Understanding Systems with Computational Models

Use this resource to reflect on your practice or identify opportunities to integrate computational models in your classroom. This resource was developed to support middle school science teachers as they integrate computational thinking into NGSS-aligned lessons. The content can be adapted for other content areas, grade bands, and contexts.

What is understanding systems with computational models?

- **Using and Modifying Computational Models to Explore a Driving Question.** Students use a computational model to explore a driving question by testing different inputs.
- **Creating Computational Models.** Students create a computational model to define relationships between key components of a system.
- **Assessing Computational Models.** Students compare a computational model to a real world system in order to analyze the overall accuracy of the model.

Look fors:

Students may understand systems with computational models when they are:

Using and Modifying Computational Models to Explore a Driving Question

- Identifying a question to explore using a computational model
- Setting up multiple and different scenarios to collect data from a computational model
- Making predictions about how the model will behave with different inputs

Creating Computational Models

- Identifying different parts of the system that the model is representing
- Defining relationships between different parts of a system
- Automating relationships between parts of the system with a flowchart or programming/modeling software

Assessing Computational Models

- Testing and debugging computational models
- Considering how the model represents the real world system
- Considering bias in the outputs of a computational model

Activities and examples:

Activities that may integrate computational models into science	You might use this when...	Template Student resources to use or modify to integrate computational modeling in your classroom	Example An example of a student resource applied to a science topic
Creating and Assessing a Computational Model	Students are designing models to comprehend systems you cannot directly observe because of size, time, or visibility.	Template	Example
Using, Assessing, and Modifying a Computational Model	Students are using computational models to collect data about a scientific phenomenon in order to inform a driving question.	Template	Example

Prompting questions:

Ask students to reflect on their process or progress with these prompting questions:

Using and Modifying Computational Models to Explore a Driving Question

- ❑ What real-world phenomenon is this model based on?
- ❑ How can this model help you to better understand this phenomenon?
- ❑ What settings can you change?
- ❑ What question will you explore with this computational model?
- ❑ What scenarios will inform your question?
- ❑ What changes can you make to the model to better inform your question?

Creating Computational Models

- ❑ What system will you model?
- ❑ What are the parts of this system?
- ❑ What is the purpose of your model?
- ❑ Can you remove any parts of the system and still achieve the purpose of the model?
- ❑ Sketch or describe the relationship between the parts of the system.
- ❑ Define the relationships between the parts of the system that you will include in your model.

Assessing Computational Models

- ❑ Does each step in your model have the result you intend it to?
- ❑ Does a partner testing your model get the same results as you?
- ❑ Are there certain inputs where you do not get the intended result?
- ❑ How is this model similar to the system in the real world?
- ❑ How is this model different from the system in the real world?
- ❑ Would you make any changes to this model to make it more similar to the real world? If so, what would you do?
- ❑ Did the creator make any assumptions about the system when he/she created the model? If so, how are those assumptions affecting the model?

Understanding Systems with Computational Models: Creating and Assessing a Computational Model

A system is a group of things which affect each other, such as plants and animals in a food web or parts of a machine. Models and simulations represent relationships and processes of systems with interrelated parts. Models can be computational or non-computational. **Computational models** represent mathematical relationships between parts of a system and are created using a computer. In this activity, you will create a computational model that represents a real world system.

1 Part 1: Identifying a Problem

Computational models can help us to understand real-world phenomena that are difficult to observe because of size, time, and/or visibility.

- Identify a real-world process or problem that a computational model might help you to illustrate.
- How does this phenomenon relate to your life and/or community?
- What do you wonder about this phenomenon?
- How can this model help you to better understand this phenomenon?

2 Part 2: Describe the Phenomenon

Sketch and label the phenomenon you will model here:

Think about the parts of the phenomenon, the purpose of each part, and if the part will perform an action in your program. Then, consider if the action depends on a variable. If it does, describe how the part, action, and variable are related. Here, you are describing the mathematical relationships you may illustrate in your model.

