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]
- USING a Computer Model to do Science document [student handout]
- Experimental Design form document [student handout]
- Model observation form [student handout]
- Project design form [student handout]
- Model design form [student handout]
- Lesson plans for 5 lessons
- Simple Slide presentation presentations with instructions
- New commands and concepts sheets for each lesson [student handout]

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

DAY 1 – 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)	Preview of 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: Modifying the model: 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: Finishing your model and using your model as an experimental test bed.

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 "USING a Computer Model to do Science" document.
Computer Science	Define debugging and give an example of some debugging you had to do in your code [LO6].

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.

Pre-requisites 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: Preview of 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 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: Preview of 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. [ex) 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.*

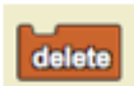
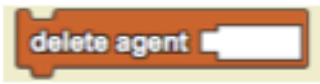
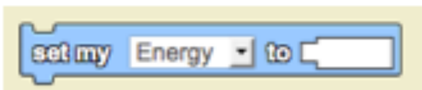
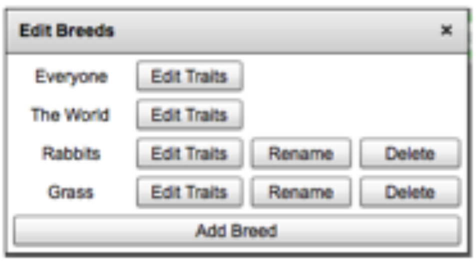
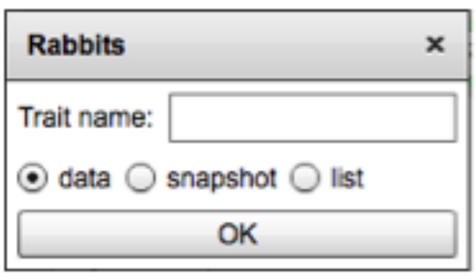
(DIS) *In the preview of the Rabbits and Grass model, we use technology to present information in multiple modes of representations. We provide multiple means of action, expression, representation and engagement. These are all principles of Universal Design for Learning.*

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

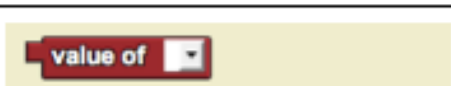
(EDS) *We validate the use of place [by situating the topic of ecosystems within the local environment] to keep the students engaged and make a connection of science and community.*

(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.*

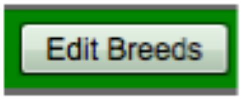
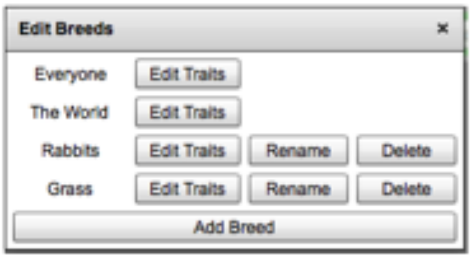
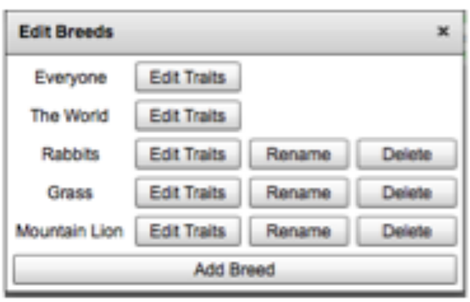
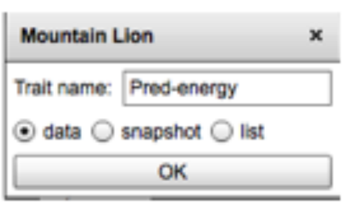
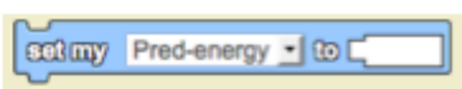
StarLogo Nova Blocks introduced in Module 3 Lesson 2

	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.

