minutes? days? months? years?)* *What are the variables of interest?*
Automation
What happens each time through the forever (or main) loop?
Assumption(s)
What real life elements or behaviors were left out of this model?
Analysis
What patterns did you observe? Do these patterns occur in real-life?

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	

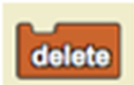
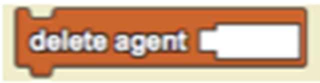
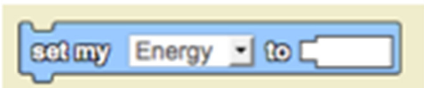
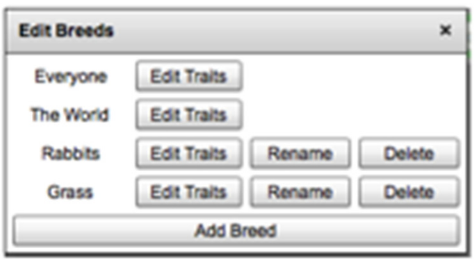
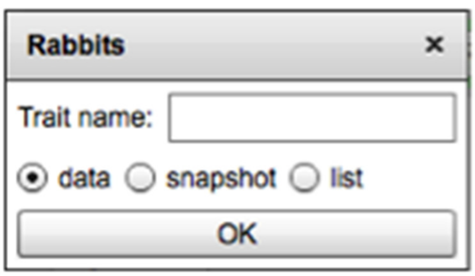
Experimental Design Form

Name(s): ____ Date: _________________

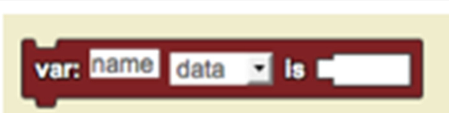
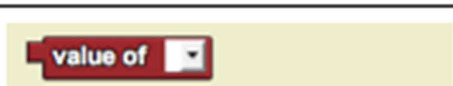
Model name: ____

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?
Prediction
What effect do you think the changes you make will have on the model?
Data Collection
What data will you collect?
Data Analysis
How will you analyze your data? (i.e. look for patterns, compare final values, look at the graph)
Interpretation
What is the answer to your question? How does the analysis of your data help you answer your question?

StarLogo Nova Blocks introduced in Module 3 Lesson 2

	The delete block deletes the current agent.
	The delete agent block deletes the agent referenced.
	The set my (trait) to (value) block is used to set the current agent's trait to some value. In this case, Energy is a new trait created by the user.
 	The user created the Rabbits trait "Energy" using the Edit Breeds panel. Click on "Edit Breeds" in the Spaceland panel. Then click on the "Edit Traits" button next to Rabbits. From here you can give an agent a new trait by clicking on "Add Trait" Then specify a trait name and type. The type can either be "data", "snapshot", or "list". For Energy, we want to store a value or number, so choose "data" and click OK. In computer science, this is called declaring a variable. The variable in this case is a number variable called "Energy".

Optional StarLogo Nova Blocks to use in Module 3 Lesson 2

	Creates a variable of the type indicated and sets its value.
	After creating a variable, this block sets the value.
	Returns the value of an existing variable.

3

Lesson 3
Adding a Predator

50 minutes (1 day)

Lesson Overview

Now that we have created a simple ecosystem with two trophic levels, we might want to ask some questions about more complicated ecosystems with more trophic levels. In this lesson students will modify the Rabbits and Grass model by adding a predator, a Mountain Lion, to answer a new question. “Does adding top predator increase or decrease the stability of an ecosystem?” In the second activity, students will design and run experiments to see if adding a predator has an impact on the ecosystem. This activity will reinforce the concepts of energy flow through ecosystems and the often unexpected results of interactions in complex adaptive systems.

Teaching Summary

Getting Started – 5 minutes

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

Activity #1: Adding a Predator – 20 minutes

2. New Concepts: adding breeds and setting user-defined traits
3. Testing your model

Activity #2: Designing and Running Experiments – 20 minutes

4. Designing your experiment
5. Running your experiment
6. Collecting and analyzing data

Wrap-Up – 5 minutes

7. In the real world, what might impact how animals use and gain energy?
8. Was your prediction about how adding a predator would impact the ecosystem correct? Why or why not?
9. How can computer models be useful in understanding ecosystems?

Lesson Objectives

The student will:
- ✓ Modify a simple computer model
- ✓ Learn CS concepts of user-defined variables and subclasses or breeds
- ✓ Practice Pair Programming and Iterative design, implement, test cycle
- ✓ Design and conduct an experiment
- ✓ Collect and analyze data to look for patterns

Teaching Guide

Materials, Resources and Preparation

For the Students
- Rabbits and Grass model
- Scientific Practices with Computer Modeling & Simulation sheet
- Experimental Design Form
- New Commands and Concepts sheet
- Computers

For the Teacher
- Computer and projector
- Slide presentation with simple commands

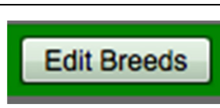
Getting Started - 5 min

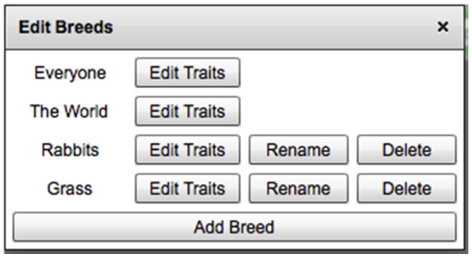
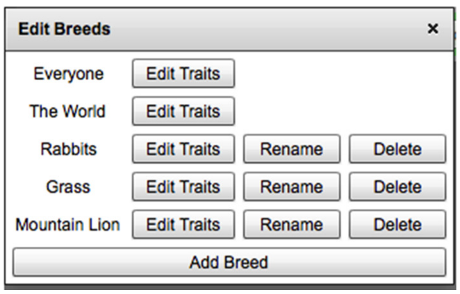
1. Review of previous day's lesson and link to where we are going today
- Last time we learned about and experimented with the Rabbits and Grass model. Now we are going to add another type of organism to the ecosystem, a predator, and see its impact on the ecosystem. What's your prediction? What do you think is going to happen to the ecosystem when we add a predator?
- Review Ecosystem concepts of interactions, trophic levels and energy flow through an ecosystem.

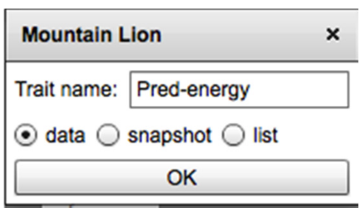
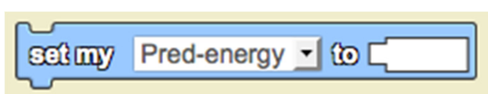
Activity #1: Adding a Predator - 20 min

We'll be adding a new organism into our virtual ecosystem. It needs to be a new "breed" or type of agent because it behaves differently from the Rabbit agents and Grass agents. Let's add a mountain lion.

2. New Concepts: adding breeds and setting user-defined traits
- Adding Breeds (a predator) and using create and do block.
- Giving breeds new traits (defining and setting user-defined variables)

	Use the Edit Breeds button in the Spaceland area to create a new breed.

<table>
<tr><td></td><td>Click on “Add Breed” to add a new breed.</td></tr>
<tr><td></td><td>In the “New Breed” dialog box, give the breed a name and press OK.</td></tr>
<tr><td></td><td>You will see the Breed on the next panel. (We added the breed called “Mountain Lion.”)

Next, click Edit Traits next to the new breed label for “Mountain Lion.”</td></tr>
<tr><td></td><td>Create a new trait (or variable) for the Mountain Lion breed called “Pred-energy.”</td></tr>
<tr><td></td><td>The set my (trait) to (value) block is used to set an agent’s trait to some value. In this case, the Mountain Lion’s Pred-energy is a being initialized.</td></tr>
</table>

3. Testing and debugging your model

- After adding your breed and creating it, test your setup.
  Did your Mountain Lion appear? Is it the color, shape and size you wanted it to be?
- After giving your predator some behaviors, test it.
  Hint: Look at the Rabbit breed’s procedures for Hop, Reproduce, and Die. Do you want similar behaviors for the Mountain Lion? How are the behaviors of a mountain lion similar and different from a rabbit?
- Test your model.
  Check to see if your agents react to collisions, if energy value changes as expected, and if your agents move as expected.

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

Activity #2: Designing and Running Experiments - 20 min

Use the “Experimental Design” form to describe and report on your investigation.
In this activity students will run an experiment using the model they have modified by adding a predator. Students will have freedom to design their own experiments and there are many options, from simple to more complex experiments.

4. Experimental design

- Designing your experiment and asking scientific questions.
  Use the “Experimental Design” form and the “Scientific Practices with Computer Modeling & Simulation template and guide students as they develop a scientific question in pairs. Emphasize the need to run repeated trials and to clearly identify the variables, as well as the difference between a question and a *testable* question.
- Determine and record which variable will you be changing, the range for that variable, and how many trials to conduct at each setting. This information should be written into your template documents before beginning.
- Determine how you will be collecting and analyzing data. Is there instrumentation you will be using to monitor and record the behavior of the system? How long will you continue to collect data? How will you look for patterns in your data? [Will you draw a graph and/or make a table to record your observations?]
- See the next page for a sample of an experimental design.

5. Running your experiment

- Run your experiment in pairs so the question can be answered.
- Follow what you described in the Experimental Design form to determine which variable you will be changing, and how many trials you will make at that setting.
- After running the trials at each setting and recording the outcome data, move to the next setting in the range. Again, conduct these trials and record the outcome.

6. Collecting and analyzing data

- Compare the data you collected. Do you notice a trend?
- 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 *Students may have difficulty clearly stating how collecting and analyzing data generated by the model helps them answer their question. One way to focus them on this task is to start with the possible outcomes and work backwards to how that outcome helps answer the question.*

Experimental Design form

Name(s): ____Date: _______________

Model name: __Rabbits and Grass with Predator ____________________

Question
What is your question? How does adding a predator change the balance of the ecosystem? [We saw that without a predator there were three types of outcome: a) both rabbits and grass were gone, b) only grass remained, or c) there were cycles of boom and bust for both populations.]
Variables
What are the dependent and independent variables in your experiment? The independent variables are time and the number of predators. The dependent variables are the population size of rabbits and grass.
Range
What is the range of values you will use for each variable? Time will run from 0 to 400 ticks. Number of predators will be either 0 or 1. Initial population size of rabbits is 40 and initial grass population is 20
Trials
How many trials will you run at each setting? Why? We will run 10 trials at each setting. In other words. 10 trials with a predator and 10 trials without a predator. I know 1 is not enough, 100 would be great but we don't have enough\ time so I chose 10.
Data Collection
What data will you collect? After 400 ticks we will collect population size of rabbits and grass, and which of the three outcome types took place: a) both rabbits and grass were gone, b) only grass remained, or c) there were cycles of boom and bust for both populations.
Data Analysis
How will you analyze your data? We will compare the number of times each outcome happened with and without a predator.
Interpretation
How does the analysis of your data help you answer your question? If the number of times each outcome happened with and without a predator were different, we can say that we believe that adding a predator had an impact. If the number of time each outcome happended are the same between the model with and without a predator, we can say that we believe that adding a predator had no impact.
Prediction
What is your prediction? Why? I predict that with the predator, there will be more times when all of the rabbits will die off. This would look like more a's and b's. I think this might happen because the predator is likely to eat all of the rabbits.

Wrap-Up - 5 min

7. In the real world, what might impact how animals use and gain energy?
8. Was your prediction about how adding a predator would impact the ecosystem correct? Why or why not?
9. How can computer models be useful in understanding ecosystems?

Assessment Questions

- How would you compare the health of the ecosystem with and without a predator?
- What was the impact of adding a predator?
- What is an example of how an IF/THEN was used in this model?

Background Information

Document: Ecosystems as Complex Adaptive Systems
Document: Add a predator
Document: Scientific Practices with Computer Modeling & Simulation

Standards Addressed

NGSS Performance Expectations

Ecosystems: Interactions, Energy, and Dynamics MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

NRC Disciplinary Core Ideas

Interdependent Relationships in Ecosystems DCI-LS2.A: Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Growth of organisms and population increases are limited by access to resources. **Ecosystem Dynamics, Functioning, and Resilience** DCI-LS2.C: Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

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. 1B: Ask question to identify and/or clarify evidence and/or the premise(s) of an argument. 1C: Ask questions to determine relationships between independent and dependent variables and relationships in models. **Practice 2: Developing and using models** 2A: Evaluate limitations of a model for a proposed object or tool. 2C: Use and/or develop a model of simple systems with uncertain and less predictable factors. 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 design solutions under a range of conditions.

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.

Practice 5: Using mathematics and computational thinking
5B: Use mathematical representations to describe and/or support scientific conclusions and design solutions.
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.
6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.

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
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

1. Patterns:
1B: Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.
1D: Graphs, charts, and images can be used to identify patterns in data.
3. 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.
4. 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.

5. Energy and Matter:
5B: Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.
7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.
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	Abstraction	2-12	Use abstraction to decompose a problem into sub problems.
CT	Algorithms	3A-3	Explain how sequence, selection, iteration and recursion are the building blocks of algorithms.
CT	Connections to other fields	2-15	Provide examples of interdisciplinary applications of computational thinking.
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	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.

Responsiveness to Varied Student Learning Needs

In Project GUTS, we integrate teaching strategies found to be effective with learners with various backgrounds and characteristics such as economically disadvantaged students (EDS), students from groups that are underrepresented in STEM (URG), students with disabilities (DIS), English Language learners (ELL), girls and young women (FEM), students in alternative education (ALT), and gifted and talented students (GAT).

In each lesson we describe the accommodations and differentiation strategies that are integrated in the activities to support a wide range of learners.

Module 3 Lesson 3: Adding a Predator

(FEM) *Careful planning of partners for the on-computer activity is a strategy that encourages participation for the girls in science.*

(EDS) *We recommend acknowledging different cultures' relationship and perception of top predators and making clear that they are not either bad or good.*

(URG) *Students are given "agency" as the creators of their own models, and as researchers seeking to answer a question or understand a phenomenon. The models that students build are their own creations.*

(DIS)(GAT) *There is ample opportunity to extend level of content and time for practice by compacting areas already mastered and to allow more time for students to complete previous experiments and customizations. This differentiation strategy of pacing can benefit a wide range of students including those with learning disabilities and/or gifted and talented students.*

Experimental Design Form

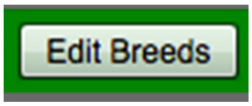
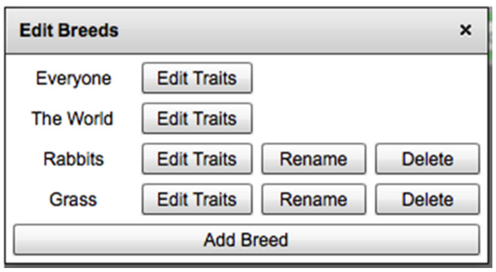
Name(s): ______________________________ Date: ______________
Model name: ____

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?
Prediction
What effect do you think the changes you make will have on the model?
Data Collection
What data will you collect?
Data Analysis
How will you analyze your data? (i.e. look for patterns, compare final values, look at the graph)
Interpretation
What is the answer to your question? How does the analysis of your data help you answer your question?

Lesson 3 - Student Activity #1 Guide

Adding a Predator

Use the instructions below to add a new breed:

<table>
<tr><td></td><td>Use the Edit Breeds button in the Spaceland area to create a new breed.</td></tr>
<tr><td></td><td>Click on “Add Breed” to add a new breed.</td></tr>
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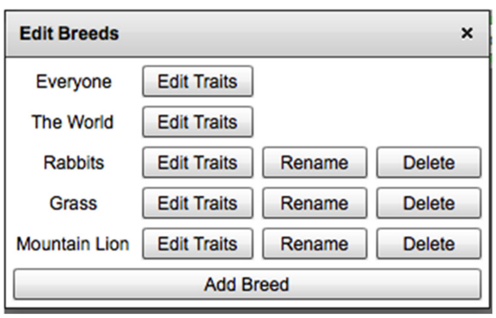
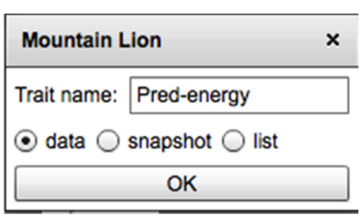
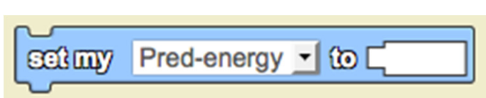
<tr><td></td><td>You will see the Breed on the next panel. (We added the breed called “Mountain Lion”.

Next, click Edit Traits next to the new breed label for “Mountain Lion”</td></tr>
<tr><td></td><td>Create a new trait (or variable) for the Mountain Lion breed called “Pred-energy”.</td></tr>
<tr><td></td><td>The set my (trait) to (value) block is used to set an agent’s trait to some value. In this case, the Mountain Lion’s Pred-energy is a being initialized.</td></tr>
</table>

Lesson 3 - Student Activity #2 Guide

Designing and Running Experiments

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.

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?
Prediction
What effect do you think the changes you make will have on the model?
Data Collection
What data will you collect?
Data Analysis
How will you analyze your data? (i.e. look for patterns, compare final values, look at the graph)
Interpretation
What is the answer to your question? How does the analysis of your data help you answer your question?

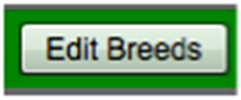
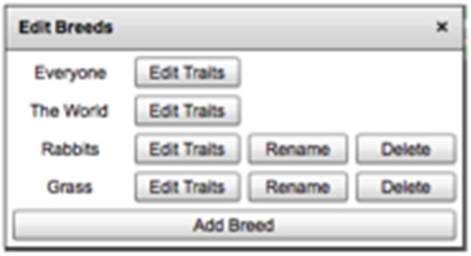
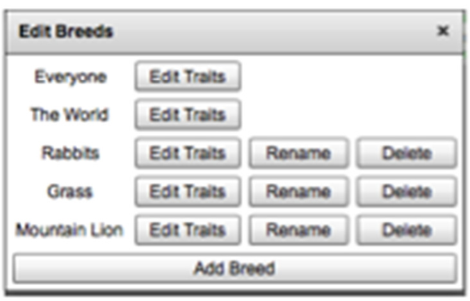
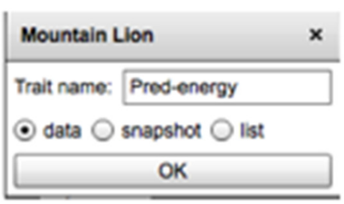
Scientific Practices with Computer Modeling & Simulation

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	

StarLogo Nova Blocks introduced in Module 3 Lesson 3

	Use the Edit Breeds button in the Spaceland area to create a new breed.
	Click on "Add Breed" to add a new breed.
	In the "New Breed" dialog box, give the breed a name and press OK.
	You will see the Breed on the next panel. (We added the breed called "Mountain Lion". Next, click Edit Traits next to the new breed label for "Mountain Lion"
	Create a new trait (or variable) for the Mountain Lion breed called "Pred-energy".
	The set my (trait) to (value) block is used to set an agent's trait to some value. In this case, the Mountain Lion's Pred-energy is a being set to a starting value. This is called "initializing" the variable.

3

Lesson 4

Create Your Own Ecosystem Model

50 minutes (1 day)

Lesson Overview

In this lesson students will design their own ecosystems projects consisting of a question, experimental design and model. In the first activity, students will learn about the computational science cycle and use it to scope their project. This leads to a second activity where they start designing and implementing their model.

