Introduction to System Modeling

Minimum Teaching Time: 3 Class Periods (assuming 50 minute periods)

Instructional Setting:

- Classroom with a computer and projector

Lesson Discovery Question:

- How can we construct system models that will help us explain how something works?

Lesson Key Concepts (DCI & CCC)	● Systems consist of interacting parts that act together, resulting in a particular outcome or outcomes. ● Systems can have both inputs and outputs of matter and/or energy. ● Matter and/or energy may flow between components of a system. ● Tracking the flows of matter and/or energy through a system can help understand phenomena. ● Defining the boundaries of a system helps the user to focus on relevant components.
Lesson Key Practices	● Identify which components and relationships of a system are relevant to explaining a phenomenon ● Develop a model to describe the flow of energy and matter through a system

NGSS Connections Primary Subcomponents	
Science and Engineering Practices	**Crosscutting Concepts**
Developing and Using Models • Develop or modify a model - based on evidence - to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors.	**Systems and System Models** • Models can be used to represent systems and their interactions - such as inputs, processes, and outputs – and energy and matter flows within systems

Lesson Introduction:

In the previous Introduction to Modeling Off-the-Shelf lesson, students were engaged in learning to construct models of systems and processes, focusing on consensus of classroom modeling norms and in selecting only the details and components necessary to make the model useful.

In this lesson, students extend their skills in constructing models to solve problems or answer questions, with an emphasis on identifying the components of a system: **inputs**, **outputs**, **boundaries**, and **flow of matter and energy**. Presented with a scenario in which fish in an aquarium are unhealthy, they explore the addition of a treasure chest bubbler to the system - beginning by answering the question of how the bubbler works to raise the lid of the treasure chest, and culminating with consideration of how the bubbler works to increase dissolved oxygen in the aquarium and benefit the fish.

Additional Resources to Support Teacher Background Knowledge [Bozeman Science: Systems and System Modeling]

Science Words
System **System Model** **Input** **Output** **Component** **Flow of Matter or Energy** **Boundary**

Advance Preparation

- Prepare copies of student resources as needed (see phase summaries).

- If you plan to use lesson slides, use the Mi-STAR lesson slide template with the relevant material from this lesson or modify the Lesson Slide Guide that has been provided as needed.
- Acquire clear cups or glasses, straws, and cupcake papers for the Uncover activity.
- Plan for students to use either whiteboards or large pieces of poster paper, and markers, when constructing models in small groups.

Safety Considerations

- None for this lesson.

Mi-STAR Lesson Structure

Anchoring Experience

Phase Summary:
Students watch several short videos of a treasure chest aquarium bubbler, and then create initial models to explain how the bubbler works.
Resources Needed for this Instructional Phase:
• Per Class
  ○ Computer with projector and speakers
  ○ Anchor Video: Fish Tank Treasure Chest
  ○ Anchor Video: Finding Nemo
• Per Group
  ○ Whiteboard or poster paper and markers
• Teacher Resources
  ○ Lesson Slide Guide

Student Steps:

1. Students are introduced to this lesson's phenomenon:

   - *Example Introduction: The fish in your aquarium don't seem as healthy as they used to be. You're researching to see what you might try to help them feel better. One suggestion you find is to add a treasure chest bubbler to the tank, but you're not sure where the bubbles come from or why the treasure chest lid opens. You've found a video online, but to make sure you understand how it works, you sketch out an initial model.*

2. Students watch Anchor Video: Fish Tank Treasure Chest, and may watch Anchor Video: Finding Nemo to remind them where they've seen a similar treasure chest bubbler.
Teacher Note: Students will be eager to share their experiences with fish they have owned. We suggest having students do a turn-and-talk to provide everyone a chance to talk about

fish they've owned, without taking the full class period.

3. In small groups, students create an initial model of what makes the bubbles in the treasure chest bubbler and why the lid opens.

Teacher Note: You may elect to have students sketch models individually before working on the small group model.