Student Activity #1 Guide: Patterns of Growth in 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 color 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
- Using a Computer Model to conduct a Scientific Investigation sheet
- Experimental Design Form
- New Commands and Concepts sheet

For the Teacher

- Computer and projector
- Slide presentation with simple commands
- Rabbits and Grass base model

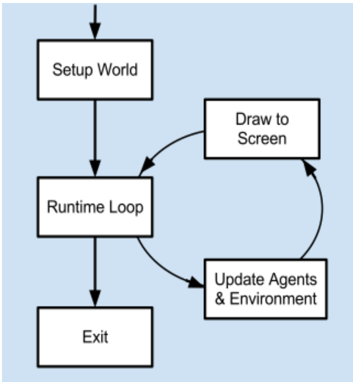
Getting started - 5 min

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:

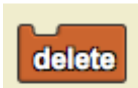
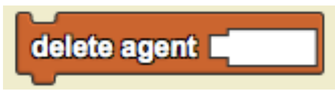
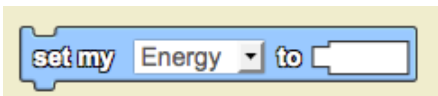
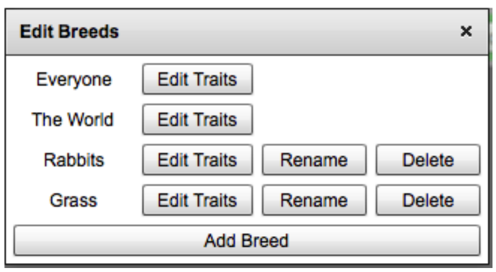
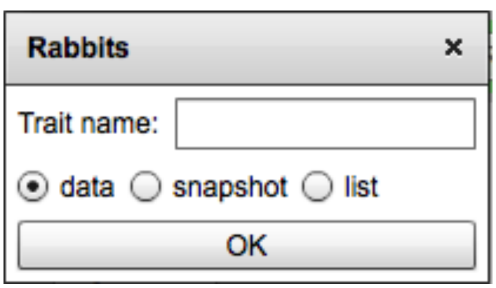
Model observation form

Model name: ______Rabbits and Grass____

Abstractions
Who are the Agents? What is the Environment? What are the Interactions? What do ticks represent? 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.
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 are the assumptions made in 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."