Teaching Summary

Getting Started – 5 minutes (Review)

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

Activity #1: Computational Science Cycle – 20 minutes (New Learning)

2. Introduce computational science cycle
3. Define your computational science project

Activity #2: Designing and Developing Your Model – 20 minutes (Creative / Discovery)

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 an original design for a computational science project
- ✓ Develop a scientific question that can be answered with data output from running a model
- ✓ Use abstraction to develop an idea for a model
- ✓ Use the computational science cycle and Project Design form to develop their question, model, and experimental design
- ✓ Practice pair programming and iterative design, implement, test cycle

Teaching Guide

Materials, Resources and Preparation

For the Students
- Computers
- StarLogo Nova reference guide
- Project Design Form
- Scientific Practices with Computer Modeling & Simulation

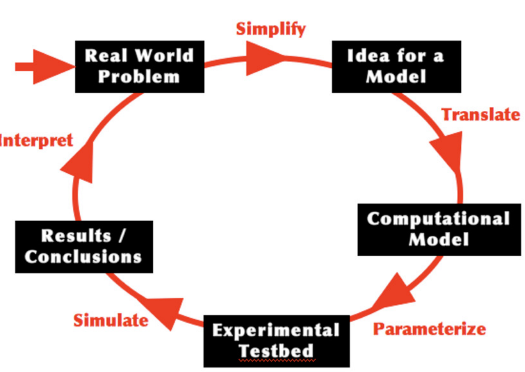
For the Teacher
- Computer and projector
- Slide presentation with simple commands
- StarLogo Nova reference page on Chase and Runaway

Getting Started - 5 min

1. **Review of previous day's lesson and link to where we are going today**
   - What commands enabled agents to react to their environments and other agents? What was the impact of adding a top predator to your ecosystem?
   - Next you are going to develop your own ecosystems projects.

Activity #1: Computational Science Cycle - 20 min

In this activity, the teacher will introduce the computational science cycle and worksheet. Students will work in teams to develop their questions and projects.



2. Introduce the Computational Science Cycle

The computational science cycle illustrates a simplified version of a process used by computational scientists working in STEM fields.

Note that while this "idealized" process is shown as a cycle, computational scientists often perform the practices in different orders, going back and forth between steps.

Here's a description of the cycle:

Stage 1: 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.

Stage 2: 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.

Stage 3: From the description and diagram of the model, translate from the description 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.>

Stage 4: Parameterize the model. Describe the range of values and increments for the variables and parameter in your experiment design. Describe the collection and analysis of data output from models.

Stage 5: Simulate and collect data. Use the computational model as a test bed for running experiments.

Stage 6: 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.

Repeat: The computational science cycle itself is an iterative process. In evaluating the model against the real world, one might find verification errors (e.g., bugs in code) or validation errors (e.g. when comparing model behavior to real world data there are differences that suggest that the wrong assumptions or simplifications were made). In either case, the whole computational cycle repeats. It is an iterative refinement process.

Stage 7: Share your model and findings.

Teaching Tip *Use the Rabbits and Grass with predator example when walking students through this cycle.*

3. Define your computational science project

- Hand out the Project design form to students in teams. Give them time to think of a local ecosystem to model.
- Have students specify their question and describe the model and experimental design on the Project design form.

Teaching Tip *Have students report out on their designs at the end of the class. We call these interim reports “pin ups” because you pin up your poster or diagram showing your idea.*

Teaching Tip *Guide students to start simple. Ecosystems with just a few trophic levels can demonstrate a wide range of behaviors. Customizing the existing Rabbits and grass with predator to become another ecosystem such as fish and plankton with a shark is completely acceptable.*

Activity #2: Designing and Developing Your Model - 20 min

In this activity, students will work in teams to develop their model and refine their design.

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, and creating agents (see cookbook page). New breed specific variables can be created in the edit Breeds panel.
   - Once agents are created, they will need to have their variables initialized. Agents have different shapes, colors, and sizes.
   - Next, if changes to the environment are needed, agents can be created and used to edit the terrain during the startup phase.
   - Agent behaviors can be implemented as procedures on the breed page corresponding to the agent.

5. **Interactions**
   - The students should then create code that gives their chosen agents behaviors and interactions with other agents and the environment.
   - See the cookbook pages for descriptions of different interactions that can be implemented.

   Teaching Tip *Students in pairs should take turns as pilot and navigator. More advanced students could choose several modifications to implement – a minimum should be to add at least one modification of their own devising. Guide their learning by having them pose questions to which they would like answers.*

Wrap-Up – 5 min

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

Assessment Questions

- Ask students to describe their use of scientific practices by filling out the Scientific Practices with Computer Modeling & Simulation form.

Standards Addressed

NGSS Performance Expectations

Ecosystems: Interactions, Energy, and Dynamics MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

NRC Disciplinary Core Ideas

Interdependent Relationships in Ecosystems DCI-LS2.A: Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which

consequently constrains their growth and reproduction. Growth of organisms and population increases are limited by access to resources.

Ecosystem Dynamics, Functioning, and Resilience
DCI-LS2.C: Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

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.
1B: Ask question to identify and/or clarify evidence and/or the premise(s) of an argument.
1C: Ask questions to determine relationships between independent and dependent variables and relationships in models.

Practice 2: Developing and using models
2A: Evaluate limitations of a model for a proposed object or tool.
2C: Use and/or develop a model of simple systems with uncertain and less predictable factors.
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 design solutions under a range of conditions.

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.

Practice 5: Using mathematics and computational thinking
5B: Use mathematical representations to describe and/or support scientific conclusions and design solutions.
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.
6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.

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
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

1. Patterns:
1B: Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.
1D: Graphs, charts, and images can be used to identify patterns in data.

3. 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.

4. 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.

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

7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.
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	Abstraction	2-12	Use abstraction to decompose a problem into sub problems.
CT	Algorithms	3A-3	Explain how sequence, selection, iteration and recursion are the building blocks of algorithms.
CT	Connections to other fields	2-15	Provide examples of interdisciplinary applications of computational thinking.
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	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.

Responsiveness to Varied Student Learning Needs

In Project GUTS, we integrate teaching strategies found to be effective with learners with various backgrounds and characteristics such as economically disadvantaged students (EDS), students from groups that are underrepresented in STEM (URG), students with disabilities (DIS), English Language learners (ELL), girls and young women (FEM), students in alternative education (ALT), and gifted and talented students (GAT).

In each lesson we describe the accommodations and differentiation strategies that are integrated in the activities to support a wide range of learners.

Module 3 Lesson 4: Create Your Own Ecosystem Model

(EDS) *Analyzing real-world phenomena in their schools and neighborhoods, and asking authentic questions using project-based learning, are effective teaching strategies to engage economically disadvantaged students.*

(URG)(FEM) *Students are given "agency" as the creators of their own models, and as researchers seeking to answer a question or understand a phenomenon. The models that students build are their own creations. Having students generate the problems and possible solutions, an important scientific practice, is also very motivating for all students, including girls.*

(FEM) *Careful planning of partners for the on-computer activity is a strategy that encourages participation for the girls in science.*

(DIS)(GAT) *There is ample opportunity to extend level of content and time for practice by compacting areas already mastered and to allow more time for students to complete previous experiments and customizations. This differentiation strategy of pacing can benefit a wide range of students including those with learning disabilities and/or gifted and talented students.)*

(GAT) *The teacher can promote autonomy and the forging of authentic connections to the ecosystems content and to the practice of computer modeling.*

(GAT) *Grouping students of similar interests and ability, incorporating standards from a higher grade, providing opportunities for self-directed projects are successful strategies for gifted and talented students.*

Project Design Form

Name(s): ____ Date: ______________

Model name: ____

As you create a computer model of a scientific phenomenon, use this form to help you organize your thoughts and develop the model from start to finish.

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?
What question do you seek to answer?
How will it be modeled? What abstractions are used?
Who are the <u>Agents</u>? What is the <u>Environment</u>? What are the <u>Interactions</u>? *How much time will the main forever loop represent? (minutes? days? months? years?)* *What are the parameters of interest?*

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?
Prediction
What effect do you think your variables will have on the model?

Data Analysis
How will you analyze your data?
Interpretation
How does the analysis of your data help you answer your question?
Going further
If you had more time, what further changes would you make to your model?

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	

3

Lesson 5

Designing and Running an Experiment and Sharing Your Findings

50 minutes (1 day)

Lesson Overview

In this lesson students will complete their ecosystems models and then design and run experiments using their models as experimental test beds. The second activity is the preparation of a presentation on their model, experimental design and findings.

Teaching Summary

Getting Started – 5 minutes

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

Activity #1: Designing and Running Experiments – 20 minutes

2. Designing your experiment
3. Running your experiment
4. Collecting and analyzing data

Activity #2: Preparing Your Presentation – 20 minutes

5. Presenting your project

Wrap-Up – 5 minutes

Since this is an open-ended exploration and creative activity, there isn't a formal wrap-up.

Lesson Objectives (across both activities)

The student will:

- ✓ Develop an original design for a computational science project
- ✓ Develop a scientific question that can be answered with data output from running a model
- ✓ Use abstraction to develop an idea for a model
- ✓ Use the computational science cycle map to develop their question, model, and experimental design
- ✓ Practice pair programming and iterative design, implement, test cycle

Teaching Guide

Materials, Resources and Prep

For the Students

- Computers
- StarLogo Nova reference guide
- Experimental Design Form

For the Teacher

- Computer and projector
- Slide presentation with simple commands
- StarLogo Nova reference page on Chase and Runaway

Getting Started - 5 min

1. Review of previous day's lesson and link to where we are going today

Activity #1: Designing and Running Experiments - 20 min

Use the "Scientific Practices with Computer Modeling & Simulation" form to describe and report on your investigation.

2. Experimental design

- Assign students to work in small groups.
- Hand out the experimental design form and review its contents.
- Give students time to plan and describe their experiment using the form.
- Ask "What are the dependent and independent variables?"
- Ask "What are the variables that already exist in this model?" Choose one variable to experiment with, then use the "Experimental Design handout" to describe experiments and record data from your experiments.
- Ask "How many trials do you need to run at each setting of the one variable?"

3. Running your experiment

- Students are to run the experiment they described in the form and collect data.
- What is the range of values for the variable you chose?
- How many trials will you run at each setting?
- How will you capture the data?
- Currently the data output to file function is not available in StarLogo Nova. An alternative is to grab screen shots of the graph and label it with the settings.
- Show students how to do a screen grab and name their file.
- Another alternative is to keep the line graph recording all experiments without clearing the line graph.

4. Collecting and analyzing data

- Ask "What patterns do you see in the collected data?"
- Ask "What correlations do you think exist between the variable setting and the outcomes?

Activity #2: Preparing Your Presentation - 20 min

5. **Presenting your project**
   - Guide students in using the guidelines below to prepare a slide presentation.

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.

Standards Addressed

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MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

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CT	Modeling & simulation	3B-8	Use models and simulation to help formulate, refine, and test scientific hypotheses.
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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?
Prediction
What effect do you think the changes you make will have on the model?
Data Collection
What data will you collect?
Data Analysis
How will you analyze your data? (i.e. look for patterns, compare final values, look at the graph)
Interpretation
What is the answer to your question? 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	
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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	

MODULE 4 (Physical Science) INTRODUCTION

Module Name: Chemical Reactions

Content of this Introduction:
1. Overview of the Module
2. Prerequisite knowledge
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 Physical Science module explores chemical reactions: the conditions under which they occur, the evidence of a chemical reaction, limiting reactants versus reactants in excess, and when chemical reactions stop.

The chemical reaction simulated in the base model is that of Silver Nitrate and Copper.
$2\ AgNO_{3\ (aq)} + Cu_{\ (s)} \text{--->} Cu(NO_3)_{2\ (aq)} + 2\ Ag_{\ (s)}$

The goal is to run experiments with different amounts of reactants and predict the amount of product formed. Students use, modify and customize an agent-based model of a chemical reaction and experiment with factors that impact the rate of a chemical reaction.

2. Prerequisite knowledge and assumptions encompassed by the Module

This Physical Science module offers some disciplinary core concepts through direct instruction and activities but assumes the students are familiar with concepts such as what are atoms and ions, and what is evidence of a chemical reaction. Students are also to be familiar with solids dissolving in water; the concepts of single replacement (displacement) and double replacement reactions; and balancing equations.

It is necessary to have completed Module 1 is a prerequisite for this model.

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
- Link to the video presentation of the Silver nitrate and copper chemical reaction OR access to materials for the live demonstration.
- Silver nitrate and copper base StarLogo Nova model (detailed in Lesson plans)
- Guided Introduction to StarLogo Nova document [for reference]

- CS Concepts guide document [for reference & student handout]
- StarLogo Nova Blocks Reference Guide [for reference & student handout]
- Scientific Practices with Computer Modeling & Simulation 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
- Associated student activity sheets
- Slide presentation with instructions

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

DAY 1: Introduction to Chemical Reactions

Pacing Guide

Getting started	Properties of matter, chemical formulas and evidence of a chemical reaction.	15 mins
Activity 1	Demonstration (live or via downloaded video) of silver nitrate and copper chemical reaction	15 mins
Activity 2	Previewing the Chemical Reaction base model	15 mins
Wrap-Up	Signs of a chemical reaction.	5 mins

Learning Objectives: Students will…

Disciplinary Core Concepts	Differentiate between atoms and ions. Identify evidence of a chemical reaction. Learn the importance of water as a medium for some chemical reactions to occur.
Cross cutting concepts	The initial preview of the base model will suggest that cause and effect relationships may be used to predict both microscopic and macroscopic behavior. The conservation of matter is suggested but not explicitly stated in this first lesson.
Modeling and Simulation	Learn how computer models can be used to run simulations when dangerous or expensive materials are involved. Identify aspects of the chemical reaction that are not included in the base model.

Assessments of understanding:

Complex Adaptive Systems	What features of a complex adaptive system are exhibited in the model of silver nitrate and copper chemical reaction?
Disciplinary Core Ideas	What is the difference between atoms and ions? What evidence of a chemical reaction was seen in real life an in the computer model? Could the chemical reaction take place without water?
Modeling and Simulation	Why might we want to simulate chemical reactions on a computer rather than in real life?

DAY 2: Modeling Chemical Reactions

Pacing Guide

Getting started	Chemical Reaction overview	10 mins
Activity 1	Analyzing the base model	20 mins
Activity 2	Modifying the base model to add/remove water molecules and move the copper rod.	15 mins
Wrap-Up	How does his model help us learn about the chemical reaction?	5 mins

Learning Objectives: Students will…

Disciplinary Core Concepts	Differentiate between chemical and physical properties of substances. Identify atomic symbols and chemical formulas of the reactions in this module. Identify which reactant is limiting and which is in excess. Identify signs of a chemical reaction and when a chemical reaction stops.
Modeling and Simulation	The role of parameters and initial conditions are presented and students gain experience with the representation of entities within the model. The setup procedures and other code block are examined. Automation is observed in this USE phase (student's using a largely pre-built model).
Computer Science	Begin to understand the execution order of code and gain exposure to the CS concepts of "looping", parameters and logic, expressions, variables and functions. Use various debugging and testing methods to ensure program correctness.

Assessments of understanding:

Disciplinary Core Ideas	What is the difference between the chemical and physical properties of copper? Describe how many silver nitrate molecules are needed to react with each copper atom? Which reactant is limiting the reaction? Which reactant is in excess in the reaction? How do we know that a chemical reaction has taken place? How do we know when a chemical reaction has stopped?
Modeling and Simulation	Assessment of whether student was able to implement modifications to the base model.
Computer Science	Use of CS concepts and constructs such as looping, logic, expressions, conditionals, functions and variables.

DAY 3: Products of Chemical Reactions

Pacing Guide

Getting started	When does a chemical reaction stop?	5 mins
Activity 1	Modifying the model to add the production of copper nitrate	25 mins
Activity 2	Running experiments with different initial quantities of copper or silver nitrate	15 mins
Wrap-Up	What are models good for?	5 mins

Learning Objectives: Students will…

Disciplinary Core Concepts	Identify the products of a chemical reaction. Identify the factors that stop a chemical reaction. Learn about concepts of limiting reactants and reactants in excess. Learn the importance of balancing chemical equations.
Crosscutting concepts	Patterns: Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems. 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. Energy and Matter: Matter is conserved because atoms are conserved in physical and chemical processes.
Modeling and Simulation	Learn how to make new breeds and create agents in agent-based modelling. Collect and analyze data to look for patterns.

Assessments of understanding:

Disciplinary Core Ideas	What were the reactants in the chemical reaction we studied? What were the products in the chemical reaction we studied? What determines which are the limiting reactants? What determines which are the reactants in excess? In your own words, describe the law of conservation of mass.
Modeling and Simulation	What aspects of the chemical reaction were included in the base model? What do the agents represent? Are there agents that are not part of the "essential" behavior of the model?
Computer Science	What is an instruction? What is a loop? What is an iteration?

DAY 4: Complex Ions in Solution

Pacing Guide

Getting started	Ionic compounds, ionic equations, and complexes.	10 mins
Activity 1	Modifying the model further: creating hydrated copper ions and turning the solution blue.	20 mins
Activity 2	Characterizing the rate of reaction	15 mins
Wrap-Up	Using computer models in scientific investigations	5 mins

Learning Objectives: Students will…

Disciplinary Core Ideas	Differentiate between chemical equations, ionic equation and net ionic equation. Learn about at least one type of complex ions. Become familiar with rate of a reaction and availability of reactants.
Cross cutting concepts	Patterns: Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems. 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. Energy and Matter: Matter is conserved because atoms are conserved in physical and chemical processes.
Modeling and Simulation	Learn to implement interactions using collisions.

Assessments of understanding:

Disciplinary Core Ideas	What is an example of an ionic compound? Describe what happens to ionic compounds in solution. In the experiment we did today, what determines the rate of silver production? In your own words, describe the shape of the silver production curve and what caused it to have that shape.
Modeling and Simulation	Student modification of the model as an experimental testbed. Adding instrumentation. How can a computer model help in figuring out the impact of availability of reactants?
Computer Science	Describe the logic involved in implementing the three stages of hydrating copper ions.

DAY 5: Factors that Impact the Rate of a Chemical Reaction

Pacing Guide

Getting Started	Availability of reactants as a limiting factor	10 mins
Activity 1	Factors impacting the rate of reaction: Mixing and Step size.	15 mins
Activity 2	Running experiments	15 mins
Wrap Up	Sharing results and conclusions	10 mins

Learning Objectives: Students will…

Disciplinary Core Ideas	Review findings on how availability of reactants impacts the rate of reaction. Become familiar with rate of a reaction and kinetic energy effect.
Cross cutting concepts	Patterns: Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems. 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. Energy and Matter: Matter is conserved because atoms are conserved in physical and chemical processes.
Modeling and Simulation	Learn how agent movement can impact outcome in simulations. Learn to simulate kinetic energy in an agent-based model. Run virtual experiments to determine how kinetic energy impacts the rate of chemical reaction.

Assessments of understanding:

Disciplinary Core Ideas	What are some factors that impact the rate of reaction? How would you design an experiment to determine the impact of one of the factors? How was an increase in kinetic energy simulated in this lesson? Describe a feedback loop in the chemical reaction studied.
Modeling and Simulation	What real-world aspects did you model? What real-world aspects did you leave out? Why? What experiments did you run in the model? Student model, shared with instructor digitally, will be the principal assessment of this activity.
Computer Science	Student model, shared with instructor digitally, will be the principal assessment of computer science learning.

4

Lesson 1

Introduction to Chemical Reactions

50 minutes (1 day)

Lesson Overview

In this lesson students will learn to recognize the changes that are characteristic of a chemical reaction. They will learn about the properties of ions in solution. They will observe a real-world example of a reaction that will become the basis in subsequent lessons of a "virtual lab" computer model. Finally, students will be introduced to the base model that is provided in this module.

Teaching Summary

Getting Started – 15 minutes

1. Properties of matter, chemical formulas and evidence of a chemical reaction.

Activity #1: Wet Lab or Virtual Lab – 15 minutes

2. Demonstration of chemical reaction- live or video via projection.

Activity #2: Previewing the Chemical Reaction Base Model – 15 minutes

3. Computer model: "silver nitrate and copper reaction," teacher-led demo.
4. Run the model and discuss abstraction and application to real-world phenomena.