4. Student groups share their initial models in a quick gallery walk, and then consider the following questions:

Example Guiding Questions
● Did you show how the bubbler works? ● Did you show how the parts work together? ● Do you think that you've included all the important pieces in your model? ● Did you include any details that weren't necessary? ● What might help you keep track of and organize the parts that should be in the model? ● What do you still not understand?

5. Students describe their own experiences, relevant to the phenomenon.

Example Guiding Questions
● Have you ever had to draw a process or explain with a drawing how something works? ● Any other times where you had to try to figure out how something works, when you could not see the whole picture? What did you do? How did you figure it out?

Uncover Your Ideas

Phase Summary:
In order to further study how air can form bubbles when moving through a tube, and how those bubbles can raise an object like the treasure chest lid, students are invited to consider a simpler system. They will use a schema (graphic organizer) to plan and create models of how bubbles move a cupcake liner upward when air is blown into a glass of water from a straw.

Resources Needed for this Instructional Phase:

- Per Class (if whole-class demo)
    - Straws
    - Cupcake papers (consider foil or waxy papers that won't get soggy quickly)
    - Clear glass, cup, or bottle filled with water, large enough diameter to accommodate cupcake papers (or use miniature muffin papers with smaller cups)
    - OR Uncover Video: Blowing Bubbles (does not include the cupcake paper)
- Per Group (if demonstrated in each group)
    - Cupcake papers
    - Clear glass, cup, or bottle filled with water, large enough diameter to accommodate cupcake papers (or use miniature muffin papers with smaller cups)
    - Straws
- Per Student
    - Uncover Student Guide: Intro Schema
    - (if done as an individual, hands-on activity)
        - Cupcake paper
        - Clear glass, cup, or bottle filled with water, large enough diameter to accommodate cupcake papers (or use miniature muffin papers)
        - Straw
- Teacher Resources
    - Lesson Slide Guide

Student Steps:

1. Students are introduced to the investigation they will conduct and the purpose of the investigation.

- *Example Introduction: We decided that our aquarium bubbler models aren't complete, so we're going to start with a simplified example. We're going to observe someone making bubbles with a straw and what happens to a cupcake paper at the surface of the water. Then, we'll make initial models of how air is moving and how it's causing movement of the cupcake paper.*

2. Students observe how bubbles form and raise the cupcake paper when air is blown into a glass of water through a straw.

3. In small groups, students use the pre-vocabulary schema in the Uncover Student Guide: Intro Schema to analyze the phenomenon and plan a model that describes how air moves through the cup when bubbles are being blown, listing all the parts, the most important part(s), what goes in and what comes out.

4. After completing the schema, small groups of students construct initial models on whiteboards, poster paper, or slides/Jamboards.

Teacher Note: Consider reminding students of modeling conventions/norms that have been used in the past (arrows, labels, etc. - possibly from the Introduction to Modeling Off-the-Shelf lesson.)

Teacher Note: As an extension, or to challenge your more able learners, ask them to try using several different sized straws or using different amounts of force in blowing into the straws, and model their observations.

Share Your Ideas

Phase Summary:
Student groups share their models in a gallery walk, and come to consensus about the essential components, inputs, outputs, flow of matter/energy, and boundary for the bubble blowing model. They work towards an answer to the question of how the treasure chest bubbler works.
Teacher Note: In the Student Steps we outline the basic goals of the Share phase; there are many ways to accomplish these goals that teachers may choose for their own classrooms. Some routines may be found in the Mi-STAR Visible Thinking and Discussion Routines document, as well as in the Phase 2 Productive Talk Canvas or virtual courses.
Resources Needed for this Instructional Phase:

- Per Student
  - Share Student Guide: Frayer Model
- Per Group
  - Share Student Guide: Examples and Non Examples (if Lesson Slide Guide is not used)
- Per Class
  - Student models from the Uncover activity
- Teacher Resources
  - Lesson Slide Guide
  - Mi-STAR Visible Thinking and Discussion Routines
  - Mi-STAR Teacher Resources: Strategies and Pedagogy

Student Steps:

1. Student groups share their straw bubble models in a quick gallery walk, which is described in the Mi-STAR Visible Thinking and Discussion Routines document.