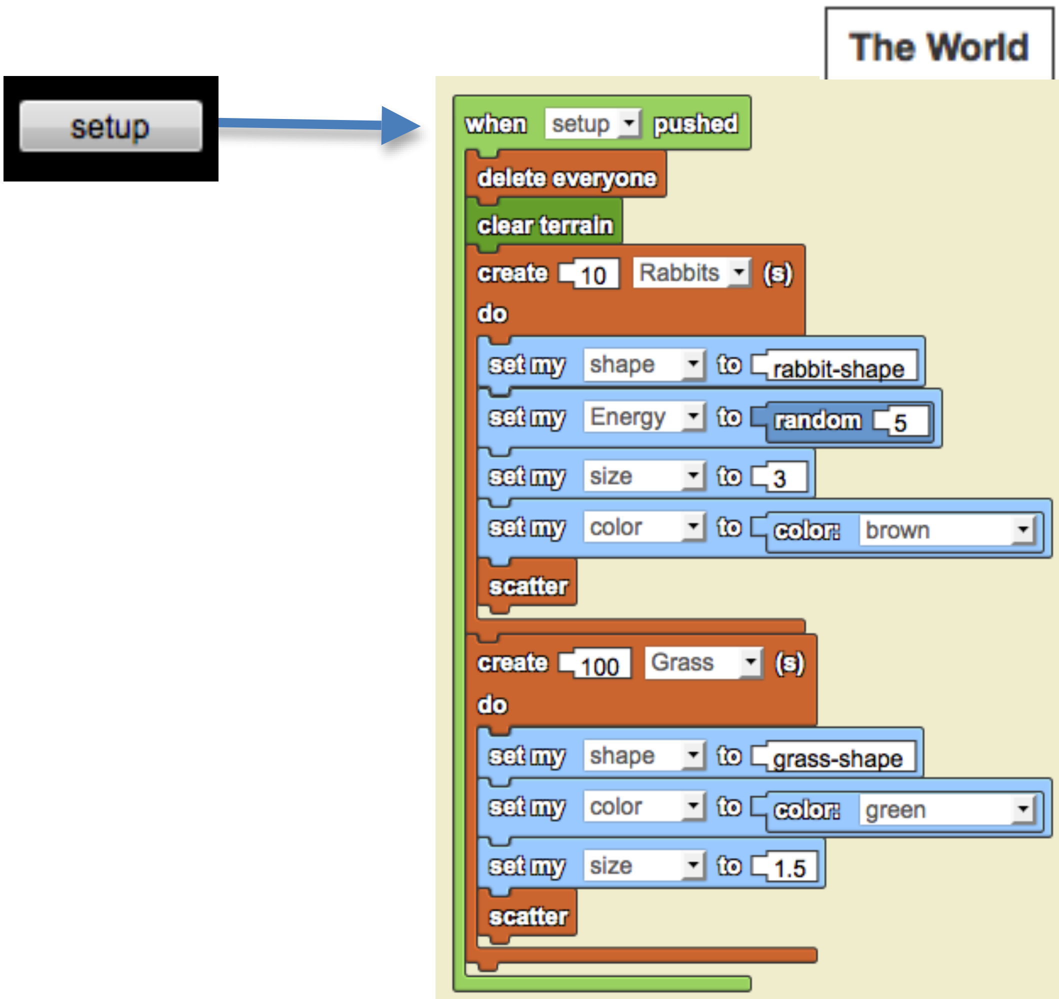
3. Assign a part to decode to each pair of students.