Wrap-Up – 5 minutes

5. Signs of a chemical reaction.

Lesson Objectives

The student will:

- ✓ Differentiate between atoms and ions [LO1]
- ✓ Identify evidence of a chemical reaction [LO2]
- ✓ Learn the importance of water as a medium for some chemical reactions to occur [LO3]
- ✓ Learn that models are important when dangerous or expensive materials are involved [LO4]
- ✓ Identify what aspects of a Chemical Reaction not included in the base model [LO5]

Teaching Guide

Materials, Resources and Preparation

For the Students

- Their attention and curiosity

For the Teacher

- Computer and projector
- If performing live demonstration: necessary reactants, beaker and safety glasses
- Slide presentation
- StarLogo Nova base model: "silver nitrate and copper reaction"

Getting Started - 15 min

1. Properties of matter, chemical formulas and evidence of a chemical reaction

- Tell students that creating and using a model of chemical reactions first requires an understanding of the atomic and ionic structures, chemical formulas and evidence of a chemical reaction. In addition, prime the students by telling students that they will learn about ionic compounds and the role of water in separating the ions. Students will identify the essential aspects of chemical structure and properties of matter as it relates to reactivity.
- Use the slide presentation to focus on one chemical reaction. There is examination of its atomic and ionic nature and states of matter. Chemical concepts to be covered in the slide presentation:
    - Physical and chemical properties of matter
    - Chemical symbols
    - Atoms, ions and ionic compounds
    - Ionic compounds in water and aqueous state
    - Properties of aqueous solutions
    - Signs of a chemical reaction

  In addition, review the properties that are characteristic of the chemical reaction and the conditions under which a chemical reaction will occur.

Activity #1: Wet Lab or Virtual Lab - 15 min

2. Live demonstration or watch and discuss video

- The activity is a teacher-led demonstration of a copper and silver nitrate reaction. The demonstration can either be live (if the teacher is able to obtain reactants and the necessary equipment) or it can be virtual, via one of the many videos available for download online.
  Some examples: https://www.youtube.com/watch?v=rgYhkVy5cBU
  https://www.youtube.com/watch?v=dccDiAwztUQ
- The demonstration should be accompanied by a slide presentation using direct instruction and discussion to review key concepts, such as atoms and their ionic counterparts, ionization in water, and the notions of a chemical compound and complexes.
- To do a live demonstration requires a solution of silver nitrate and copper rod or copper ribbon. It is recommended to use a concentration of 0.5 M of silver nitrate solution and to

give the reaction at least 30 minutes for the full effect of a chemical reaction to occur. It is recommended to start the reaction at the beginning of class. To make 0.5 M solution of silver nitrate, dissolve 3.4 g of solid silver nitrate in 40 mL of water.

Activity #2: Previewing the Chemical Reaction Base Model - 15 min

3. Introduce the StarLogo Nova base model: “silver nitrate and copper reaction”

- Focus on the reactants and the setup procedures.
- Show the connections between the model interface, Spaceland, and the Workspace (coding window) below.
- Emphasize that agents in this model are used to represent real-world entities, in this case, ionic compounds and molecules.
- The reaction modeled is: Aqueous silver nitrate added to solid copper will react to form solid silver and aqueous copper nitrate.

  In a balanced chemical equation format:

  $2\ AgNO_3\ (aq) + Cu\ (s) \dashrightarrow Cu(NO_3)_2\ (aq) + 2\ Ag\ (s)$

- Discussion: What part of the code determines the total number of Copper agents created?
- Go over what this block means in the Copper Setup:

  Discuss: why 200 steps? [Spaceland has boundaries between -50 and 50 in x, y and z dimensions. Spaceland is centered at (0,0,0) and considering the number of steps diagonally, 200 steps is a safe bet.]

- Go over the Copper Setup procedure, emphasizing how agents can be created at specific (x,y) coordinates with a specific heading, and agents can create new agents within repeat loops.

4. Run the model and discuss abstraction and application to real-world phenomena.

- Each atom of silver or copper is represented by one computer modeling agent.
- Each compound of silver nitrate is represented by one computer modeling agent.
- Each water agent in the model corresponds to 1 water molecule (H_2O)
- Copper atoms are stationary and present in a single location.
- Fluid motion is represented by the “Wiggle Walk” for each agent – see silver nitrate tab in workspace.

Wrap-Up - 5 min

5. What are signs of a chemical reaction?

- What are signs of a chemical reaction? [Precipitate, color change, bubbles, temperature change]
- Role of water in chemical reaction. [ions dissociating]
- Do chemical reactions depend on randomness?

Extension: Does the silver depositing on the copper rod remind you of a real-world application? [silver plating]

Assessment Questions

- What is the difference between atoms and ions?
- What evidence of a chemical reaction was seen in real life and in the computer model?
- Would the chemical reaction take place without water?
- Why might we want to simulate chemical reactions on a computer rather than in real life?
- What aspects of a chemical reaction were not included in the computer model?

Background Information

- http://www.chemistry-blog.com/2009/04/03/chemistry-lab-demonstrations-silver-nitratecopper-wire/
- http://chemmovies.unl.edu/chemistry/dochem/DoChem019.html

Standards Addressed

NRC Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

PS1.B: Chemical Reactions
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy.

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.
1B: Ask question to identify and/or clarify evidence and/or the premise(s) of an argument.
1E: Ask questions that require sufficient and appropriate empirical evidence to answer.
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.

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

1. Patterns:
1A: Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

3. 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.
3E: Phenomena that can be observed at one scale may not be observable at another scale.

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.

5. Energy and Matter:
5A: Matter is conserved because atoms are conserved in physical and chemical processes.
6. Structure and Function
6A: Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.

7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

CSTA K-12 Computer Science Standards

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	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	2-9	Interact with content-specific models and simulations to support learning and research.

4

Lesson 2
Modeling Chemical Reactions

50 minutes (1 day)

Lesson Overview

In this lesson students will explore the role of reactants in a chemical reaction. Discussion will be closely tied to the example reaction modeled. Emphasis is placed on concept of limiting reactant and reactants in excess. Students will make some modifications to the model and run experiments to determine the consequences of varying the quantities of reactants.

Teaching Summary

Getting Started: – 10 minutes
1. Chemical reaction overview

Activity #1: Analyzing the Model – 20 minutes
2. Examine the base model

Activity #2: Modifying the Silver Nitrate and Copper Reaction Model – 15 minutes
3. Add or remove water molecules
4. Move the copper rod to a different location

Wrap-Up – 5 minutes
5. How does this model help us learn about the chemical reaction?

Lesson Objectives

The student will:
- ✓ Differentiate between chemical and physical properties of substances [LO6]
- ✓ Identify atomic symbols [LO7]
- ✓ Identify chemical formulas of the reactions in this module [LO8]
- ✓ Identify which reactant is limiting and which is in excess [LO9]
- ✓ Identify signs of a chemical reaction and when a chemical reaction stops [LO10]

Teaching Guide

Materials, Resources and Preparation

For the Students
- StarLogo Nova base model: "silver nitrate and copper reaction"
- Model Observation Form
- Student Activity Sheet

For the Teacher
- Computer and projector
- Slide presentation
- StarLogo Nova base model: "silver nitrate and copper reaction"

Getting Started – 10 min

1. Chemical reaction overview
- Use the slide presentation to review chemical reactions and computer science concepts.
- Creating and using a model of chemical reactions first requires an understanding of the different aspects of a chemical reaction. In addition, the following concepts are needed before proceeding and need to be reviewed in class:
  - Writing chemical equations
  - Balancing chemical equations
  - Limiting reagents
  - Chemical and physical properties of silver, copper, silver nitrate and copper nitrate
  - Atomic symbols and chemical formulas of reaction in this module
- Introduce the silver nitrate and copper chemical reaction:

  $2\ AgNO_3\ (aq) + Cu\ (s) \dashrightarrow Cu(NO_3)_2\ (aq) + 2\ Ag\ (s)$
- Introduce the computer science concepts to be used today:
  - (x, y) coordinates and heading
  - Repeat loop
  - Agent count

Activity #1: Analyzing the Model – 20 min

2. Examine the base model
- Hand out the Model Observation form.
- In pairs, have students examine the base model to determine the agents, their behaviors and interactions between agents.
- Have students record their observations on the Model Observation form.
- If time permits, ask each pair to report out to the class on a single aspect discovered about the model.

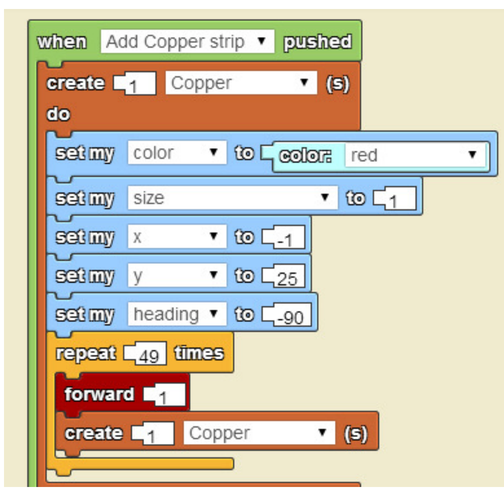
Activity #2: Modifying the Silver Nitrate and Copper Reaction

Model – 15 min

3. **Add or remove water molecules**
    - Guide students in modifying the code to add or remove some or all of the water molecules in the model.
    - Ask "does it affect the execution of the model and real-world representation?"

    Extension: Discuss abstraction in computer modeling.

4. **Move the copper rod to a different location**
    - Offer a challenge to students who finish the previous task quickly.
    - The challenge is to modify the code to move the copper rod somewhere else in the solution, keeping the number of copper agents the same. This number can be tested when executing the program and checking the number of atoms of copper in a databox (interface).
    - To complete this challenge, students will need to figure out how to set up agents in specific (x,y) coordinates with specific headings. They will also get a deeper understanding about using repeat loop and agents creating agents.



Wrap-Up – 5 min

5. Discussion: Ask students:
Does it matter where the copper is placed when you modify the code?
Does the model allow you to add more copper? [Try clicking on "Add copper" button twice.]
Would the shape of copper, such as coil or rod, matter from the model perspective?

Assessment Questions

- What is the difference between the chemical and physical properties of copper?
- Describe how many silver nitrate molecules are needed to react with each copper atom?
- Which reactant is limiting the reaction?
- Which reactant is in excess in the reaction?
- How do we know that a chemical reaction has taken place?
- How do we know when a chemical reaction has stopped?

Standards Addressed

NRC Scientific and Engineering Practice Standards

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1A: Ask questions that arise from careful observation of phenomena, models, or unexpected results.
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1C: Ask questions to determine relationships between independent and dependent variables and relationships in models.
1E: Ask questions that require sufficient and appropriate empirical evidence to answer.
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 4: Analyzing and interpreting data
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).
4H: Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.

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.
6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
6H: Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

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 Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
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3E: Phenomena that can be observed at one scale may not be observable at another scale.

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.

5. Energy and Matter:
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6. Structure and Function
6A: Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.

7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

CSTA K-12 Computer Science Standards

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	Modeling & simulation	2-10	Evaluate the kinds of problems that can be solved using modeling and simulation.
CT	Modeling & simulation	2-9	Interact with content-specific models and simulations to support learning and research.

Lesson 2 - Student Activity #2 Guide

Modifying the Silver Nitrate and Copper Reaction Model

Remix the base model: “silver nitrate and copper reaction and change its name to include your name and your partner’s name.

Challenge #1:
Modify the code to add or remove some or all of the water molecules in the model.

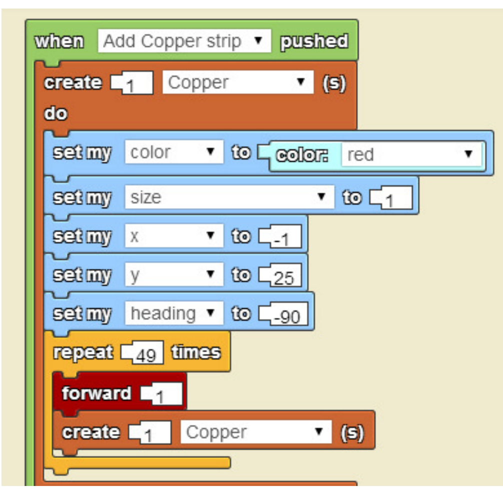
Reminder: Execute your model every time you add a piece of code. Debug as needed. Save often.

Hint: Look at the setup instructions for the water agents.
After you change the code, go up to the SpaceLand interface, save the model and click on “Run Code’ before running the model by clicking on the interface buttons. Debug the model as needed.

Q: Does removing the water molecules affect the execution of the model and real-world representation? If time allows after you are done, think about what is included in this model and what is missing.

Challenge #2:
Modify the code to move the copper rod somewhere else in the solution keeping the number of agents of copper the same. Please note: The base model gives 150 copper agents to represent 150 copper atoms.

Hint: Look at the setup instructions for the copper agents (section shown below)



After you change the code, go up to the interface and hit “Save” and “Run Code” before executing the model. Debug the code as needed.

What does the command “set my x to” do? What does the command “set my heading to” do?
What happens if you change the number of times the loop repeats?

Model Observation Form

Name(s): ____Date: __________
Model name: ____

Abstractions
Who are the <u>Agents</u>? What is the <u>Environment</u>? What are the <u>Interactions</u>? *How much time does the main forever loop represent? (minutes? days? months? years?)* *What are the variables of interest?*
Automation
What happens each time through the forever (or main) loop?
Assumption(s)
What real life elements or behaviors were left out of this model?
Analysis
What patterns did you observe? Do these patterns occur in real-life?

4

Lesson 3

Products of Chemical Reactions

50 minutes (1 day)

Lesson Overview

In this lesson students will engage in discussion on the reactants and products of a chemical reaction. Emphasis is on balancing chemical equations, the amounts of reactants used up and products formed. Focus will be on the products and the observation of the atomic rationale for conservation of mass.

Teaching Summary

Getting Started – 5 minutes

1. When does a chemical reaction stop?

Activity #1: Modifying the Model – 25 minutes

2. The production of copper nitrate

Activity #2: Running Experiments – 15 minutes

3. Different initial quantities of copper or silver nitrate

Wrap-Up – 5 minutes

4. What are models good for?

Lesson Objectives

The student will:

- ✓ Identify the products of a chemical reaction [LO11]
- ✓ Identify the factors that stop a chemical reaction [LO12]
- ✓ Learn about concepts of limiting reactants and reactants in excess [LO13]
- ✓ Learn the importance of balancing chemical equations [LO14]
- ✓ Learn how to make new breeds and create agents in agent-based modeling [LO15]

Teaching Guide

Materials, Resources and Preparation

For the Students

- StarLogo Nova base model: "silver nitrate and copper reaction"
- Student Activity Sheet
- Experimental Design Form

For the Teacher

- Computer and projector
- Slide presentation
- StarLogo Nova base model: "silver nitrate and copper reaction"

Getting Started - 5 min

1. **When does a chemical reaction stop?**
   - In this slide presentation you will review the chemical reaction being modeled.
   - Discuss the conservation of mass and how the balancing of chemical equations preserves this law.
   - Illustrate how 2 $AgNO_3$ is broken apart in water, then how 2 NO_3 bind with one Cu to produce the "product" $Cu(NO_3)_2$
   - Introduce the concepts of the limiting reagent and reactants in excess.
   - The key question to pose to students is, "When does the reaction stop?"
   - Tell students that this will be the basis for our investigations today.

   Computer science concepts: Agents represented by breeds. Default breed in StarLogo Nova is "Turtle." Breeds can be added and renamed.

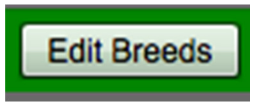
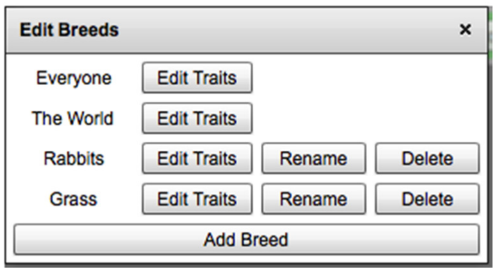
Activity #1: Modifying the Model – 25 min

2. **The production of copper nitrate**
   - Review the chemical reaction being represented in the base model so far and what is missing. Aqueous silver nitrate added to solid copper will react to form solid silver and aqueous copper nitrate.

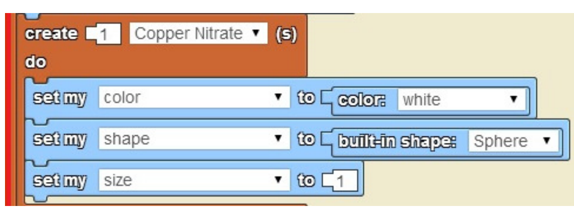
     Chemical reaction: $2\ AgNO_3\ (aq) + Cu\ (s) \rightarrow Cu(NO_3)_2\ (aq) + 2\ Ag\ (s)$

   - Note that in our model we have breeds for $AgNO_3$, Cu, and Ag, but no $Cu(NO_3)_2$. We are missing one of the products!
   - Review the concept of conservation of mass and that to be accurate, all mass must be accounted for.
   - So let's add the production of copper nitrate to the model: first we will need to make a breed called "copper nitrate," then create the agents with breed copper nitrate inside a collision block, and give the copper nitrate agents some behavior. Copper nitrate is a soluble ionic compound - it stays suspended in water.
   - Have students open and remix the StarLogo Nova base model "silver nitrate and copper reaction."

- Pose the challenge: modifying the code to add copper nitrate agents.
- Introduce new computer science concept: adding new breeds.
- Review the breeds that students know already. "Turtles" are the default breed of agents in StarLogo Nova. New breeds can be added using the "Edit Breeds" panel and the new breed can be given traits.
- Show the edit breeds panel and demonstrate how to add a breed.

<table>
<tr><td>
</td><td>Use the Edit Breeds button in the Spaceland area to create a new breed.</td></tr>
<tr><td>
</td><td>Click on "Add Breed" to add a new breed.</td></tr>
<tr><td>
</td><td>In the "New Breed" dialog box, give the breed a name and press OK.</td></tr>
</table>

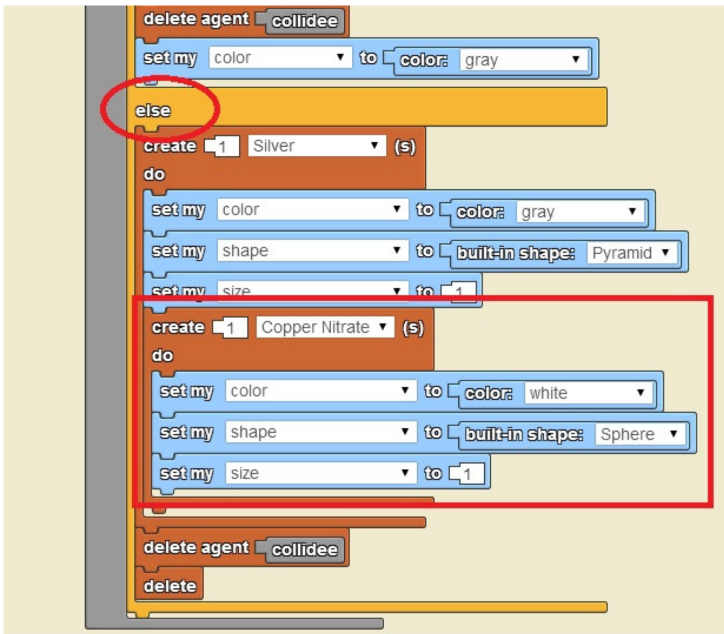
- Point out to the students that once you add a new breed, a new page for that breed appears in the Workspace. This is where the procedures for agents of that breed are written and stored.
- Next, we'll need to create a copper nitrate agent when there is a collision between a "gray" copper, and a silver nitrate.
- The newly created copper nitrate should have the following traits: its shape should be a sphere, its color should be white and its size should be 1.