Teacher Note: You may use a gallery walk, or other appropriate whole group routine. Regardless of the routine you choose, including the below guiding questions ensures students encounter the scientific principles necessary to answer the Lesson Discovery

Question. These questions support students to make sense of the phenomenon through the lens of the lesson's CCC, which is Systems and System Models.

2. Students engage in productive talk around the bubble models:

Teacher Note: More information about productive talk strategies can be found in the Mi-STAR Teaching Pedagogy and Strategies Resource document.

Example Guiding Question	**Example Student Answers**
What do we agree was going in?	*Air*
What do we agree was coming out?	*Bubbles*
Was matter moving through this?	*Yes, the air was moving through the parts*
Was energy moving through this?	*Yes, we know that when things change, there is energy involved. We saw the bubbles moving and the cupcake paper rising, so there has to be energy in the system.*
What was/were the most important part(s)?	*Person, straw, water, cup, cupcake paper*
What if we took away one of those parts?	*The system wouldn't function/work the same way*
What parts were not important?	*Desk/table, person's body beyond nose/mouth*
What could we draw in our model to focus on the most important part(s)?	A boundary
What do scientists and engineers call something that has parts that work together, a flow of energy/matter, and inputs and outputs?	A system

How can this activity help us understand what's going on with the bubbles and movement of the treasure chest bubbler?	*It shows that if air is forced through a tube or straw, it can cause an object to move.*

3. Students come to a class consensus on definitions for input, output, boundary, and components. Then they agree upon a description of a system model and its characteristics, filling in the first two boxes of the Share Student Guide: Frayer Model as in the example below.

***System*:** A group of related parts that make up a whole and can carry out functions its individual parts cannot.

System Model: shows all of the parts and how they work together. It shows the inputs to the system, the outputs to the system, and the boundary of the system. It shows the flow of energy or matter through the system. This helps explain how the system works.