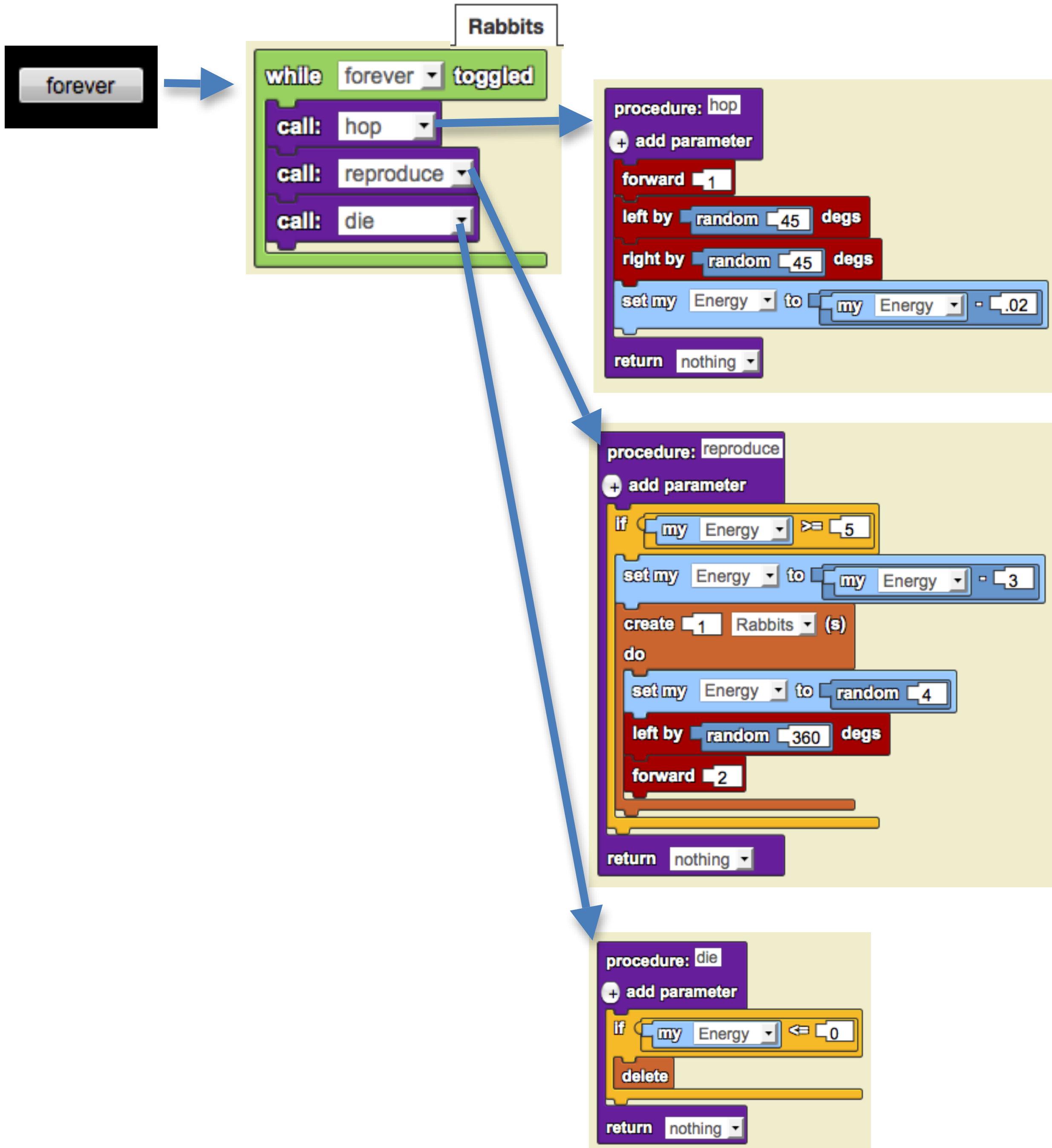
- Assign partners to share a computer
- Assign each pair a piece of the model to decode: Rabbits, Grass, or World. The detailed description of an agent's procedures can be added to the model observation form.
- Give the students 5 minutes to decode then ask students to share out.

[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?

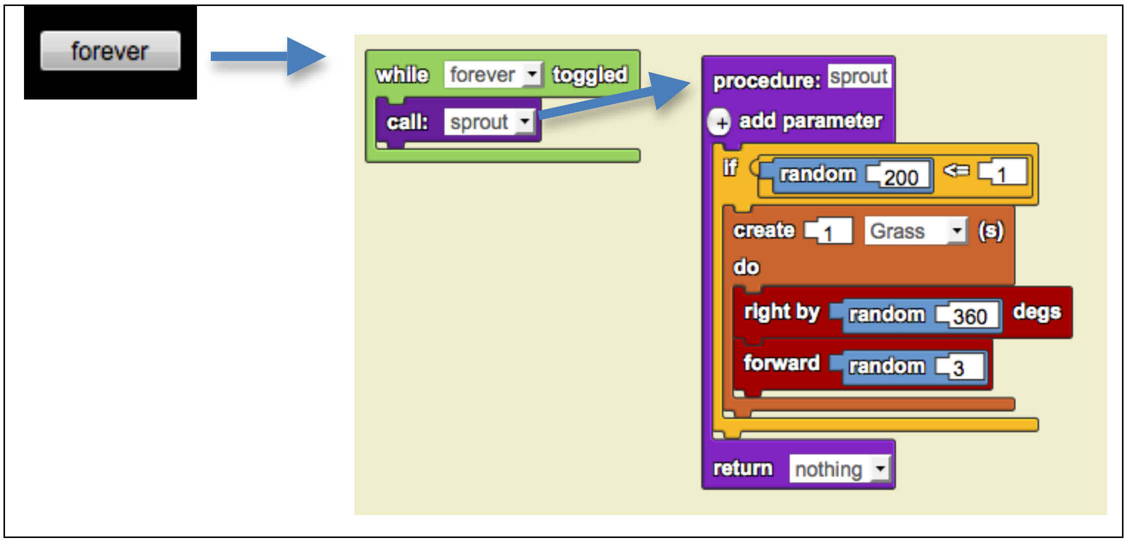
- Demonstrate how to trace execution of the program starting with Setup button.
- As a group, trace execution of the program starting with Run button.