- Where is the correct location of this procedure? [in the copper tab]
- Review what we learned about the base model in the previous lesson. The first time a silver nitrate reacts with copper, the copper turns gray. The second time a silver nitrate reacts with a copper, silver and now copper nitrate are produced. So we know that the copper nitrate should be created when the silver is created. (See the code blocks on the next page.)
- Next we need to give the copper nitrate some movement. This code should be added to the copper nitrate page. [You can copy and paste the Wiggle Walk procedure from the water page or the silver nitrate page to the copper nitrate page.]
Extension: Create a data box to display the amount of copper nitrate produced.

Extension: Introduce the concept of inheritance of all agents from the “everyone” breed in StarLogo Nova. Then show how the Wiggle Walk procedure can be moved into the “everyone” page and removed from the other breed specific pages. Why might this be a good idea? [Avoids duplication, prevents one of the breeds from having a different behavior, and is easy to change, since it is in one place.]

Extension: Move this whole collision procedure from the copper page to the silver nitrate page. Change the heading of the collision block to reflect “On collision with copper” instead of “On collision with silver nitrate” and execute the model. What do you notice? [The silver ends up deposited at the location of the center of the silver nitrate rather than the copper. As a result, the copper strip does not get “plated” evenly.]



Activity #2: Running Experiments – 15 min

3. Different initial quantities of copper or silver nitrate

- Run experiments with the modified model. Experiment with different initial quantities of copper or silver nitrate and record the amount of silver produced. (If a student’s modification of the model was unsuccessful, the base model can be used for this experimentation.)
- Instruct the students on using the Experimental Design Form to guide their experimentation. Remind students to include multiple trials at every different setting of the initial amounts used.
- Students are to note when the copper is in excess and when the silver nitrate is in excess. Also, how much silver was produced in each case?

Wrap-Up – 5 min

4. What are models good for?

Lead a discussion with the students:

- What is your conclusion about the limiting reagent? When does the reaction stop?
- What experiments did you run that validate this conclusion?
- If your goal was not to waste reactants, how is the model helping in figuring out the

amounts needed from reactants and when the reaction stops?

Assessment Questions

- What were the reactants in the chemical reaction we studied?
- What were the products in the chemical reaction we studied?
- What determines which are the limiting reactants?
- What determines which are the reactants in excess?
- In your own words, describe the law of conservation of mass.

Standards Addressed

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.
1B: Ask question to identify and/or clarify evidence and/or the premise(s) 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.
1E: Ask questions that require sufficient and appropriate empirical evidence to answer.
1F: Ask questions that can be investigated within the scope of the classroom, outdoor environment, and based on observations and scientific principles.
1G: Ask questions that challenge the premise(s) of an argument or the interpretation of a data set.

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 4: Analyzing and interpreting data
4D: Analyze and interpret data to provide evidence for phenomena.
4G: Analyze and interpret data to determine similarities and differences in findings.

Practice 5: Using mathematics and computational thinking
5C: Create algorithms (a series of ordered steps) to solve a problem.

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.
6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
6E: Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.
6H: Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

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 Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

PS1.B: Chemical Reactions
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy.

NRC Crosscutting Concepts

1. Patterns:
1A: Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

3. 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.
3C: Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.
3E: Phenomena that can be observed at one scale may not be observable at another scale.

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.

5. Energy and Matter:
5A: Matter is conserved because atoms are conserved in physical and chemical processes.

6. Structure and Function
6A: Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.

7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

CSTA K-12 Computer Science Standards

CT	Abstraction	3A-9	Discuss the value of abstraction to manage problem complexity.
CT	Data representation	2-8	Use visual representation of problem state, structure and data.
CT	Modeling & simulation	2-10	Evaluate the kinds of problems that can be solved using modeling and simulation.
CT	Modeling & simulation	2-9	Interact with content-specific models and simulations to support learning and research.
CPP	Data collection & analysis	2-9	Collect and analyze data that are output from multiple runs of a computer program.
CPP	Programming	2-5	Implement a problem solution in a programming environment using looping behavior, conditional statements, logic, expressions, variables and functions.

Lesson 3 - Student Activity #1 Guide

Modifying the Model

Your Challenge: Change the code to add copper nitrate agents to represent the missing chemical product from the model.

The reaction modeled is:
Aqueous silver nitrate added to solid copper will react to form solid silver and aqueous copper nitrate.
Chemical reaction: 2 $AgNO_3$ (aq) + Cu (s) ---> $Cu(NO_3)_2$ (aq) + 2 Ag (s)

Start with base model - StarLogo Nova base model: “silver nitrate and copper reaction”
Remix the base model and change its name to include your name and your partner’s name.

Reminder: Save and test your model every time you add a piece of code. Debug if needed. Save often.

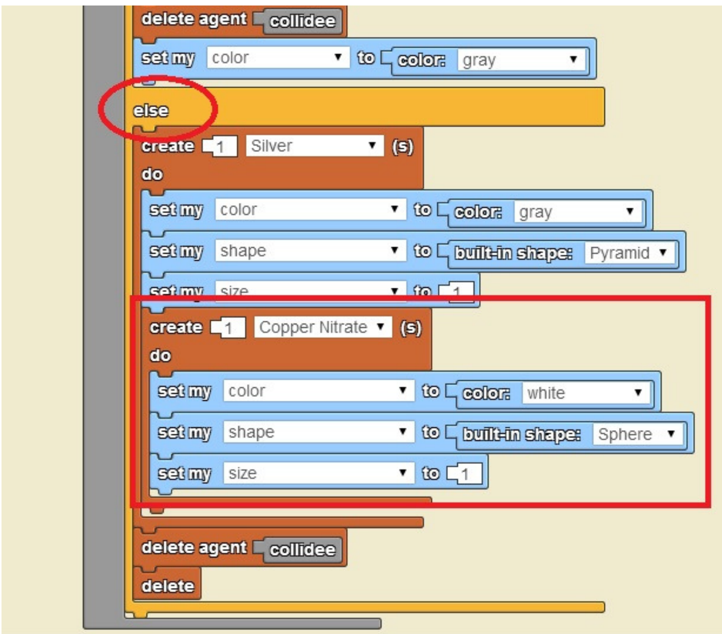
[Hints: (A) Add breed for new agent, (B) create agents inside a collision block, (C) give the agent some movement in water since it is a soluble ionic compound.]

One solution to the Challenge:

A- Add the copper nitrate agent as a new breed.
Click on edit Breed. Click on add Breed. Name the breed ‘copper nitrate”. Exit edit breed.

Is there a new page/tab in Workspace now that they created copper nitrate breed?

B- When “gray” copper collides with silver nitrate, copper nitrate is created.
Give the copper nitrate agent the following traits:
Shape is sphere, color is white and size is 1.



Where is the correct location of this procedure? Why?

C- Add movement to copper nitrate: copy and paste Wiggle Walk procedure from water page or silver nitrate page to the copper nitrate page.
To copy, with the mouse clicked, drag a box over the piece of code you want to copy, and click on the copy button under the drawers.

Lesson 3 - Student Activity #2 Guide

Running Experiments

Start with the modified base model.

Your Challenge: Run experiments with different initial quantities of copper or silver nitrate and get the amount of silver produced. How much silver is produced in each case? Note when the copper is in excess and when the silver nitrate is in excess.

Use the Experimental Design Form to guide you.
Multiple trials are needed at every different setting of initial amounts used.

Can you predict what amount of silver nitrate is needed to use up all the copper with no excess left of either?

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?
Prediction
What effect do you think the changes you make will have on the model?
Data Collection
What data will you collect?
Data Analysis
How will you analyze your data? (i.e. look for patterns, compare final values, look at the graph)
Interpretation
What is the answer to your question? How does the analysis of your data help you answer your question?

4

Lesson 4

Complex Ions in Solution

50 minutes (1 day)

Lesson Overview

In this lesson students will engage in discussion on the ionic equations and formation of complex ions. Students will discover the underlying chemical cause of the emergent blue hue that develops in the physically demonstrated silver nitrate/copper reaction. Emphasis is on the complex ion Cu(II).3H_2O or simply hydrated copper ion complex. Students will add instrumentation to the model and run experiments to determine the impact of the availability of reactants on the rate of chemical reaction.

Teaching Summary

Getting Started – 10 minutes

1. Ionic compounds, ionic equations and complexes

Activity #1: Modifying the Model Further – 20 minutes

2. Create hydrated copper ions
3. Turn the solution blue

Activity #2: Running Experiments – 15 minutes

4. Characterizing the rate of reaction

Wrap-Up – 5 minutes

5. Using computer models in scientific investigations.

Lesson Objectives

The student will:

- ✓ Differentiate between chemical equations, ionic equation and net ionic equation [LO16]
- ✓ Learn about at least one type of complex ions [LO17]
- ✓ Get more familiar with collision blocks in StarLogo Nova [LO18]
- ✓ Become familiar with rate of a reaction and availability of reactants [LO19]

Teaching Guide

Materials, Resources and Preparation

For the Students

- StarLogo Nova modified model from Lesson 3
- Student Activity Sheet
- Experimental Design Form

For the Teacher

- Computer and projector
- Slide presentation document
- StarLogo Nova modified model from Lesson 3

Getting Started - 10 min

1. **Ionic compounds, ionic equations and complexes**
   - Discuss a simple ionic compound and its equation: Silver nitrate, $Ag(NO_3)$ in water dissociates to one ion of Ag^+ and one $(NO_3)^-$ ion. Review the definition of an ion [An ion is an atom or molecule with a net electric charge, due to the loss or gain of one or more electrons.]
   - Discuss that the product copper nitrate, $Cu(NO_3)_2$ which was produced in our experiment, is also an ionic compound.
   - Copper nitrate is an ionic compound that is soluble in water. It dissociates to Cu^{+2} [or Cu(II) by convention] and two $(NO_3)^-$ ions. Review the definition of an ionic compound, “An Ionic Compound is made of positive ions (cations) and negative ions (anions) held tightly together” and the term “soluble” meaning it dissolves in water.
   - Copper ions, Cu(II), in water form a complex ion with 3 water molecules, which produces the blue hue (or color) in the solution. This complex can be referred to in many different ways:
     - $[Cu(H_2O)_3]^{+2}$
     - more conventionally referred to as $Cu(II).3H_2O$
     - simply referred to “hydrated copper ion complex”

   - It takes “colliding” with 3 different water molecules to form the “hydrated copper ion complex” or $Cu(II).3H_2O$. We can think of it as three stages going from $Cu(II).H_2O$ with one water molecule, to $Cu(II).2H_2O$ with two water molecules, to $Cu(II).3H_2O$, the final form with three water molecules attached.

Activity #1: Modifying the Model Further – 20 min

2. **Create hydrated copper ions**
   - Have students open and remix their modified model from Lesson 3.
   - Pose the goal of this activity, to implement the formation of the intermediary ionic compounds up leading to the hydrated copper ion $Cu(II).3H_2O$.
   - Ask students for suggestions on how this task might be approached given the StarLogo Nova tools and techniques they know of. [Hint: new breeds can be formed upon collision.]
   - If necessary, guide students in sketching out the model design using the Model Design Form.

- Students will need to add 3 additional breeds, one for each of the hydrated copper ions: Cu(II).H_2O, Cu(II).2H_2O, Cu(II).3H_2O. Refer to Lesson 3 on how to add new breeds.
- Remind the students to check the Workspace area after they add the new breeds. Did new pages/tabs appear?
- Write the collision procedures for each of the intermediate ions, such that when a copper collides with a H_2O it becomes a Cu(II).H_2O, then when a Cu(II).H_2O collides with a H_2O it becomes a Cu(II).2H_2O, and finally, when a Cu(II).2H_2O collides with a H_2O it becomes a Cu(II).3H_2O.
- Remind student to check that they add the new collisions in the correct pages corresponding to the intermediary ionic compounds.

3. Turn the solution blue

- Review that something special happened as the copper ions became fully hydrated. The solution turned blue! We are going to mimic this phenomenon in the model.
- We are going to change the code within the collision blocks to create the agents with their own traits (specifically color):

  Cu(II).H_2O: Shape is sphere, color is cyan and size is 1
  Cu(II).2H_2O: Shape is sphere, color is sky blue and size is 1
  Cu(II).3H_2O: Shape is sphere, color is blue and size is 1

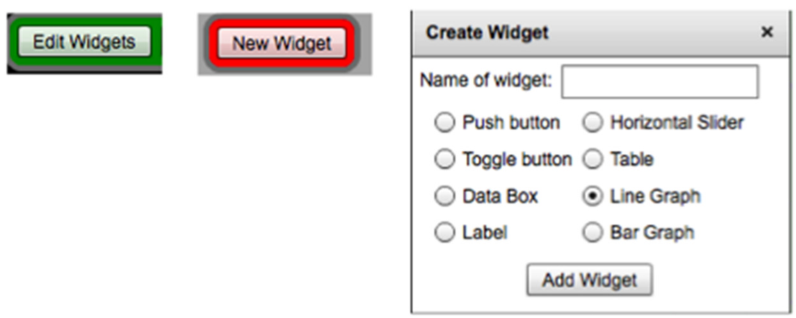
Teaching Tip *It is possible to drag a selection box around a group of blocks on one page, and "copy and paste" them to a new page. This is a real time-saver.*

- In the copper breed page, we create Cu(II).H_2O and change the color of the agent to cyan.

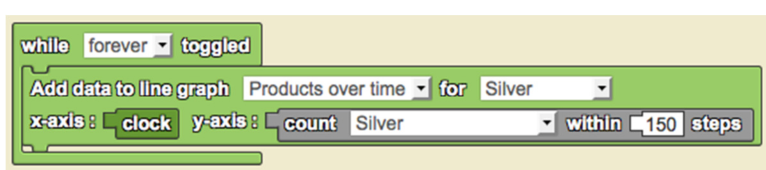
- Make similar collision blocks for the breeds Cu(II).H_2O and Cu(II).2H_2O and set the color of the new agent according to the specifications above.
- Check your code and test your model. Did something get changed? Does the model execute correctly?
- Ask the student what is missing from the code. Did they remember that these new agents are ions diffused in water? [Hint: They need to add a Wiggle Walk procedure to make the agents appear to be moving randomly.]

Activity # 2: Running Experiments – 15 min

4. **Characterizing rates of reactions**
   - The rate of reaction is how fast the product is made or reactants consumed.
   - Let's add some instrumentation so we can graph how fast the products are made.
   - In order to collect and visualize quantitative data we need to add a line graph in StarLogo Nova. The graph will collect data on the time elapsed since the model started running and the cumulative number of products produced over time.
   - With this information we will be able to compare patterns in the collected data.
   - For this model, what products do we want to monitor?
   - Let's create a new line graph called "Products produced over Time."
   - Demonstrate how to create a line graph using the slide presentation or StarLogo Nova.

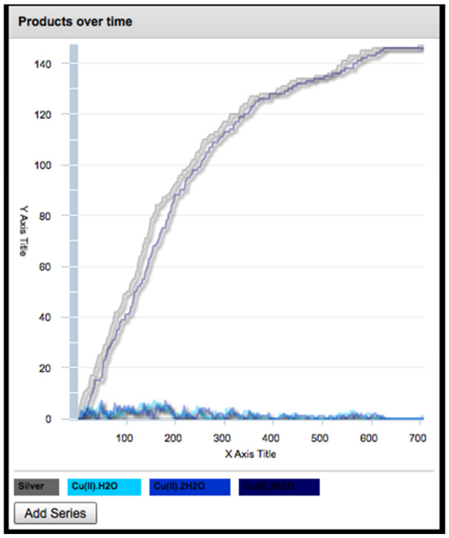


   - Drag the line graph off to the side of Spaceland.
   - Add new series to the graph by double clicking on New Series and changing the name and line color. For example,
     - Create a new series called "Silver" then select gray as its line color.
     - Create a new series called "Cu(II).1H2O" then select cyan as its line color.
     - Do the same for the other products you want to monitor.
   - Finally, click "Edit Widgets" to leave editing mode and return to play mode.
   - Next, we want "The World" to update the line graph each time through the forever loop, so we need to add a while forever toggled command to the page labeled "The World."
   - Notice that we need the "clock" along the x-axis and the count of agents of different breeds on the y-axis. We can get the count of agents with different characteristics using the count command. Since the whole Spaceland is less than 150 steps square, saying "within 150 steps" will get us the number of turtles that fit this criterion across all of Spaceland. See the example below.



   - Add in similar "Add data to line graph" command blocks to the "while forever toggled" loop for each of the other products you would like to monitor in the line graph.

Test your model



- Does your line graph work? [If not, save the model and return to your galleries by clicking on "my profile." Select and reopen the model.]

- What patterns can you now see that were difficult to see without a line graph?
- In our current model, various factors may impact the speed at which the product is made.
- One is the availability of reactants. Using the Experimental Design form, design an experiment to determine the impact of the availability of reactants on the rate of production.
- Ask students to compare their results of their experiments and suggest reasons why the shape of the products curve is what it is.

Wrap-Up – 5 min

5. Using computer models in scientific investigations.
   - How is this computer model helping in figuring out the impact of availability of reactants and the rate of reactions in this experiment?
   - If time allows, have some students volunteer to present their models and point out any new learning/code they are proud of.

Assessment Questions

- What is an example of an ionic compound?
- Describe what happens to ionic compounds in solution.
- In the experiment we did today, what determines the rate of silver production?
- In your own words, describe the shape of the silver production curve and what caused it to have that shape.

Standards Addressed

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.
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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.
3D: Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

Practice 4: Analyzing and interpreting data
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.
4H: Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.

Practice 5: Using mathematics and computational thinking
5C: Create algorithms (a series of ordered steps) to solve a problem.

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.
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- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
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- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
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- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

PS1.B: Chemical Reactions
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy.

NRC Crosscutting Concepts

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1A: Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

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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.

5. Energy and Matter:
5A: Matter is conserved because atoms are conserved in physical and chemical processes.

6. Structure and Function
6A: Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.

7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

CSTA K-12 Computer Science Standards

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.
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CT	Modeling & simulation	2-10	Evaluate the kinds of problems that can be solved using modeling and simulation.
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.
CPP	Data collection & analysis	2-9	Collect and analyze data that are output from multiple runs of a computer program.
CPP	Programming	2-5	Implement a problem solution in a programming environment using looping behavior, conditional statements, logic, expressions, variables and functions.

Lesson 4 - Student Activity #1 Guide

Modifying the Model Further

Your Challenge: Alter your model to include the formation of hydrated copper ions. First you will need to create additional breeds Cu(II).H_2O, Cu(II).2H_2O, Cu(II).3H_2O

Copper in water forms a complex with 3 water molecules which makes the solution slowly turn blue as the complex Cu(II).3H_2O forms.

1. Start with modified model from Lesson 3
2. Remix the base model and change its name to include your name and your partner's name.

Reminder: Save and test your model every time you add a piece of code. Debug if needed. Save often.

3. In the Interface (Spaceland) add 3 additional breeds:

Cu(II).1H_2O
Cu(II).2H_2O
Cu(II).3H_2O

Hint: Refer to Lesson 3 on how to add new breeds.

Check the Workspace area. Did new pages/tabs appear?

4. Change the code using collision blocks to create the following agents with their own traits:

Cu(II).H_2O: Shape is sphere, color is cyan and size is 1. It is created when one copper nitrate agent collides with one water molecule.
Cu(II).2H_2O: Shape is sphere, color is sky blue and size is 1. It is created when one Cu(II).H_2O agent collides with one water molecule.
Cu(II).3H_2O: Shape is sphere, color is blue and size is 1. It is created when one Cu(II).2H_2O agent collides with one water molecule.