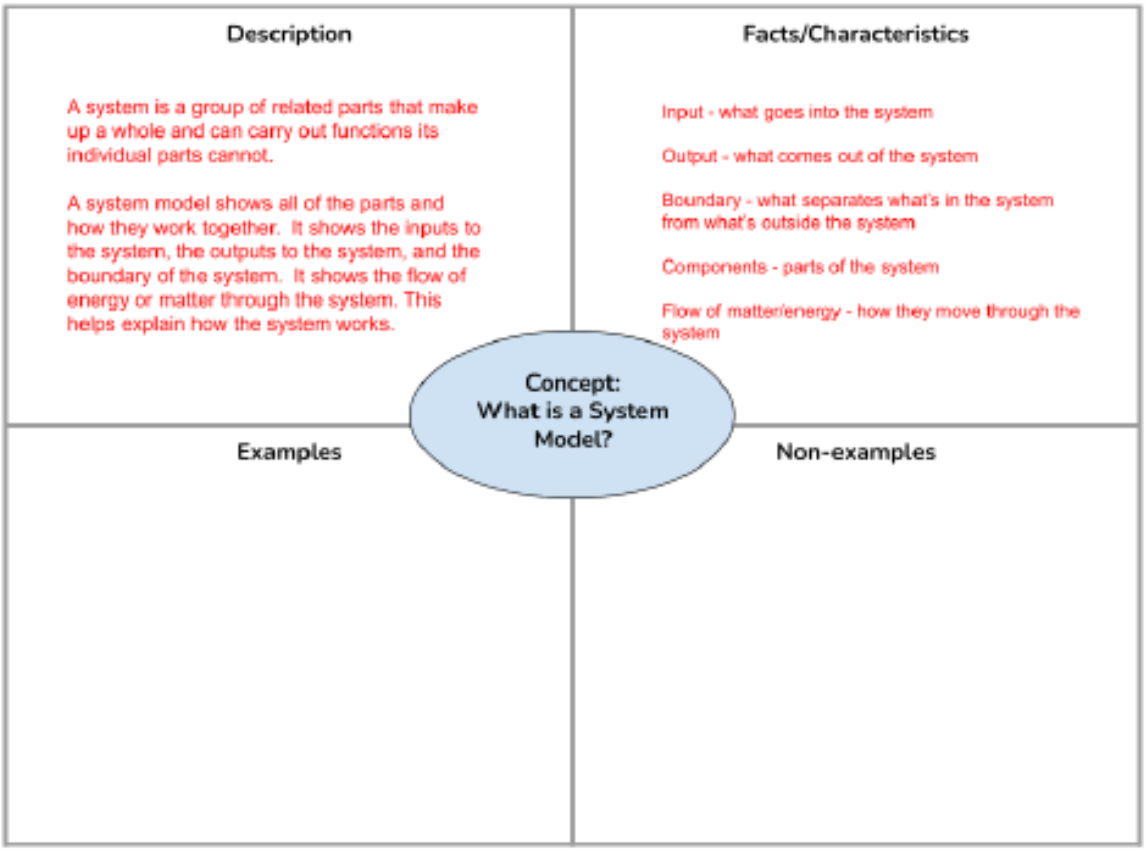
Input: What goes into the system***.***

Output: What comes out of the system

Boundary: What separates the inside from the outside of the system (so that we can focus on that important part)

Components: The parts of the system (these should be important to understanding how the system works).

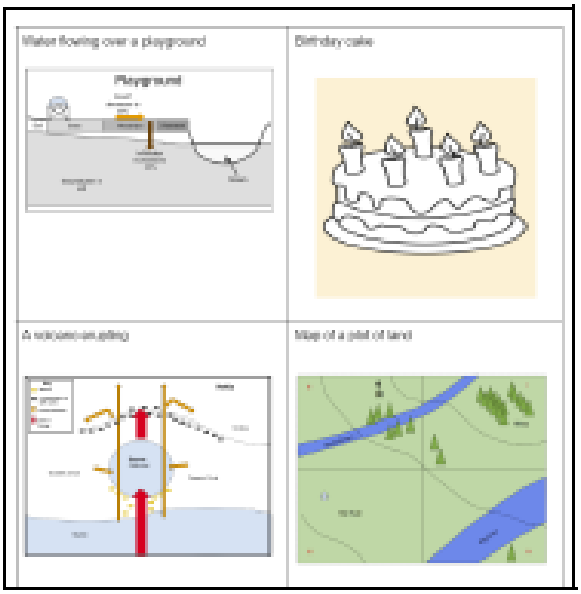
Flow of matter and/or energy: How matter and/or energy moves through the system
Teacher Note: This may be a whole-class, teacher-guided activity, or students may work in small groups to complete the description and characteristics.