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 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 #2: Experimental Design – 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.*

Student Activity #1 Guide:

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

1) Open your saved StarLogo Nova 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.

Student Activity #2 Guide:

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

1. Use the **Experimental Design form** to plan your experiment.

2. Record your data and analyze your results.

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>? *What do ticks represent?*   *What are the variables of interest?*
Automation
What happens each time through the forever (or main) loop?
Assumption(s)
What are the assumptions made in this model?
Analysis
What patterns did you observe? Do these patterns occur in real-life?

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?
Data Collection
What data will you collect?
Data Analysis
How will you analyze your data?

Interpretation
What is the answer to your question?
Interpretation
How does the analysis of your data help you answer your question?

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. 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
- Using a Computer Model to conduct a Scientific Investigation 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

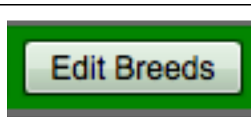
- Last time we learned about and experimented with the Rabbits and Grass model. Now we are going to add another type of organism to the ecosystem, a predator, and see its impact on the ecosystem. What's your prediction? What do you think is going to happen to the ecosystem when we add a predator?
- Review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

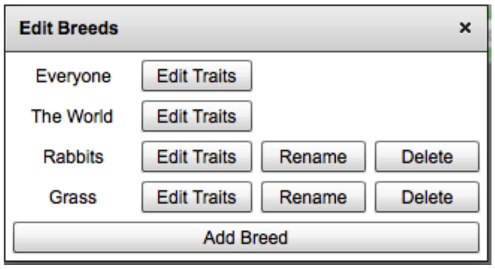
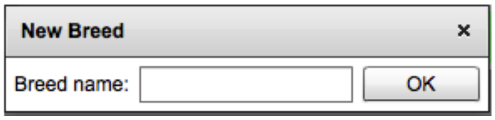
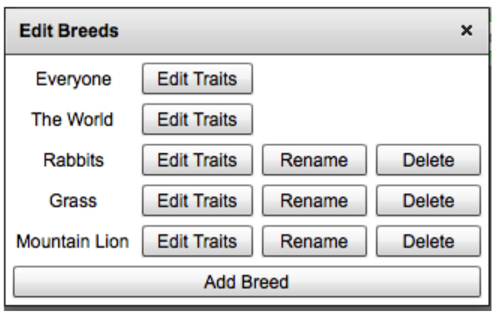
Activity #1: Adding a Predator - 20 min

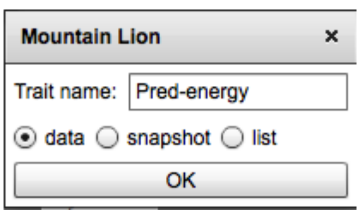
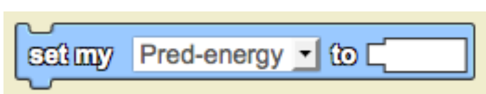
We'll be adding a new organism into our virtual ecosystem. It needs to be a new "breed" or type of agent because it behaves differently from the Rabbit agents and Grass agents. Let's add a mountain lion.