The complex Cu(II).3H_2O is the final ionic product created in the solution turning the solution blue.

Tip: It is possible to drag a selection box around a group of blocks on one page, and "copy and paste" them to a new page. This is a real time-saver.

Reminder: Execute your model every time you add a piece of code. Debug if needed. Save often.

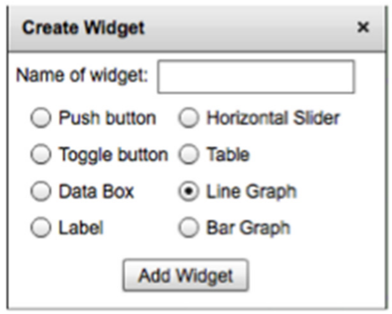
5. These new agents are ions moving about in water.
Set up a Wiggle Walk procedure for each agent on its own page.

Lesson 4 - Student Activity #2 Guide

Running Experiments

Your Challenge: Add instrumentation to your model so you can observe the rate of reaction then characterize the rate of reaction.

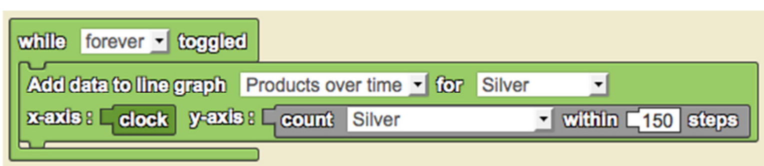
Start with modified model from Activity 1 and add a new widget, a line graph.



On the line graph window, add a new series to the graph by double clicking on New Series and changing the name and line color. For example,

- Create a new series called "Silver" then select gray as its line color.
- Create a new series called "Cu(II).1H2O" then select cyan as its line color.
- Do the same for the other products you want to monitor.

Finally, add the corresponding commands to the World's page to update the line graph as time advances (clock tick).



Use the experimental design form to design and document your experiment. Try to determine the impact of reactant availability on the rate of reaction (production of products).

What do you observe?
Did the rate of the reaction increase as the number of reactants increased? Or visa versa?

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?
Prediction
What effect do you think the changes you make will have on the model?
Data Collection
What data will you collect?
Data Analysis
How will you analyze your data? (i.e. look for patterns, compare final values, look at the graph)
Interpretation
What is the answer to your question? How does the analysis of your data help you answer your question?

4

Lesson 5

Factors that Impact the Rate of a Chemical Reaction

50 minutes (1 day)

Lesson Overview

In this lesson students will make modifications to the model and run experiments to examine the effect of temperature on the rate of a chemical reaction.

Teaching Summary

Getting Started – 10 minutes

1. Availability of reactants as a limiting factor

Activity #1: Factors Impacting the Rate of Reaction – 15 minutes

2. Mixing – the simulation of movement
3. Step size – the simulation of kinetic energy

Activity #2: Running Experiments – 15 minutes

4. Impacts of mixing or step size

Wrap-Up – 10 minutes

5. Sharing results and conclusions

Lesson Objectives

The student will:

- ✓ Review findings on the rate of reaction from the last lesson [LO16]
- ✓ Learn how agent movement can impact outcome in simulations [LO17]
- ✓ Learn to simulate kinetic energy in an agent-based model [LO18]
- ✓ Run experiments to determine how kinetic energy impacts the rate of chemical reaction [LO19]
- ✓ Become familiar with rate of a reaction and kinetic energy effect [LO20]

Teaching Guide

Materials, Resources and Preparation

For the Students

- StarLogo Nova modified model from Lesson 4
- Project Design Form

For the Teacher

- Computer and projector
- Slide presentation document
- StarLogo Nova modified model from Lesson 4

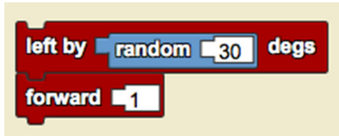
Getting Started - 10 min

1. **Availability of reactants as a limiting factor in the rate of chemical reaction**
   - Discuss the shape of the silver production curve in the last lesson.
   - Discuss how, when the resources are limited, there are fewer to react and thus the reaction is slower.
   - Next we are going to examine other factors that can impact the rate of chemical reaction.

   Extension: If students have already completed the "Ecosystems" module, make the connection between a population growth curve in an ecosystem when there is a carrying capacity and this curve we see in the production of silver. This is an example of a negative or balancing feedback loop.

Activity #1: Factors Impacting the Rate of Reaction – 15 min

2. **Mixing – the simulation of movement**
   - Have students open and remix their modified model from Lesson 4.
   - Pose the goal of this activity, to examine the impact of different movement in the model of the chemical reaction.
   - Ask students for suggestions on how this task might be approached given the StarLogo Nova tools and techniques they know of. [Hint: Wiggle walk can be altered to make agents walk in circles, wavy lines, or straight lines.]
   - If necessary, guide students in sketching out the model and experimental design using the Project Design form.
   - Students will need to manipulate the wiggle walk turn radius and bias. Discuss the mathematics involved, referring back to the Dice and Data activity from Module 1. Bias occurs when one direction is more likely than another. For example, a strong right bias can cause agents to walk in clockwise circles.
   - When agents walk in tight circles, there is not much mixing, whereas if agents walk mostly in a straight line, they tend to walk across SpaceLand.



- Compare the following three walks and determine what trail they would produce if repeatedly executed (in a forever loop).

3. **Step size – the simulation of kinetic energy**
   - We can simulate the kinetic energy of an atom or molecule by changing the number of forward steps it takes, from 1 to 2 to 3. By increasing the number of forward steps it takes, we are increasing the speed of the agent. In the real world, this is usually accomplished by increasing the temperature of the reaction. This increase in kinetic energy of reactants causes the rate of the reaction/speed to increase. In other words, the reactants are consumed faster.
   - Have students open and remix their modified model from Lesson 4.
   - Pose the goal of this activity, to examine the impact of different movement in the model of the chemical reaction.
   - Allow students some time to experiment informally with the step size the agents take.

Activity # 2: Running Experiments – 15 min

4. **Impacts of mixing or step size**
   - Starting with modified model from Activity 1 or 2 above, have the students focus on an experimental design.
   - Guide students in sketching out the model modifications and experimental design using the Project Design form.
   - Run experiments at different kinetic energies or different movement (wiggle walks).
   - Capture data on the rate of reaction as seen in the production of products.
   - Remind students that in their experimental designs, the initial amount of copper and silver nitrate should remain the same throughout the experiment.
   - Run multiple trials of the experiment. For example, if experimenting with different step sizes, you may first run the experiment with forward step size set to 1 and record the time when about **half the copper** is used up. Since we are starting with 150 copper agents, click the forever button to stop the simulation when the copper count goes down to about 75 atoms. Run this same experiment 5-10 times if possible before changing the step size to 2, then 3. [Note to teacher: step sizes of greater than 3 will not work in this model. See teaching tip below.] In this experiment, students may observe that the reaction arrives at the half point faster when the kinetic energy increases.

     Teaching Tip *This simulation will not work for a number of steps over three because the width of the copper bar is 3 agents wide, and the agents would jump over the bar if the forward step was higher than 3. There is a solution, but it would require adding a repeat loop outside the Wiggle Walk.*

Wrap-Up – 10 min

5. **Sharing results and conclusions**
   - Have students discuss their experiments and conclusions with another pair.
   - Have students discuss whether their results were in conflict or agreement with the findings of the other pair.

Assessment Questions

- What are some factors that impact the rate of reaction?
- How would you design an experiment to determine the impact of one of the factors?
- How was an increase in kinetic energy simulated in this lesson?
- Describe a feedback loop in the chemical reaction studied.

Standards Addressed

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.
1B: Ask question to identify and/or clarify evidence and/or the premise(s) 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.
1E: Ask questions that require sufficient and appropriate empirical evidence to answer.
1F: Ask questions that can be investigated within the scope of the classroom, outdoor environment, and based on observations and scientific principles.
1G: Ask questions that challenge the premise(s) of an argument or the interpretation of a data set.

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.
3D: Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

Practice 4: Analyzing and interpreting data
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.
4H: Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.

Practice 5: Using mathematics and computational thinking
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
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.
6D: Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
6E: Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.
6G: Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.
6H: Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

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 Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

PS1.B: Chemical Reactions
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change. Some chemical reactions release energy, others store energy.

NRC Crosscutting Concepts

1. Patterns:
1A: Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
1D: Graphs, charts, and images can be used to identify patterns in data.

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

3. 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.
3C: Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.
3E: Phenomena that can be observed at one scale may not be observable at another scale.

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.

5. Energy and Matter:
5A: Matter is conserved because atoms are conserved in physical and chemical processes.

6. Structure and Function
6A: Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.

7. Stability and Change:
7A: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.

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	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	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	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.
CPP	Data collection & analysis	2-9	Collect and analyze data that are output from multiple runs of a computer program.
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.

Project Design Form

Name(s): ______________________________ Date: ____________

Model name: ____

As you create a computer model of a scientific phenomena, use this form to help you organize your thoughts and develop the model from start to finish.

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?
What question do you seek to answer?
How will it be modeled? What abstractions are used?
Who are the Agents? What is the Environment? What are the Interactions? *How much time will the main forever loop represent? (minutes? days? months? years?)* *What are the parameters of interest?*

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?
Prediction
What effect do you think your variables will have on the model?

Data Analysis
How will you analyze your data?
Interpretation
How does the analysis of your data help you answer your question?
Going further
If you had more time, what further changes would you make to your model?

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	

Model Observation Form

Name(s): ____Date: __________

Model name: ____

Abstractions
Who are the Agents? What is the Environment? What are the Interactions? *How much time does the main forever loop represent? (minutes? days? months? years?)* *What are the variables of interest?*
Automation
What happens each time through the forever (or main) loop?
Assumption(s)
What real life elements or behaviors were left out of this model?
Analysis
What patterns did you observe? Do these patterns occur in real-life?

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?
Prediction
What effect do you think the changes you make will have on the model?
Data Collection
What data will you collect?
Data Analysis
How will you analyze your data? (i.e. look for patterns, compare final values, look at the graph)
Interpretation
What is the answer to your question? 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?
What do the agents represent? *What does the space or environment represent?* *What are the Interactions?* *How much time does the main forever loop represent? (minutes? days? months? years?)* *What are the assumptions made? What real life elements or behaviors were left out of this model?*
How will it be modeled?
What happens when simulated time advances?

Project Design Form

Name(s): ______________________________ Date: ______________

Model name: ____

As you create a computer model of a scientific phenomenon, use this form to help you organize your thoughts and develop the model from start to finish.

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?
What question do you seek to answer?
How will it be modeled? What abstractions are used?
Who are the <u>Agents</u>? What is the <u>Environment</u>? What are the <u>Interactions</u>? *How much time will the main forever loop represent? (minutes? days? months? years?)* *What are the parameters of interest?*

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?
Prediction
What effect do you think your variables will have on the model?

Data Analysis
How will you analyze your data?
Interpretation
How does the analysis of your data help you answer your question?
Going further
If you had more time, what further changes would you make to your model?

Scientific Practices with Computer Modeling & Simulation

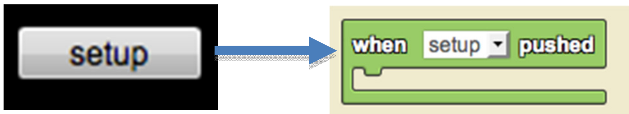
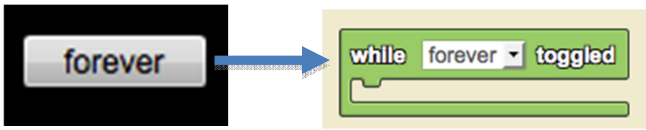
Name: ____ Date: ________________

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

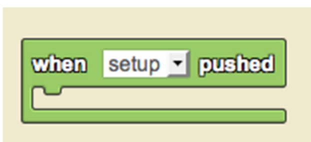
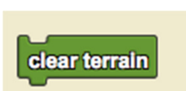
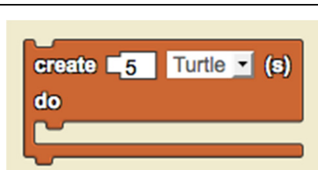
Practices:	
Asking questions and defining problems	
Develop and use a model	
Plan and carry out an investigation	
Analyze and interpret data	
Use mathematics and computational thinking	
Construct explanations and design solutions	
Engage in argument from evidence	
Obtain, evaluate, and communicate information	

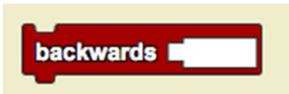
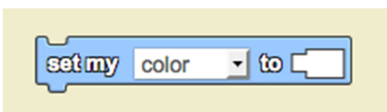
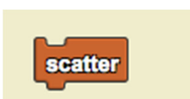
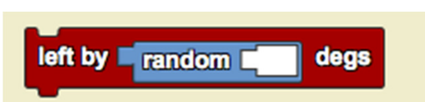
StarLogo Nova Blocks introduced in Module 1 Lesson 1

Event Handling

	When “setup” (on the interface) is clicked, code blocks placed inside this block will run once.
	When “forever” (on the interface) is clicked it runs code blocks inside this block until “forever” is clicked again.

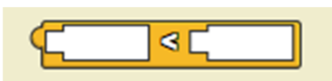
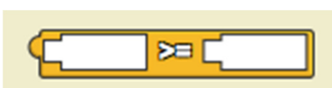
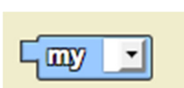
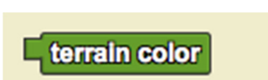
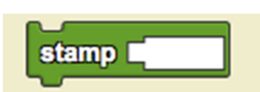
StarLogo Nova Blocks introduced in Module 1 Lesson 2

	Executes commands when the push button widget is pressed. Widgets can be created using the *Edit Widgets* feature.
	Executes commands when the toggle button widget is turned on. When the toggle button widget is turned off, nothing occurs. Widgets can be created using the *Edit Widgets* feature.
	Removes all stamping or drawing modifications done to the terrain.
	Adjusts the pen tool. If the pen is down, the agent stamps the terrain at each position as it moves along the terrain. If the pen is up, the agent does not stamp the terrain.
	Deletes all agents.
	Creates a specific number of agents of the specific breed. Attach other blocks to specify traits and properties of these agents. Additional breeds are created in the interface.

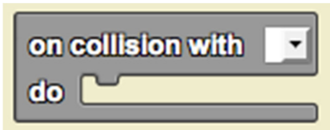
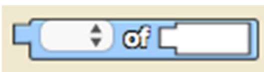
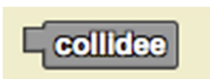
	Moves an agent forward by a certain number of steps.
	Moves an agent backwards by a certain number of steps.
	Rotates an agent left by a certain number of degrees.
	Rotates an agent right by a certain number of degrees.
	Sets the color of an agent by picking from a list of standard colors or by choosing a color at random.
	Sets an agent's trait to a particular value.
	Places agents in random positions on the terrain.
	Returns a random integer from 0 to the input but NOT including the number entered (non-inclusive).
	Random can be used in place of a number anywhere a number would fit. In this example, instead of having a constant turn angle, an agent following this command would turn different amounts each time this command was executed.

StarLogo Nova Blocks introduced in Module 1 Lesson 3

	Carries out the specific procedures if the condition is true. This conditional block ONLY runs the main block IF the condition after the "if" is met.

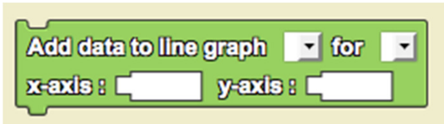
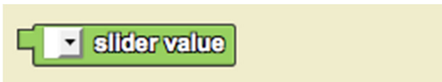
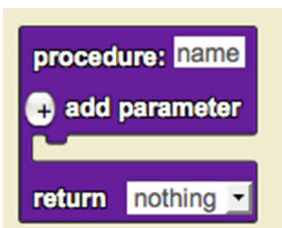
	Carries out the specific procedures if the condition is true. Otherwise (if the condition is false) carries out procedures in the second block.
	Determines whether the two inputs are equivalent and returns true or false. Usually used after an “if” in a conditional block.
	Determines whether the two inputs are unequal and returns true or false. Usually used after an “if” in a conditional block.
	Determines if the first input is less than the second input and returns true or false. Usually used after an “if” in a conditional block.
	Determines if the first input is greater than the second input and returns true or false. Usually used after an “if” in a conditional block.
	Determines if the first input is less than or equal to the second input and returns true or false. Usually used after an “if” in a conditional block.
	Determines if the first input is greater than or equal to the second input and returns true or false. Usually used after an “if” in a conditional block.
	Returns an agent’s trait.
	Returns the color of the terrain the agent is currently on.
	Colors a grid square on the terrain in the agent’s current position.
	Colors a circle on the terrain in the agent’s current position.

StarLogo Nova Blocks introduced in Module 1 Lesson 4

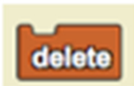
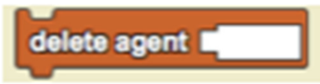
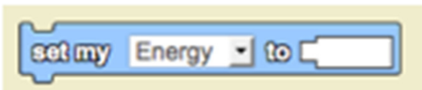
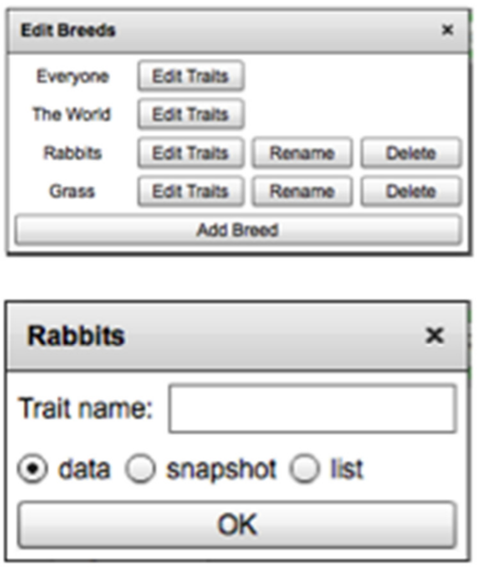
	Specifies a series of actions to be executed after a collision between two breeds. If the two breeds are the same, each agent in the collision must perform the same action after the collision. If the two breeds are different, each agent in the collision can be given different commands.
	‘Trait of’ block is used to specify which trait of the agent it should check for (X, Y, Z, color, size, heading, shape or a trait that you have added)
	Specifies the other agent in the collision.
	Counts the number of agents of a specific breed in a given radius with a specific trait. This can be used to detect other agents that are nearby and have specific traits.

StarLogo Nova Blocks introduced in Module 1 Lesson 5

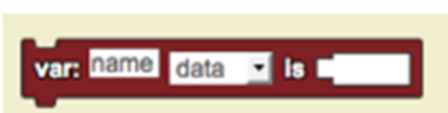
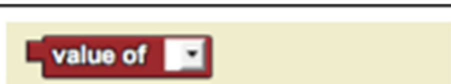
	Push this button to get access to the widgets. Widgets are user-input and output elements like buttons, data output, tables, and graphs.
	This button appears AFTER clicking “Edit Widgets.” Select the type of widget you’d like to add. Give the widget a name. “Push button” – a button that runs once or pops up after being pushed “Toggle button” – a button that stays on until turned off “Data Box” – a data display box “Label” – a place for the user to enter descriptive text “Horizontal Slider” – a slider to control the value of a variable “Table” – a configurable data table with rows and columns “Line Graph” – a configurable line graph with one or more lines “Bar Graph” – a configurable bar graph with one or more bars

	After creating a data box, use this block to set its value to a number or a color.
	After creating a line graph widget and naming a series (on the interface), this block adds data to the line graph. It will plot the point x, y based on the blocks that you provide. Usually these values are variables that you have defined.
	After setting up a slider widget, you can use the value of the slider in your code using this block.
	Returns the current value of the clock. This can be used when you plot data vs. time.
	Changes the value of the clock. This block is particularly useful for resetting the clock on setup.
	Creates a procedure with a name and a list of commands. Procedures are useful for organizing code into reusable modules. Some procedures just make changes to the agents and the world and return nothing. Other procedures calculate values and return the result.
	Calls the procedure selected.