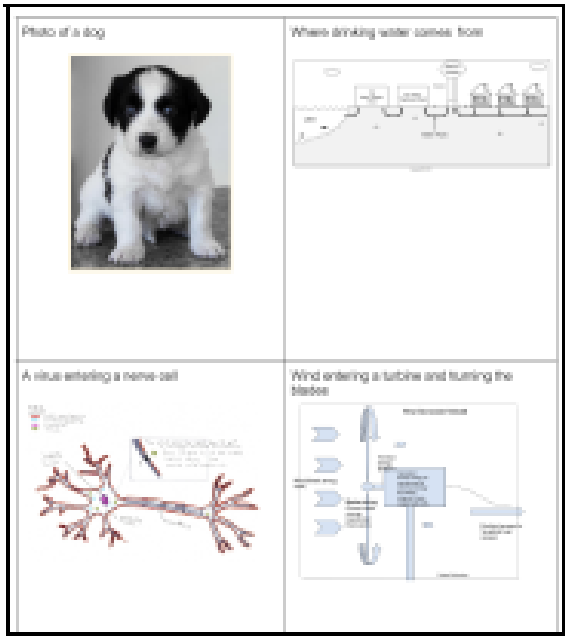


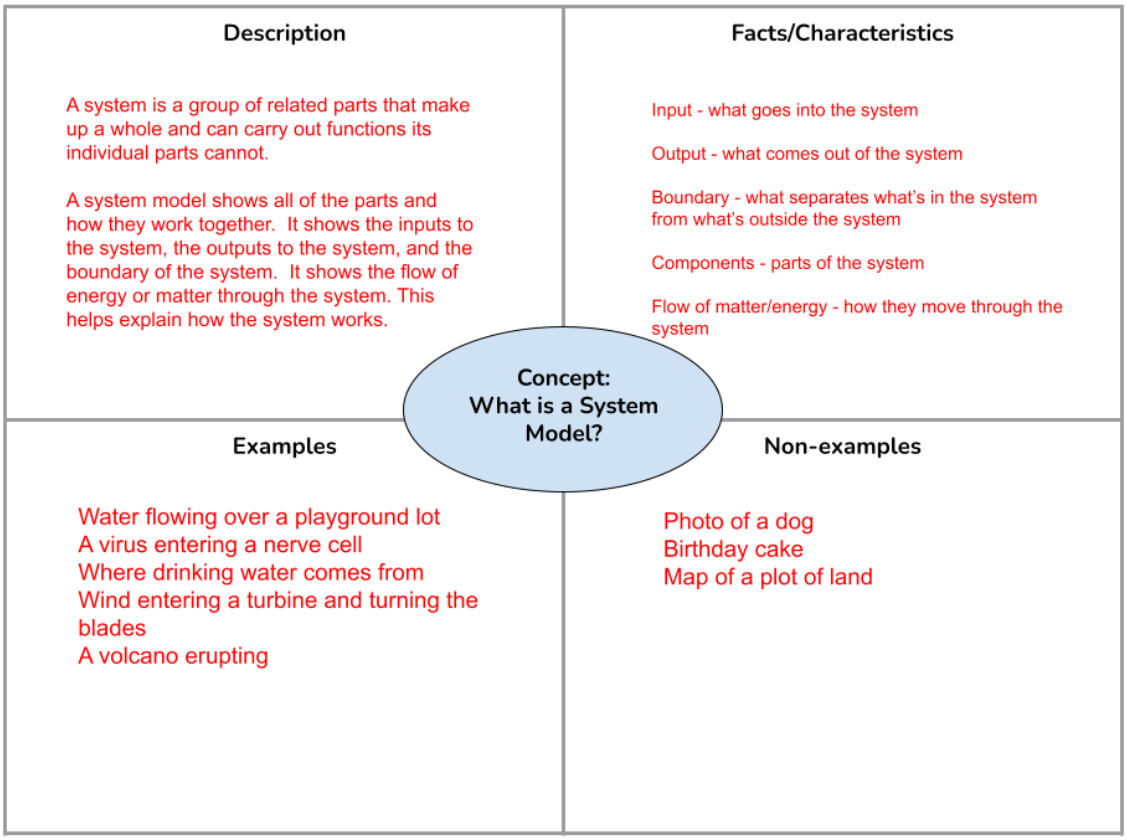
Teacher Note: In Mi-STAR, conceptual vocabulary is introduced after students have uncovered the related concepts through an investigation. This provides students with a mental context for the vocabulary so that they use the vocabulary with conceptual understanding. Use whichever method you feel is appropriate for you and your students to develop vocabulary at this point of the lesson. See the Vocabulary section in the Mi-STAR Teacher Resources: Strategies and Pedagogy catalog for tools and more information.

4. Students are given a list of examples and non-examples of system models in this Share Student Guide: Examples and Non Examples. Students work in small groups to complete the bottom boxes of the Frayer Model by sorting the examples and non-examples of system models. They should use the characteristics list in the Frayer Model as a checklist to help them decide the groupings.

Teacher Note: The examples/non-examples are illustrated on slides in the Lesson Slide Guide as well.







Teacher Note: Students are identifying *system models*, not systems. (Dogs are systems, but an unlabeled photo of a dog is not a system model.)

Literacy Practice: Unveiling Stories Strategy

Share Student Reading - A resource students use to compare their new understanding to the accepted body of scientific knowledge. This article from the middle school online textbook CK-12 describes scientific models. The accompanying reading guide helps them consider the text and apply it to what they've learned about models and system models.