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 an experiment - 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 "USING Computer Modeling & Simulation to do Science" 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: Using a Computer Model to Conduct a Scientific Investigation

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: Modifying the Model, Adding a predator

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

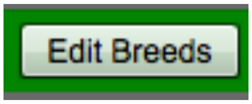
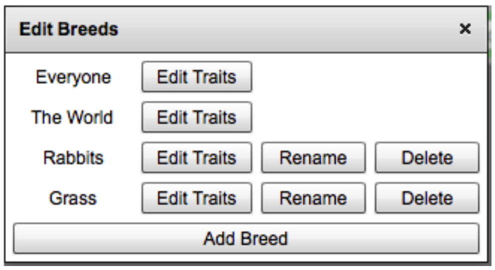
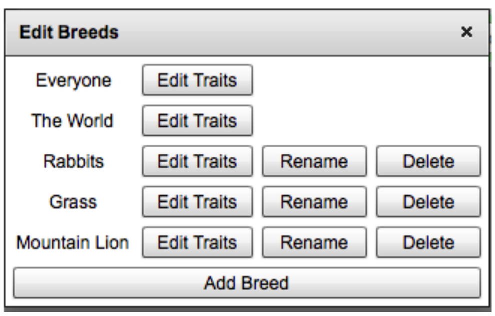
(EDS) *We recommend acknowledging different cultures' relationship and perception of top predators and making clear that they are not either Bad or Good.*

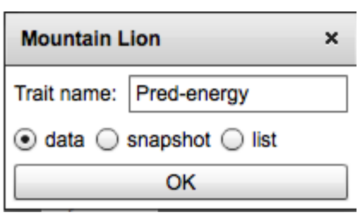
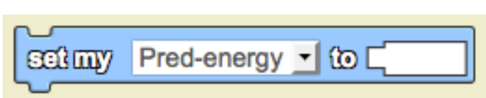
(URG) *Students are given "agency" as the creators of their own models, and as researchers seeking to answer a question or understand a phenomenon. The models that students build are their own creations.*

(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.*

Student Activity #1 Guide:

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>
<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>

Student Activity #2 Guide:

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

1. Use the **Experimental Design form** to plan your experiment.

2. Record your data and analyze your results.

Experimental Design form

Name(s): ______________________________Date: ______________

Model name: ____

Question
What is your question?
Variables
What are the dependent and independent variables in your experiment?
Range
What is the range of values you will use for each variable?
Trials
How many trials will you run at each setting? Why?
Data Collection
What data will you collect?
Data Analysis
How will you analyze your data?

Interpretation
What is the answer to your question?
Interpretation
How does the analysis of your data help you answer your question?

Scientific Practices with Computer Modeling & Simulation

Name: Date:

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

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

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: Design and develop 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
- USING Computer Modeling and Simulation to do Science

For the Teacher

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

Getting started - 5 min

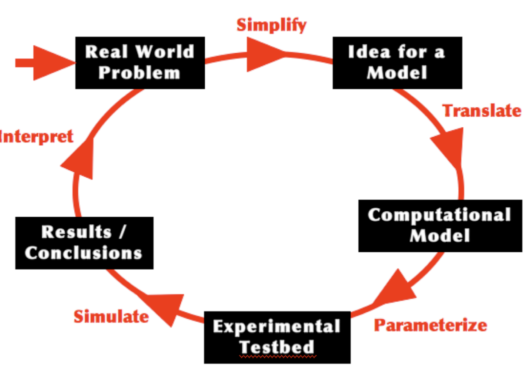
1. Review of previous day's lesson and link to where we are going today

- 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: Design and develop 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 start up 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. How would you test to see if your model reflects reality?

Assessment Questions

- Ask students to describe their use of scientific practices by filling out the USING Computer Modeling and Simulation to do Science 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.

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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.*

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Project Design Form

Name(s): ____Date: _________________

Model name: ____

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

MODEL DESCRIPTION
What will be modeled?
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>? *What do ticks represent?* *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?

Data Analysis
How will you analyze your data?
Interpretation
What question do you seek to answer?
Interpretation
How does the analysis of your data help you answer your question?

Scientific Practices with Computer Modeling & Simulation

Name: Date:

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

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

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 an experiment - 20 min

Use the "Using a computer model to conduct a Scientific Investigation" 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 your 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: Prepare 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

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 5: Finishing your model and using your model as an experimental test bed.

(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.*

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