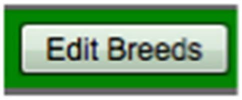
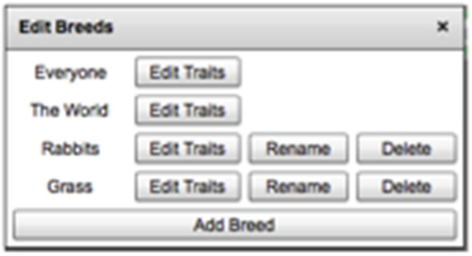
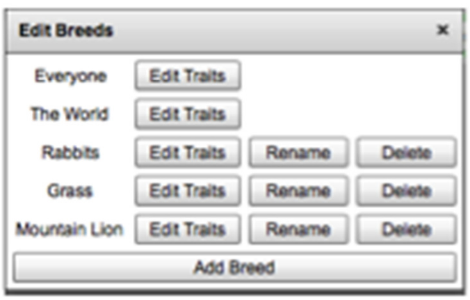
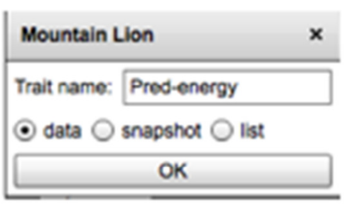
StarLogo Nova Blocks introduced in Module 3 Lesson 2

	The delete block deletes the current agent.
	The delete agent block deletes the agent referenced.
	The set my (trait) to (value) block is used to set the current agent's trait to some value. In this case, Energy is a new trait created by the user.
	The user created the Rabbits trait "Energy" using the Edit Breeds panel. Click on "Edit Breeds" in the Spaceland panel. Then click on the "Edit Traits" button next to Rabbits. From here you can give an agent a new trait by clicking on "Add Trait" Then specify a trait name and type. The type can either be "data", "snapshot", or "list". For Energy, we want to store a value or number, so choose "data" and click OK. In computer science, this is called declaring a variable. The variable in this case is a number variable called "Energy".

Optional StarLogo Nova Blocks to use in Module 3 Lesson 2

	Creates a variable of the type indicated and sets its value.
	After creating a variable, this block sets the value.
	Returns the value of an existing variable.

StarLogo Nova Blocks introduced in Module 3 Lesson 3

	Use the Edit Breeds button in the Spaceland area to create a new breed.
	Click on "Add Breed" to add a new breed.
	In the "New Breed" dialog box, give the breed a name and press OK.
	You will see the Breed on the next panel. (We added the breed called "Mountain Lion". Next, click Edit Traits next to the new breed label for "Mountain Lion"
	Create a new trait (or variable) for the Mountain Lion breed called "Pred-energy".
	The set my (trait) to (value) block is used to set an agent's trait to some value. In this case, the Mountain Lion's Pred-energy is a being set to a starting value. This is called "initializing" the variable.

CS Concepts introduced in Module 1 Lesson 1

CS Concept: Event Handling

What is an event?	An event is an action or occurrence detected by a computer program. Events can be user actions, such as clicking a mouse button or pressing a key.
What does it mean to handle an event?	To "handle" an event is to respond to an event. An event handler is typically a piece of computer code that process actions such as keystrokes and mouse movements. In StarLogo Nova, each breed can react to events independently. For example, when the "forever" button is pushed, the rabbits can eat, the grass can grow, and the wolves can hunt.

CS Concepts introduced in Module 1 Lesson 2

CS Concept: Instructions / Programs

What is an instruction?	A computer instruction is a simple command given to a computer in a computer language. Computer instructions are called "commands" in StarLogo Nova.
What is a computer program?	A computer program is a sequence of instructions that a computer runs or "executes."

CS Concept: Iteration / Looping

What is an iteration?	An iteration is a repetition of a process. Each iteration of a loop is a single time through the loop.
What is a loop?	A loop is a type of instruction that performs a set of enclosed instructions over and over again. There are different types of loop instructions such as conditional loops, iterated loops, and infinite loops.

CS Concept: Public and Private Repositories / Galleries

What is a public gallery?	A public gallery is a space where others can view your projects.
What is a private gallery?	A private gallery is a space where you can store your projects and only you can see them.

CS Concept: Remixing

What does it mean to REMIX a project?	Remixing a project means that you are copying an existing project (either one you have created or one someone else created) and are saving a version of it as your own.
Is it cheating to REMIX a project?	No, if you acknowledge that you have remixed from another source and document what you added, changed, or removed to make it your own, it is not cheating. The important thing is to learn from other projects.
Why remix?	We can learn and build off of each other's projects. Remix culture allows and encourages combining and/or editing existing materials to produce a new product. Remixing is a way to learn from others, improve upon, change, integrate, or otherwise repurpose existing work.

CS Concept: Random Numbers

What is a random number?	A random number is a number that appears to have been selected randomly from a set.
What are random numbers used for?	We generate and use random numbers any time we want to simulate a chance occurrence or chance behavior. For example, when two agents meet, there might be a chance that one passes a disease to the other. Say there is a 40 percent chance of transmission. Instead of rolling a 10-sided die, we might ask for a random number between 1 and 10. Then if we get a 1, 2, 3, or 4, which should happen 40 percent of the time, the disease would spread from one agent to the other.

CS Concepts introduced in Module 1 Lesson 3

CS Concept: Conditional Instruction

What is a conditional instruction?	A conditional instruction is a type of instruction that may, when executed by a computer, cause the computer to branch or begin execution of a different instruction sequence. Conditional instructions contain Boolean expressions. Depending on whether a Boolean expression evaluates to true or false, a different sequence of instructions is executed. IF/THEN and IF/THEN/ELSE are examples of conditional instructions.

CS Concept: Boolean Expressions

What is a boolean expression?	A Boolean expression is a mathematical expression that evaluates to one of two values (usually true or false).

CS Concept: Nesting Conditionals

What does it mean to nest conditionals?	When we layer conditionals within other conditionals we call that "nesting." Nesting of conditionals can be used to implement more complicated logical constructs.

CS Concept: Algorithms

What is an algorithm?	An algorithm is a step-by-step set of instructions for performing calculations or behaviors. Algorithms are used for problem solving, calculation, data procession, and automated reasoning,

CS Concepts introduced in Module 1 Lesson 4

CS Concept: Collision Detection

What is collision detection?	Collision detection is the determination of whether or not virtual objects are touching or overlapping.

CS Concept: Model

What is model?	A model is a representation of a system, process or object.

CS Concept: Simulation

What is simulation?	Simulation is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors/functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time.

CS Concepts introduced in Module 1 Lesson 5

CS Concept: Widgets

What is a widget?	A widget is a user interface element. Typically, a widget gets input from the user or displays output to the user. In StarLogo Nova, the user interface widgets include buttons, sliders, data boxes, graphs, and charts.

CS Concept: Variables

What is a variable?	A variable is a container for a value. The value held in the variable can be initially set and later changed. Agent variables can be created using edit breeds. Global variables are created using add widgets, specifically, adding data boxes and sliders.

CS Concepts introduced in other Modules

CS Concept: Abstraction and Decomposition

What is abstraction?	Abstraction is the process of making something easier to understand by ignoring some of the details that may be unimportant. This allows you to focus on what is important at this time to you. This doesn't mean that what you ignore is not important. It's just not important to what you're doing at that moment. Computer scientists talk about the levels or layers of abstraction.
When do you use abstraction?	In modeling, we use abstraction when we decide what we want to include in our model and what can be left out.

CS Concept: Data

What are data?	Data, in modeling and simulation, usually refers to numbers that are generated by running our model. Data (plural) can be numbers such as the number of rabbits in a population over time.
How do we collect it?	We collect and visualize data using the graphs and tables in StarLogo Nova. We can see the changing values of different variables over time. Later, we will be able to output the data to a file.

CS Concept: Data Analysis

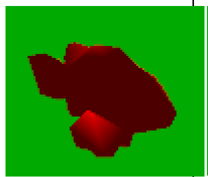
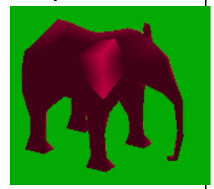
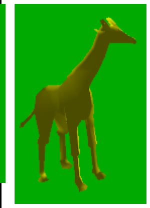
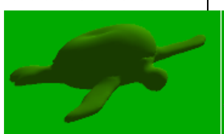
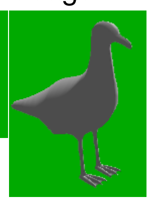
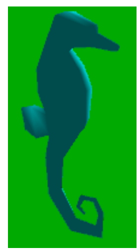
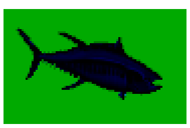
What is data analysis?	Data analysis is the process of examining data to find trends or patterns. We use mathematical descriptions such as mean, median, and mode to describe characteristics of data sets. We can also use terms such as linear, non-linear, exponential, and logistic to describe patterns of change in time series data.

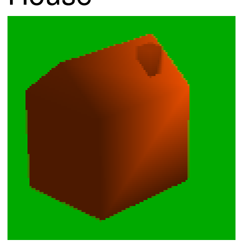
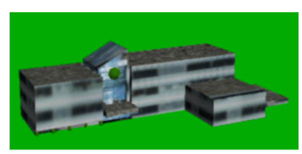
CS Concept: Breeds, Agents, and Traits

What is a breed?	A breed is a prototype for an agent. All agents inherit their type and traits from a breed. Breeds are defined using the “edit breeds” panel. After naming the breed, new traits can be added. When we create an agent, we must specify which breed or class of agent it is derived from.
What is an agent?	An agent is a virtual individual or object implemented in code. Agents have variables or traits that hold their characteristics or state. Agents also have behaviors, usually implemented as procedures.
What is a trait?	A trait is an agent variable. Agents have traits that they are created with by default such as color, breed, shape, and size. New traits can be added using the "edit breeds” panel.

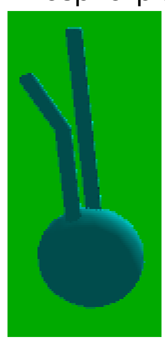
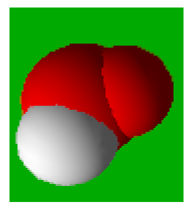
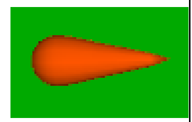
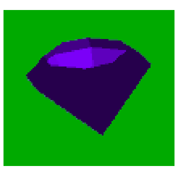
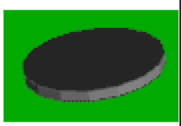
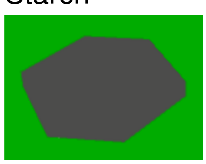
CS Concept: Decomposition and Procedures

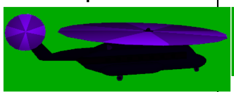
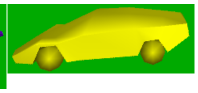
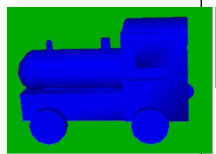
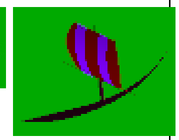
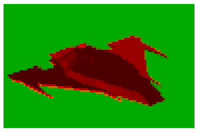
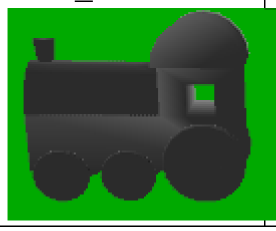
What is decomposition?	Decomposition is the breaking down of a big problem into a set of smaller problems or breaking a process into different smaller steps.
What is a procedure?	Procedures are stacks of commands that perform a particular function and can be given a name. Procedures must be “called” or “invoked” to execute or run. When we decompose a problem into smaller problems, sometimes the solutions to the smaller problems are implemented in procedures.

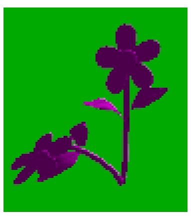
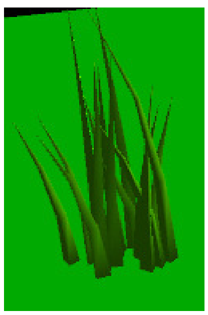
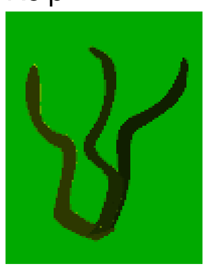
Animals					
Angel-fish 	Bear 	Clownfish 	Dog 	Elephant 	Giraffe 
Killer-whale 	Lion 	Lioness 	Otter-float 	Otter-stand 	Penguin* 
Raccoon 	Sea-turtle 	Seagull 	Seahorse 	Shark 	Simple Turtle 
Tuna 	Turtle2* 	Urchin 	Dragon* 	Mantaray 	

Buildings			
Castle* 	Freecastle* 	House 	Hospital* 

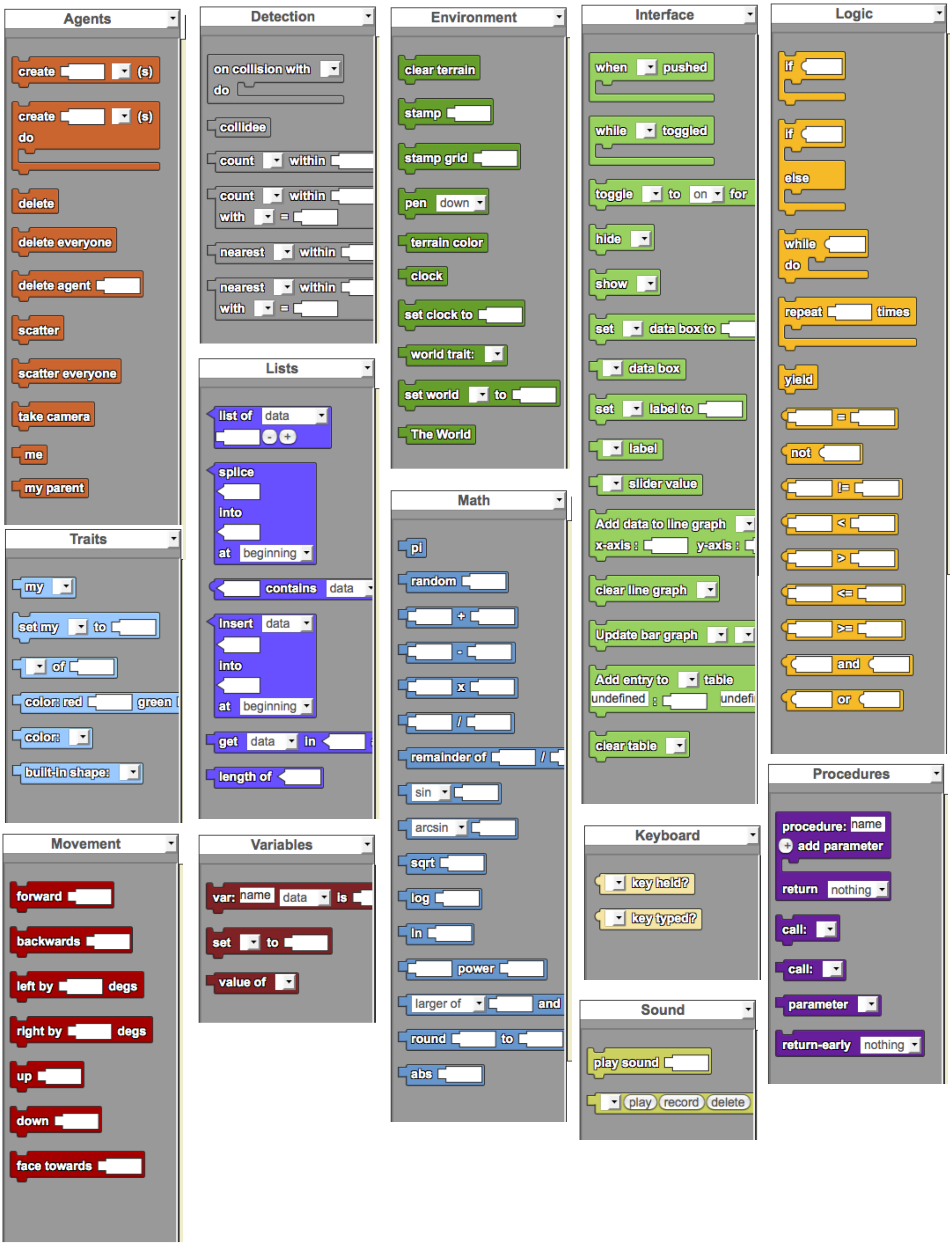
People					
fireman* 					

Objects					
Carrot (need to go up by 2 to see it all) 	Enzyme 	Hydrant 	Phospholipid 	Water-molecule 	Fireball1 
Gem 	Coin-silver 	Coin2* 	Fireball2 	Fireball* 	Earth* 
Earth-Clouds* 	Moon* 	Starch 			

Vehicles					
Helicopter* 	Lambo 	Train 	Truck* 	Boat* 	Spaceship1 
Spaceship2 	Train_wood 				

Landscape					
Flower 	Grass 	Kelp 	Rock 	Tree* 	

* set color trait to “white” for original texture in these shapes

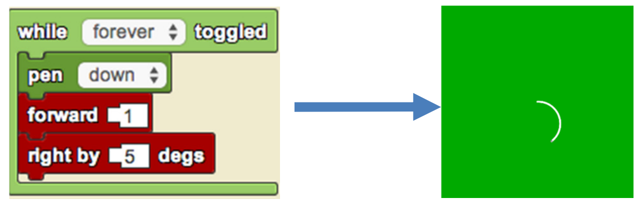

Agents
create (s)
create (s)
do
delete
delete everyone
delete agent
scatter
scatter everyone
take camera
me
my parent
Traits
my
set my to
of
color: red green
color:
built-in shape:
Movement
forward
backwards
left by degs
right by degs
up
down
face towards
Detection
on collision with
do
collidee
count within
count within
with =
nearest within
nearest within
with =
Lists
list of data
splice
into
at beginning
contains data
insert data
into
at beginning
get data in
length of
Variables
var: name data is
set to
value of
Environment
clear terrain
stamp
stamp grid
pen down
terrain color
clock
set clock to
world trait:
set world to
The World
Math
pi
random
+
-
x
/
remainder of /
sin
arcsin
sqrt
log
ln
power
larger of and
round to
abs
Interface
when pushed
while toggled
toggle to on for
hide
show
set data box to
data box
set label to
label
slider value
Add data to line graph
x-axis : y-axis :
clear line graph
Update bar graph
Add entry to table
undefined : undefi
clear table
Keyboard
key held?
key typed?
Sound
play sound
play record delete
Logic
if
if
else
while
do
repeat times
yield
=
not
!=
<
>
<=
>=
and
or
Procedures
procedure: name
add parameter
return nothing
call:
call:
parameter
return-early nothing

Math Basics for StarLogo Nova
Coordinates and Headings

Left and Right degrees turning: *Making your turtle turn while it is moving*

The movement blocks 'right by' and 'left by' are used to make your turtle agents turn while walking. The amount they turn is *relative* to where they are facing.

Thinking Challenge:
Look at the code to the right. What will happen if you have your turtles turn by a number larger than 5?