- Share Student Reading Guide

- How does this science resource support or refute your findings/understanding?

Connect Your Ideas (Connection to the Unit Challenge)

Phase Summary:
Students apply what they've learned about using a schema to create a newly revised system model to explain the workings of the treasure chest bubbler. They will identify inputs, outputs, and a boundary, as well as the flow of matter/energy through the system. They'll use class modeling norms that were developed in the Introduction to Modeling Off-the-Shelf lesson, or other classroom modeling norms as recorded in earlier activities.

Resources Needed for this Instructional Phase:

- Per Class
  - Computer with projector and speakers
  - Connect Video: Treasure Chest Bubbler
- Per Group
  - Markers, poster paper or whiteboards
  - Connect Student Guide: System Model Schema
- Teacher Resources
  - Lesson Slide Guide
  - Mi-STAR Visible Thinking and Discussion Routines
  - Mi-STAR Teacher Resources: Strategies and Pedagogy

Student Steps:

1. Students view the Connect Video: Treasure Chest Bubbler to consider again how a treasure chest bubbler works.

2. In small groups, students complete the Connect System Model Schema (now with appropriate scientific modeling terms) to plan their new system models of the treasure chest bubbler.

3. Students use their schemas to create system models of the treasure chest bubbler.

Teacher Note: When students have made significant progress on their models but aren't quite finished, you may consider allowing groups to Send Out a Spy. This routine allows one student from each group to look at other groups' models, gathering and returning with ideas for improving their own models.

4. Groups share their new treasure chest bubbler system models in a gallery walk, noticing similarities and differences. Consensus discussion focuses around these questions:

Example Guiding Question	Example Student Answers
What was challenging at first about answering the questions on the schema?	*Thinking of all the parts*
How did you decide what parts should be included? What parts could be left out?	*We included the parts that are needed to make the bubbles raise the lid. We left out other parts of the aquarium, including fish.*
How did you decide where the system boundary should be?	*Go back to the initial problem to decide*
Is there a right or wrong place for the boundary? Why or why not? What determines where the boundary goes?	*Boundaries are determined by the person who constructs the model, based on where the important parts are.*
How did you decide what inputs to list?	*We thought about the air going into the system.*
Are there any outputs in this system?	*The bubbles may float to the top of the water and leave the system.*
What's one path of the flow of matter in this system? Are there others?	*Air is matter; it flows through the tube and into the treasure chest as bubbles. The bubbles lift the lid, then move to the surface and pop.*
Use your model to predict what would happen if the input was increased or decreased.	*If the input of air was increased, the amount of bubbles would increase and the lid would probably stay up the entire*

	time. If the input was decreased, there would be fewer bubbles and maybe not enough bubbles to lift the lid.
How does a system model help us understand how the treasure chest bubbler works?	*The system model shows how air is pushed into the treasure chest and bubbles out, making the lid rise.*

Check Your Progress

Phase Summary: Students revisit the original scenario regarding whether using a bubbler will improve the health of the fish in the aquarium. Students watch a short video explaining that fish breathe oxygen from the water through their gills. Then, students apply their knowledge of the structure of system models by identifying a boundary, input and output, and flow of matter in a partially constructed model of the aquarium. They also cross out any components in the system model that are not important to explain the relationship between the bubbler and the fish's health.

Resources Needed for this Instructional Phase:

- Per Class
  - Computer with projector and speakers
  - Check Your Progress video: How do Fish Breathe?
- Per Student
  - Check Your Progress Student Guide
- Teacher Resources
  - Lesson Slide Guide
  - Check Your Progress Teacher Version

Student Steps:

1. Students view the Check Your Progress video: How do Fish Breathe? to become familiar with how fish breathe dissolved oxygen in the water.

2. In the Check Your Progress Student Guide, students complete a system model of the treasure chest bubbler providing dissolved oxygen in the aquarium for fish to breathe. Using a checklist, they add a boundary, inputs and outputs, flow of matter (air), and cross off any unimportant parts in the model.