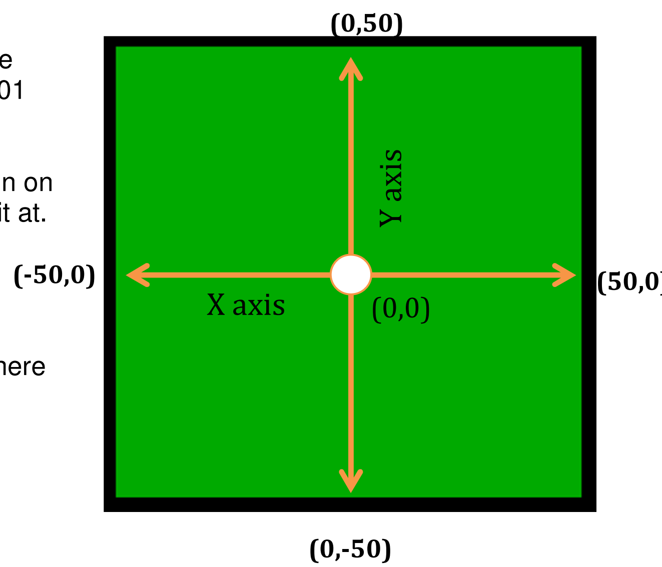


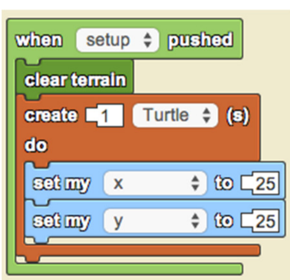
X & Y coordinates in Spaceland: *Placing your turtles on Spaceland*

This is the standard view of the area called 'Spaceland' and is the terrain where the programmed action will take place. There is 1 turtle that is created and the **default location for the turtle is (0,0). The default color and shape is a gray square.**

Spaceland is like a grid made up of patches. (0,0) is at the center of the plane. The plane is 101 patches wide and 101 patches tall.

As a programmer you can position an agent at any location on the plane by specifying what X and Y coordinate to place it at.



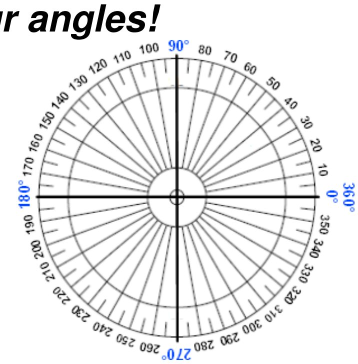


Thinking Challenge:

Look at the code to the left. Where on Spaceland will the turtle be created?

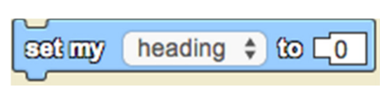
Getting your turtles to go in a <u>specific</u> direction: *know your angles!*

When turtles are created, they are facing out from the center. To have your turtles go in a specific direction you will need to set their heading, which is based on the degrees in a protractor. Notice the start of the circle is at 0 degrees, which also becomes 360 degrees after going around the circle. To go towards the top of Spaceland, the turtle would need to set its heading towards 90 degrees.



Thinking Challenge:
What will happen when you create 5 turtles that are separated by 2 steps forward (like in your Flower Turtle Project)? What direction does each of them face? How does it change with 10 turtles?

What will happen if you have your turtles set heading to 0 degrees using the blue traits block 'set my…'? In what direction will the turtles head?



Lesson 2 - Student Activity #2 Guide

Flower Turtles: Have your turtles paint a masterpiece!

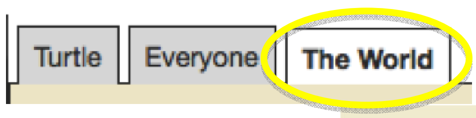
Your challenge is to make the turtles draw a flower pattern on Spaceland and to experiment with different kinds of turtle movement.

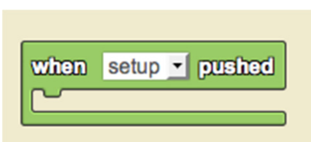
Note: Make sure to REMIX the project if you do any of the extensions.

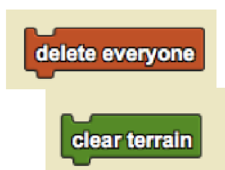
Guidelines: What your project needs to do

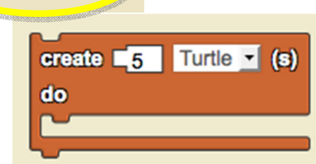
1. Start a new blank project.
2. Name it: Flower Turtles. If working in pairs, don't forget to put both partners' names in the project title.
3. **Create 5 turtles** that separate by 2 steps when the setup button is pressed.
4. **Have the turtles move and leave trails with their pens down** when the forever button is toggled.
5. When you are done, save and share your project.
6. If time, try some extensions.

In the World Page

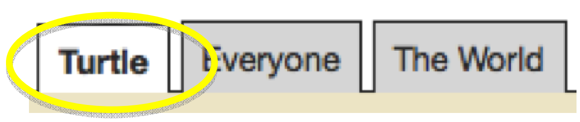








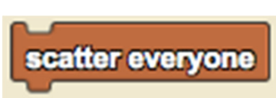
In the Turtle Page

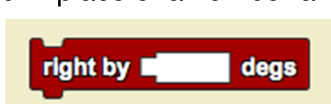


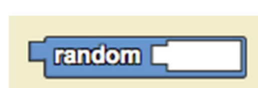
Extensions:

1- Try changing the number of turtles created and scattering them.

2- Experiment with adding a slight wiggle to the turtle's walk using the random command block. The random block can be used in place of a number anywhere a number could fit.







Lesson 3 - Student Activity #1 Guide

Name: ___________

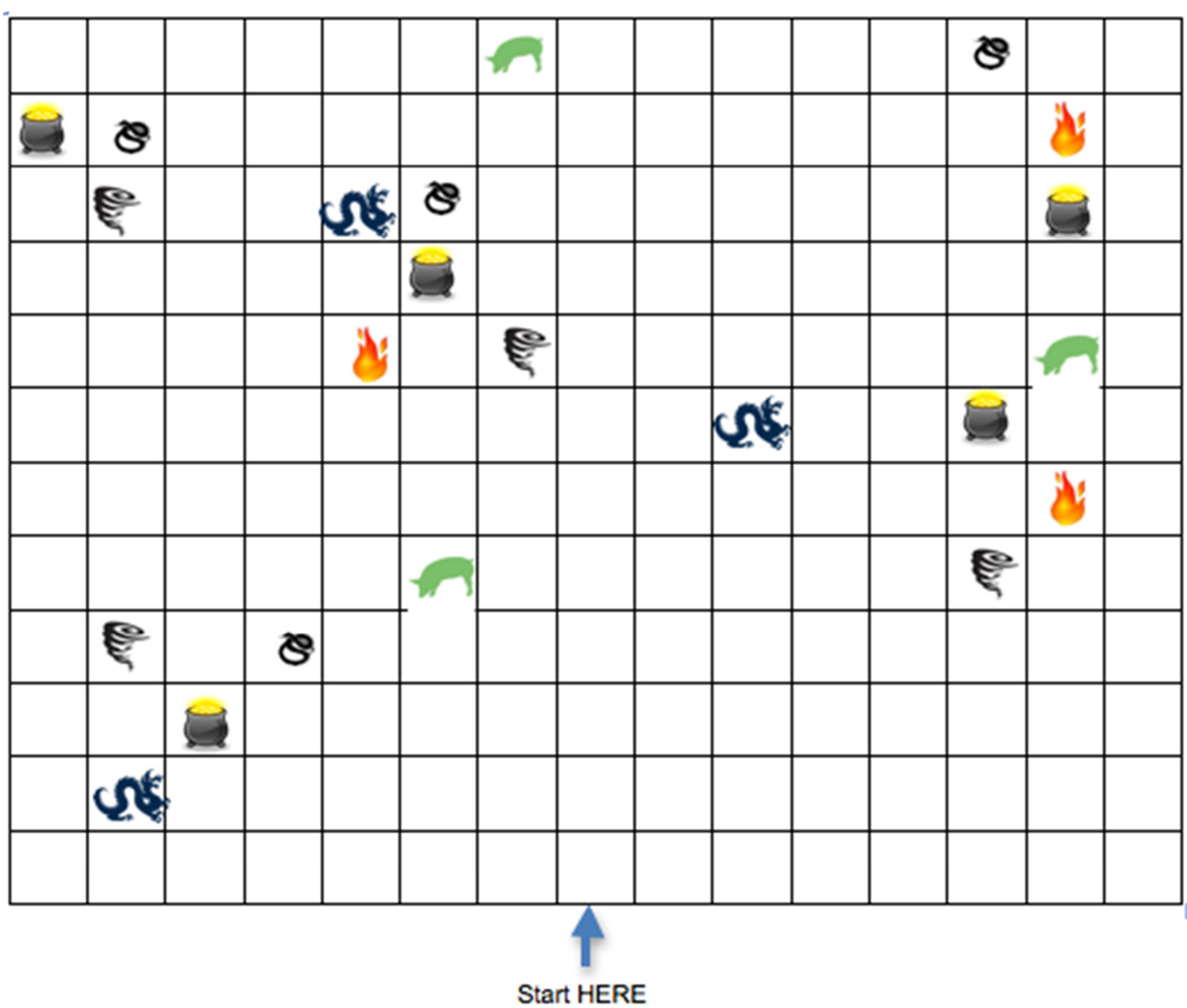
Trailblazer

Instructions and playing board

How to play: On the map, START at the designated position and heading in the direction of the arrow. Using a pencil, draw the path in the CENTER of squares. Pick up ALL the gold while avoiding the hazards, ending at START. Color the squares as necessary according to the following rules:

- **Take a step forward.**
- **If you are standing on a RED square, then turn right by 90 degrees**
- **If you are standing on a BLUE square, then turn left by 90 degrees**
- **If you are standing on a BLACK square, then turn right by 180 degrees**

Trade your map with a partner and figure out if following the landmarks lead you along the path to collect all of the gold while avoiding the hazards.



Lesson 3 - Student Activity #2 Guide

Bumper Turtles

- Start with the model "Bumper Turtles starter". (Teacher provides the link.)
- This starter model already has a button called "Paint Landmarks" and some coding associated with it.
- Click on the "Paint Landmarks" push button and see the program execute the code provided.

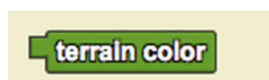
Your challenge is to make the turtles react to the landmarks created by the "Paint Landmarks" procedure, following the rules laid out in the Trailblazer activity.

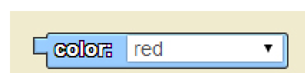
Note: DO NOT make changes to the "Paint Landmarks" procedure.

<u>**Guidelines**</u>**:** Have the turtles check the terrain color they are standing on.

1. Remix the "Bumper Turtles starter" model; add your name(s) to the title of the project.
   a. If working in pairs, don't forget to put both partners' names in the project title.
2. In the World Page, instruct your turtles to react to the landmarks according to the rules in the Trailblazer activity.
   a. Use logic blocks that evaluate the color of the terrain and tell the turtle how to turn.
3. When you are done, save and share your project.

The new command blocks, to be used in addition to the blocks you used in Lesson 1 and 2, are:





Extensions:
Change how the turtles react to the colors (not just a turn, but a new shape or color for the agent). Change the colors of the terrain stamps and make your turtle instructions match this new information.

Lesson 4 - Student Activity #1 Guide

Name ________________

Dice and Data: Chances Are and Wiggle Walk

Introduction

Probability plays a large role in models of complex adaptive systems. We'll be programming our agents to mimic the movement of creatures in the real world. There are also chance events that occur when agents interact, such as the passing of a contagion from one person to the other.

PART 1: "Chances Are"

Directions

- In your group, roll 1 die 50 times in a cup, while the partner marks down the results for all 50 rolls using the chart provided with the possible rolls (1 through 6).

For each roll of the die, record the outcome with a tic mark below next to the number rolled. After 50 rolls, sum up each row and record the sum in the column on the right.

1		Sum:
2		Sum:
3		Sum:
4		Sum:
5		Sum:
6		Sum:

Discussion:

What was the distribution of the results?

Was one number more common?

Why might that be?

Extension:

If time allows, pool all of the data from the class and see what the sums are across groups.

If you graphed this data as a bar chart, what would the graph look like? (Draw it below.)

PART 2: Wiggle Walk

Next imagine that you were going to roll two dice instead of one die and you will subtract the second number from the first number. Do you think we will still get a flat distribution (in which the probability of rolling each outcome would be the same)?

Directions

- Each group should designate a Student 1 and a Student 2, each with their own die.
- This time, roll 2 dice simultaneously and collect the data from 50 rolls.
- Students are to SUBTRACT the Student 1 die number from the Student 2 die number.
- Record the outcome on the activity sheet with a mark next to the sum of the dice rolled (some will be negative numbers). After 50 rolls, sum up each row of tic marks and record the sum in the column on the right.
- For instance, if student 1 rolls a three and student 2 rolls a six, 3 - 6 = -3, so you would put a tic mark in the -3 row.

Area for recording tic marks of subtracted numbers

5		Sum:
4		Sum:
3		Sum:
2		Sum:
1		Sum:
0		Sum:
-1		Sum:
-2		Sum:
-3		Sum:
-4		Sum:
-5		Sum:

Discussion:

What number gets created most often from the rolling and subtraction? Why?
Given this chart, what should be the most commonly created number? Why?

Extension:

If time allows, graph this data as a bar chart. What shape does the graph look like? (Draw it below.)

To understand this phenomenon, let's look at the underlying statistics:
We know that with one die we have equal probability of rolling a 1, 2, 3, 4, 5, or 6.

Fill in the chart below that shows the outcome of rolling two dice. The numbers down the first column represent the number rolled by Student 1; the numbers across the top represent the numbers rolled on the other die, by Student 2. Subtract the second number from the first number.

Student 2

Student 1

--	1	2	3	4	5	6
1	0					
2						
3						
4						
5						
6						

Discussion:
How many ways are there to make 2?
How many ways can you create a 0?
What about other numbers?
What is the most often-seen number in the matrix?
How many times is it seen?

Next, fill in the result of a left turn of random 6 followed by a right turn of random 6.

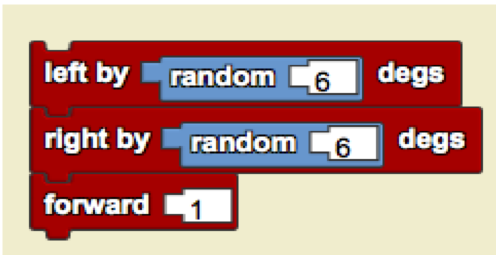
Right turn

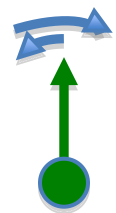
Left turn

--	1	2	3	4	5	6
1	0					
2						
3						
4						
5						
6						

Discussion:
How many ways are there to make 0?
How many ways can you roll a +2?
How many ways can you roll a -2?
What about other numbers?
What is the most often-seen number in the matrix?
How many times is it seen?

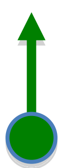
Finally, consider rolling two dice where one represents the degrees to turn to the left and the other die represents the degrees to turn to the right. That's similar to using a left turn random 6 followed by a right turn random 6, then taking a step forward.



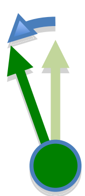


Turtle seen from above with initial heading.

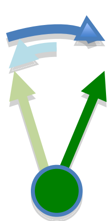
What is actually going on?



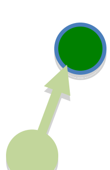
1. Agent has an initial heading.



2. Agent turns left by some random number of degrees between 1 and 6. In this case, it is 2 degrees. (Image not to scale)



3. Agent turns right by some random number of degrees between 0 and 5. In this case, it is 5 degrees, so the final heading is 3 degrees to the right of the original heading. (Image not to scale)

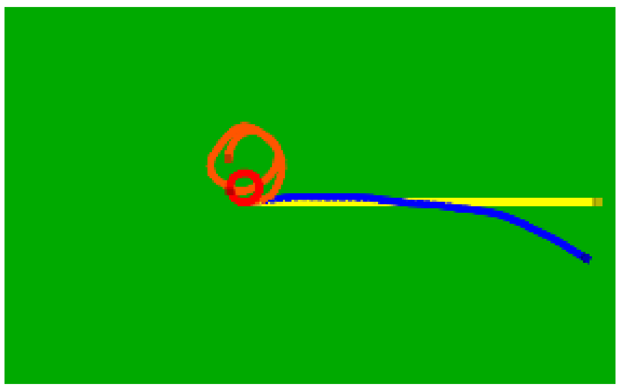


4. Agent takes one step forward at new heading. (Image not to scale)

In StarLogo Nova:

In StarLogo Nova, we use the random command to simulate the roll of a die.   Random 6 would give me the result of rolling a 60-sided die with numbers 1 through 6 on the sides. Random functions can also be used within other commands to implement random behavior.

Self-test:



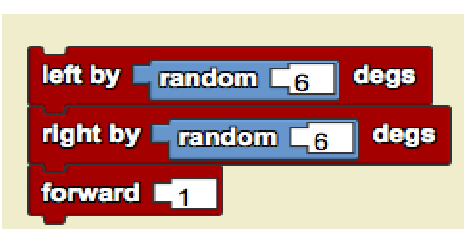
Match the command blocks a, b, c, and d with the path created by an agent following those blocks.

a.

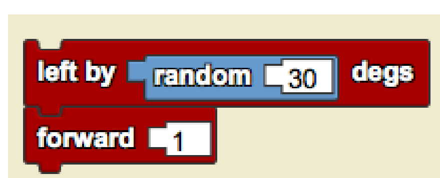

color: __________

c.


color: __________

b.


color: __________

d.


color: __________

Lesson 4 - Student Activity #2 Guide

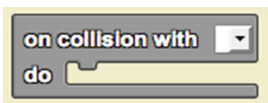
Name ___________________

Colliding Turtles

Introduction

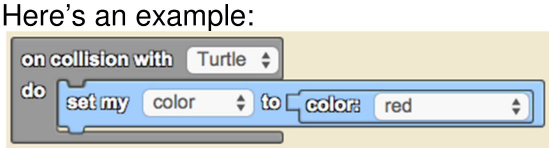
In this activity we are going to implement agents interacting with other agents upon colliding. Collisions occur when two agents bump into one another. (They do not need to be centered on the same patch, just touching.) This is different from Bumper Turtles; in Bumper Turtles, *agents were responding to colored patches in their environment*, not other agents.

We will use a collision block that looks like this. Use the pull-down arrow to select what type of object to collide with. Then put the commands that should run or execute when the collision occurs in the area below the notch.

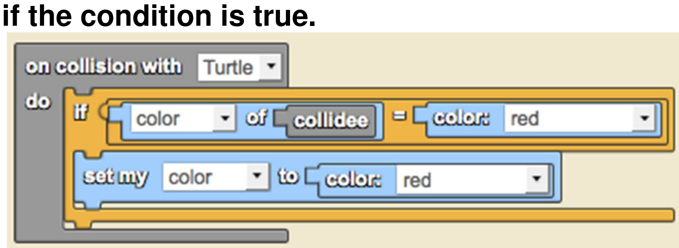


Select the object to collide with

Here's an example:



Here's another example with a conditional instruction. **The set color command only executes if the condition is true.**



Your challenge is to make the turtles react to another agent upon collision.

<u>Guidelines:</u>

1. Start from a new blank project or remix the "Colliding Turtles starter" model in the Project GUTS gallery.
2. Don't forget to put both partners' names in the project title.
3. Create 50 blue turtles (refer to Lesson 2) and 5 red turtles. (Will need 2 'create do' blocks.)
4. Have the turtles move around with a wiggle walk. (Work in the turtle page with a forever block.)
5. Use a collision block and have the turtles change a trait like color after colliding with another turtle.
6. When you are done, save and share your project.

Lesson 5 - Student Activity #2 Guide

Modeling the Spread of Disease

Part 1: Altering Colliding Turtles to create an Epidemic Model

Your challenge is to make the turtles spread disease to one another when they collide. You will learn how to use sliders to change a variable in a computer model.

Guidelines:

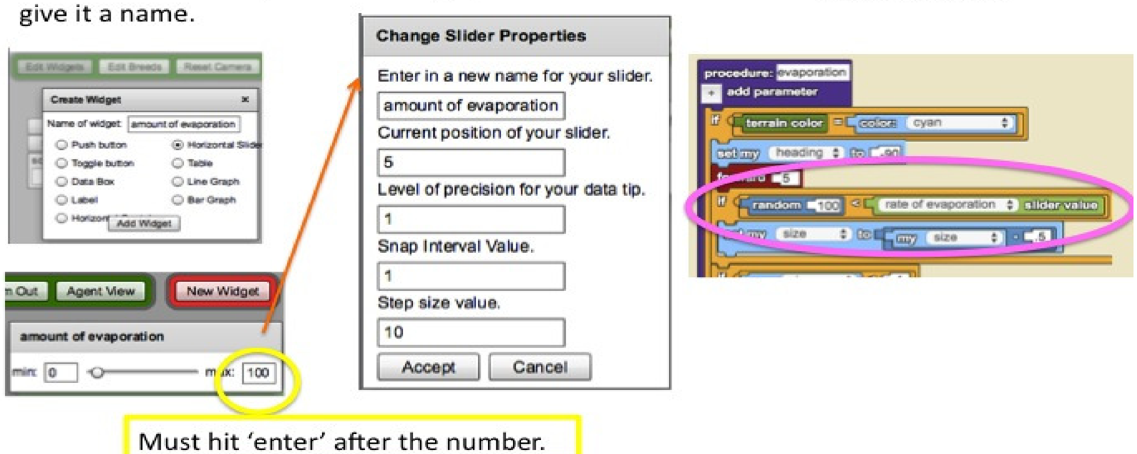
1. Remix your Colliding Turtles project or use the 'Epidemic Starter' model.
2. Name it 'Epidemic Model: *your name(s)' Don't forget to put both partners' names in the project title.*
3. Create 300 blue turtles and 5 red turtles
4. Create a transmission rate slider; set the maximum to 100.
5. Use the value in the transmission rate slider as the probability of passing on the disease.
   Note: you will need to use the random function to mimic rolling the 100-sided die.
6. Save and test your model.

How to add a slider

Step 1- Edit Widgets, Select Horizontal Slider to add a slider, give it a name.

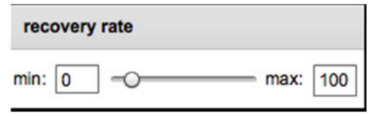
Step 2- Edit the slider by double-clicking in the gray area.

Step 3- Make sure the Slider Value is coded in the program.

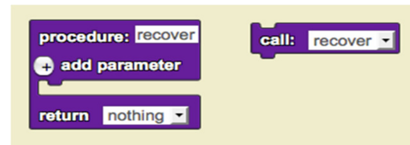


Part 2: Customizing your model [adding in recovery]

Your challenge is to make the turtles recover from the disease.



1. Create a recovery rate slider.
2. Create a recovery procedure.
3. Use the value in the recovery rate slider as the probability of recovering from the disease at each step.



Recovery Procedure: At each step, a sick person has a chance of recovering so we will need recovery to be called when the 'forever' button is toggled. You will need to use the random function to mimic rolling the 100-sided die as we did in the transmission case.

Note: the "call recover" block needs to be within the "when forever toggled" loop.

Testing your model

- Save and test your model.
- Try changing the recovery rate. Did you see any new outcomes or patterns?
- Notice that even when the recovery rate is really low, the disease goes away. Why do you think that is? Is this realistic?

When you are done, save and share your project.

Progress Monitors for Coding Projects in Module 1

Flower/Painting Turtles Progress Monitor (Agent Affecting Environment)

Goals:
- o Create Turtles that are separated by 5 steps. *[hint: Setup]*
- o Have them draw a flower. *[hint: Forever with pendown. forward and left by]*

Bonus:
- o Use the random block in turtle movement commands. *[hint: "right by" random amount]*
- o Use one block you haven't used before.

Bumper Turtles Progress Monitor (Agent-Environment Interactions)

Goals:
- o Add logic so turtles react to red squares by turning right by 90 degrees
- o Add logic so turtles react to blue squares by turning left by 90 degrees
- o Add logic so turtles react to black squares by turning around 180 degrees

Bonus:
- o Change the number of landmarks drawn in the "Paint Landmarks" procedure.
- o Use one block you haven't used before.

Colliding Turtles Progress Monitor (Agent-Agent Interactions)

Goals:
- o Create turtles of two different colors, red and blue, and do not have them leave trails.
- o Have the turtles move forward with a little wiggle in their walk.
- o Upon colliding with a red turtle, have blue turtles react by changing their color to red.
- o Add logic so turtles react to each other.
- o Change a turtle's trait after a collision. [size, color, shape, ?]
- o Save your project, upload, and share:

Bonus:
- o Create a new turtle after a collision.
- o Use one block you haven't used before.

Epidemic Model Progress Monitor

Goals:

- Create several hundred blue turtles and a few red turtles. *[hint: Setup]*
- Make them wiggle: *[hint: Forever]*
- Create a collision block in which blue turtles turn red when they encounter red turtles. *[hint: Lesson 4 Student Activity #2 Guide]*
- Create a slider and an if-then for the probability of transmission rate. *[hint: Lesson 4 Student Activity #2 Guide]*
- Create a slider and an if-then for the recovery rate. *[hint: Lesson 5 Student Activity #2 Guide]*

Bonus:

- Add a line graph with a line for infected turtles and one for healthy turtles. [*hint: Lesson 6 Student Activity #1]*
- Add a slider (or more) for one (or more) of the following:
  - Number of original healthy population
  - Number of original sick population
- Use one block you haven’t used before.

Lesson 2 - Student Activity #2 Guide

Inspecting the Water Pumping Model

Look 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 Water Pumping 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 is a tip:

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

Lesson 2 - Student Activity #3 Guide

Adding a Slider for Evaporation Rate

Adding a Slider
In Activity 2 you edited the code to change the evaporation rate. In this activity you will learn a better way to change the evaporation rate.

1) **REMIX** your model and edit the name to “Water Pumping base model ***your name your partner’s name*** **mod1**”
2) Add a slider for the evaporation rate and all necessary code.
3) Write down the slider settings you set.
4) Run an experiment using the evaporation rate slider. Use the **Experimental Design Form** to design your experiment first.
5) Record the data from your experiment and summarize your results.

Here is a tip:

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

Lesson 3 - Student Activity #1 Guide

Adding a Water Pump

In this activity, you will be adding a new pump that pulls water from the aquifer. Review what you know about how the first pump was created.

1. Open up your version of the base model. **REMIX** and rename the project with ***your name your partner's name*** **mod3**"

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.

Lesson 3 - Student Activity #2 Guide

Running 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 is a tip:

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

Lesson 4 - Student Activity #1 Guide

Computational Science and Designing Your Project

Design your project
In this activity you and your programming partner will come up with your own model based on the Water Pumping base model.

1. Open up your version of the base model. **REMIX** and rename to "Water Pumping ***your name your partner's name*** **NEW**"

2. Use the **Project Design Form** to plan your modeling.

Here is a tip:

- 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.

Lesson 4 - Student Activity #2 Guide

Designing and Developing Your Model

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 ("Water Pumping ***your name your partner's name*** **NEW**")

2. Use the **Project Design Form** to guide you as you take turns **driving** and **navigating**.

Here is a tip:

- You can copy and paste code from other models to help you work more quickly.

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

Lesson 5 - Student Activity #1 Guide

Completing and Debugging Your Code

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

1. Open up your model ("Water Pumping ***your name your partner's name*** **NEW**")

2. Test your model out and fix any issues you find.

Here is a tip:

- 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.

Lesson 5 - Student Activity #2 Guide

Running Experiments

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

1. Open up your model ("Water Pumping ***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 is a tip:

- 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

Preparing 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 questions and answers.

Here is a tip:

- 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.

Lesson 1 - Student Activity #1 Guide

Papercatchers

Name: Date:

Instructions:

1) Copy the data collected during the Papercatchers activity into the table below. Note that you may not be able to complete all 10 generations in class.

Generation	Round 1 – no paper		Round 2 - newspaper		Round 3 – sheet paper
	Population size		Population size		Population size
1	1		1		1
2					
3					
4					
5					
6					
7					
8					
9					
10					

2) In this simulation of an ecosystem, what were the independent and dependent variables?

3) Using different colored pens or markers for each Round, create line graphs of the populations over time in generations. Make note of any carrying capacity or limits on growth in each round.

Remember to label your axes.

4) Predict the population sizes in each round (no paper, newspaper, sheet paper) if we could continue for 10 generations. (Remember that each new generation occurred when the current population did the ball toss and either died or brought another person in.)

Generation	Round 1 – no paper		Round 2 - newspaper		Round 3 – sheet paper
…	Population size		Population size		Population size
10					

5) Describe how you made the prediction using mathematical and scientific reasoning.

Lesson 2 - Student Activity #1 Guide

Looking 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 Rabbits and Grass 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.

Lesson 2 - Student Activity #2 Guide

Designing and Running Experiments

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

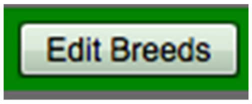
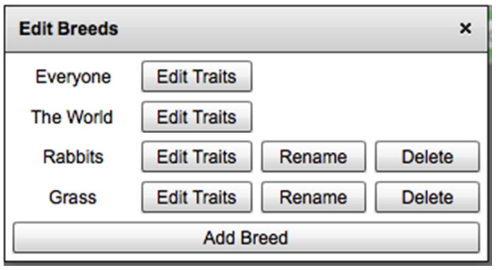
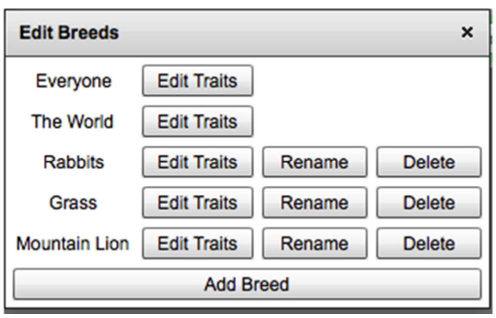
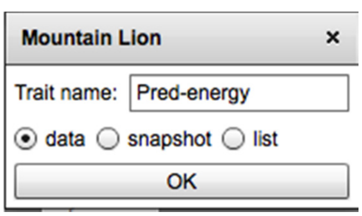
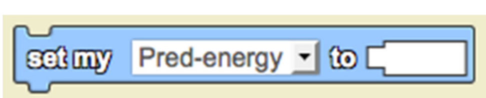
1. Use the **Experimental Design Form** to plan your experiment.

2. Record your data and analyze your results.

Lesson 3 - Student Activity #1 Guide

Adding a Predator

Use the instructions below to add a new breed:

	Use the Edit Breeds button in the Spaceland area to create a new breed.
	Click on “Add Breed” to add a new breed.
	In the “New Breed” dialog box, give the breed a name and press OK.
	You will see the Breed on the next panel. (We added the breed called “Mountain Lion.”) Next, click Edit Traits next to the new breed label for “Mountain Lion.”
	Create a new trait (or variable) for the Mountain Lion breed called “Pred-energy.”
	The set my (trait) to (value) block is used to set an agent’s trait to some value. In this case, the Mountain Lion’s Pred-energy is being initialized.

Lesson 3 - Student Activity #2 Guide

Designing and Running Experiments

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Lesson 2 - Student Activity #2 Guide

Modifying the Silver Nitrate and Copper Reaction Model

Remix the base model: “silver nitrate and copper reaction” and change its name to include your name and your partner’s name.

Challenge #1:
Modify the code to add or remove some or all of the water molecules in the model.

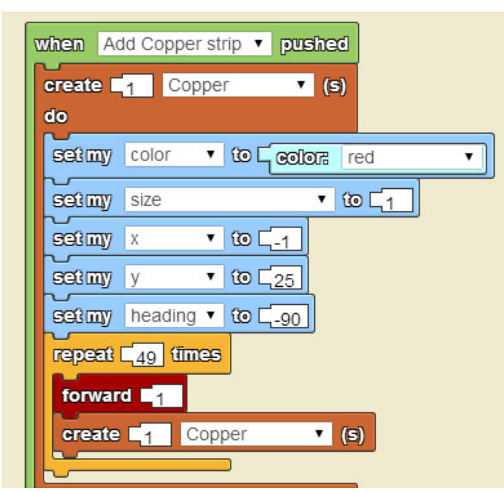
Reminder: Execute your model every time you add a piece of code. Debug as needed. Save often.

Hint: Look at the setup instructions for the water agents.
After you change the code, go up to the SpaceLand interface, save the model and click on “Run Code’ before running the model by clicking on the interface buttons. Debug the model as needed.

Q: Does removing the water molecules affect the execution of the model and real-world representation?
If time allows after you are done, think about what is included in this model and what is missing.

Challenge #2:
Modify the code to move the copper rod somewhere else in the solution keeping the number of agents of copper the same. Please note: The base model gives 150 copper agents to represent 150 copper atoms.

Hint: Look at the setup instructions for the copper agents (section shown below)



After you change the code, go up to the interface and hit “Save” and “Run Code” before executing the model. Debug the code as needed.

What does the command “set my x to” do? What does the command “set my heading to” do? What happens if you change the number of times the loop repeats?

Lesson 3 - Student Activity #1 Guide

Modifying the Model

Your Challenge: Change the code to add copper nitrate agents to represent the missing chemical product from the model.

The reaction modeled is:
Aqueous silver nitrate added to solid copper will react to form solid silver and aqueous copper nitrate.
Chemical reaction: 2 $AgNO_3$ (aq) + Cu (s) ---> $Cu(NO_3)_2$ (aq) + 2 Ag (s)

Start with base model - StarLogo Nova base model: “silver nitrate and copper reaction”
Remix the base model and change its name to include your name and your partner’s name.

Reminder: Save and test your model every time you add a piece of code. Debug if needed. Save often.

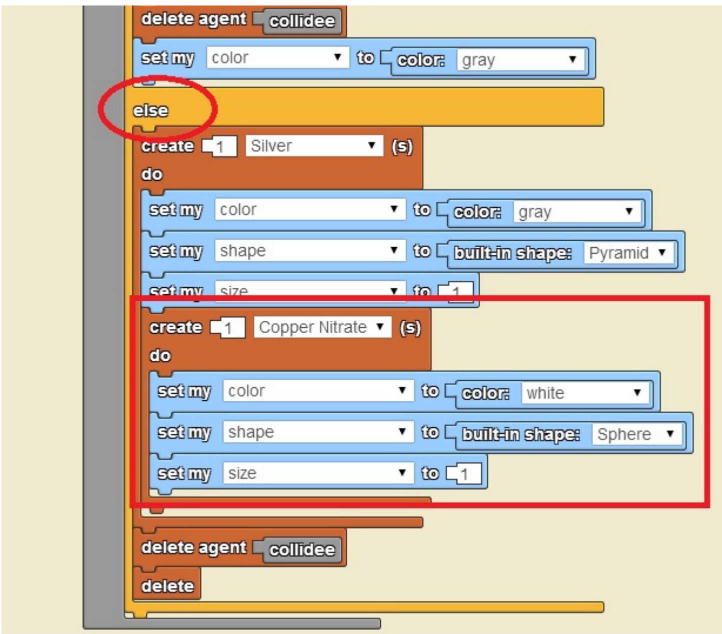
[Hints: (A) Add breed for new agent, (B) create agents inside a collision block, (C) give the agent some movement in water, since it is a soluble ionic compound.]

One solution to the Challenge:

A- Add the copper nitrate agent as a new breed.
Click on edit Breed. Click on add Breed. Name the breed 'copper nitrate". Exit edit breed.

Is there a new page/tab in Workspace now that they created copper nitrate breed?

B- When "gray" copper collides with silver nitrate, copper nitrate is created.
Give the copper nitrate agent the following traits:
Shape is sphere, color is white and size is 1.



Where is the correct location of this procedure? Why?

C- Add movement to copper nitrate: copy and paste Wiggle Walk procedure from water page or silver nitrate page to the copper nitrate page.
To copy, with the mouse clicked, drag a box over the piece of code you want to copy, and click on the copy button under the drawers.

Lesson 3 - Student Activity #2 Guide

Running Experiments

Start with the modified base model.

Your Challenge: Run experiments with different initial quantities of copper or silver nitrate and get the amount of silver produced. How much silver is produced in each case? Note when the copper is in excess and when the silver nitrate is in excess.

Use the Experimental Design Form to guide you.
Multiple trials are needed at every different setting of initial amounts used.

Can you predict what amount of silver nitrate is needed to use up all the copper with no excess left of either?

Lesson 4 - Student Activity #1 Guide

Modifying the Model Further

Your Challenge: Alter your model to include the formation of hydrated copper ions. First you will need to create additional breeds Cu(II).H_2O, Cu(II).2H_2O, Cu(II).3H_2O

Copper in water forms a complex with 3 water molecules which makes the solution slowly turn blue as the complex Cu(II).3H_2O forms.

1. Start with modified model from Lesson 3
2. Remix the base model and change its name to include your name and your partner's name.

Reminder: Save and test your model every time you add a piece of code. Debug if needed. Save often.

3. In the Interface (Spaceland) add 3 additional breeds:

Cu(II).1H_2O
Cu(II).2H_2O
Cu(II).3H_2O

Hint: Refer to Lesson 3 on how to add new breeds.

Check the Workspace area. Did new pages/tabs appear?

4. Change the code using collision blocks to create the following agents with their own traits:

Cu(II).H_2O: Shape is sphere, color is cyan and size is 1. It is created when one copper nitrate agent collides with one water molecule.
Cu(II).2H_2O: Shape is sphere, color is sky blue and size is 1. It is created when one Cu(II).H_2O agent collides with one water molecule.
Cu(II).3H_2O: Shape is sphere, color is blue and size is 1. It is created when one Cu(II).2H_2O agent collides with one water molecule.

The complex Cu(II).3H_2O is the final ionic product created in the solution turning the solution blue.

Tip: It is possible to drag a selection box around a group of blocks on one page, and "copy and paste" them to a new page. This is a real time-saver.

Reminder: Execute your model every time you add a piece of code. Debug if needed. Save often.

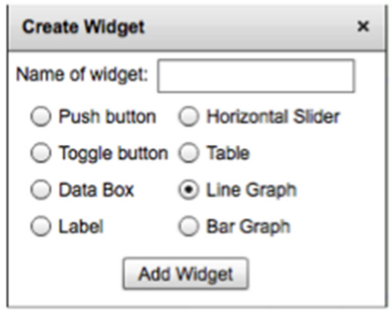
5. These new agents are ions moving about in water.
Set up a Wiggle Walk procedure for each agent on its own page.

Lesson 4 - Student Activity #2 Guide

Running Experiments

Your Challenge: Add instrumentation to your model so you can observe the rate of reaction, then characterize the rate of reaction.

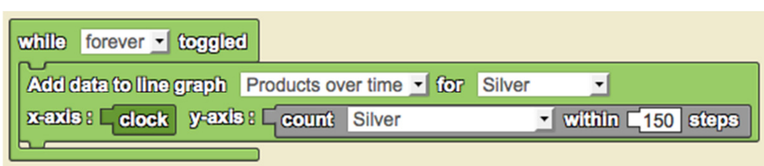
Start with modified model from Activity 1 and add a new widget, a line graph.



On the line graph window, add a new series to the graph by double clicking on New Series and changing the name and line color. For example,

- Create a new series called “Silver” then select gray as its line color.
- Create a new series called “Cu(II).1H2O” then select cyan as its line color.
- Do the same for the other products you want to monitor.

Finally, add the corresponding commands to the World’s page to update the line graph as time advances (clock tick).



Use the experimental design form to design and document your experiment. Try to determine the impact of reactant availability on the rate of reaction (production of products).

What do you observe?
Did the rate of the reaction increase as the number of reactants increased? Or vice versa?