Parts Objects in the model	**Purpose** Role of the object in the system	**Action** Something the object might do	**Variable** A characteristic of the object that may determine if/how the action occurs	**How does the variable determine whether the object will do the action? Describe the relationship or equation.**
Ex: Lake	*Ex: storing water*	*Ex: Evaporate*	*Ex: Temperature*	*Ex: If the temperature is greater than 100 degrees C, the lake will evaporate*

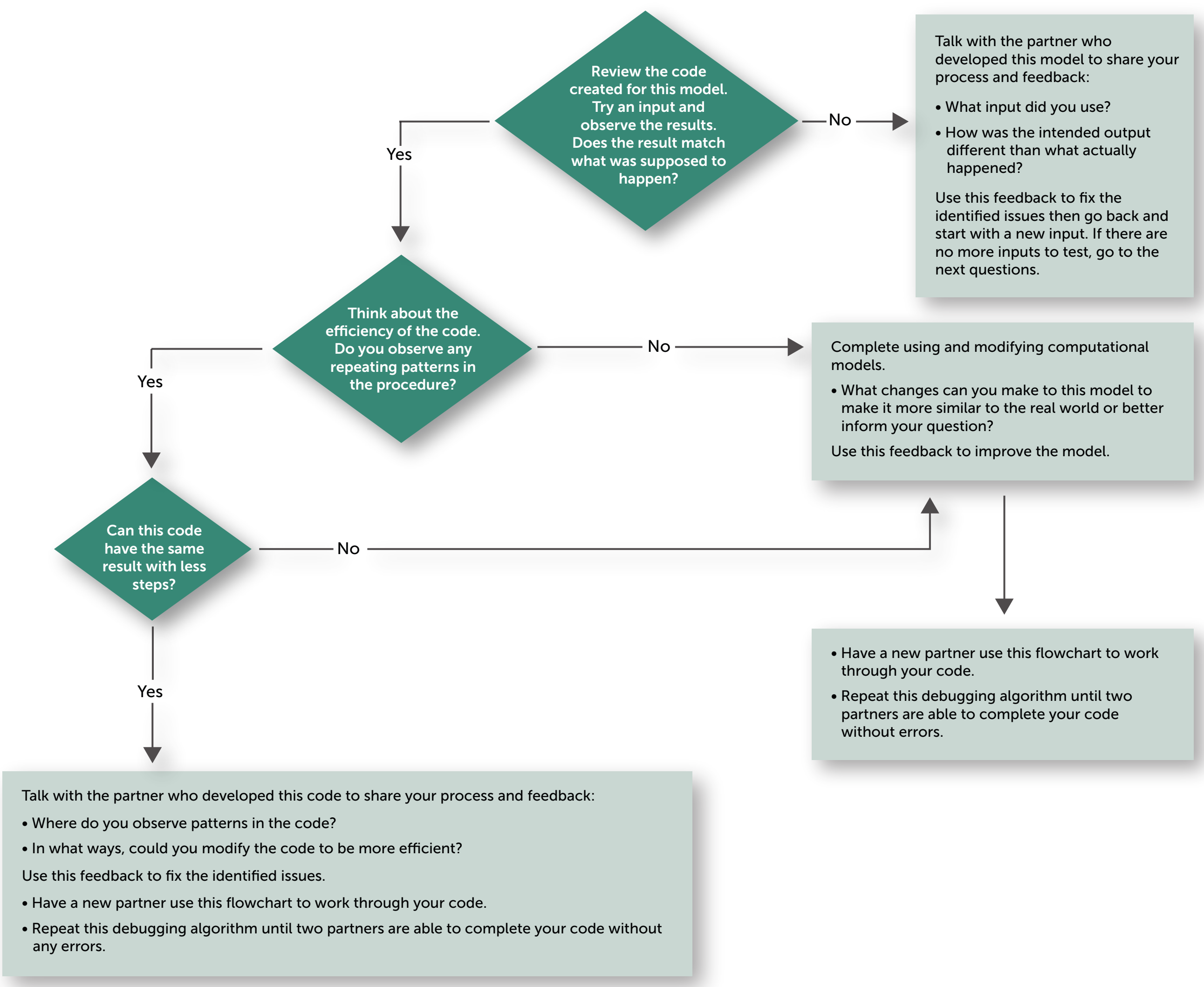
A model is a type of abstraction, or reduction of something to a very simple set of characteristics. In the last column of the chart, circle the relationships between parts, actions, and variables that are essential to understanding the purpose of the model you described in Part 1. Explain below:

3 Part 3: Drafting Your Computational Model

Now you will use a computational tool to create your computational model. There are many tools available to create computational models, such as coding platforms (e.g., Scratch, Snap, StarLogo Nova) or computational modeling platforms (e.g., SageModeler, Insight Maker, Loopy). Your teacher will tell you which tool(s) you may use for this assignment.

4 Part 4: Pair Debugging and Assessing Your Computational Model

(Note: Use this step if coding was used to create the model.)



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How does a submarine not sink or float (remain neutrally buoyant) in water? What factors determine if a submarine will sink or float?

A model can help me understand how a submarine remains neutrally buoyant by demonstrating the effect of variables on a submarine's buoyancy.

2 Part 2: Describe the Phenomenon

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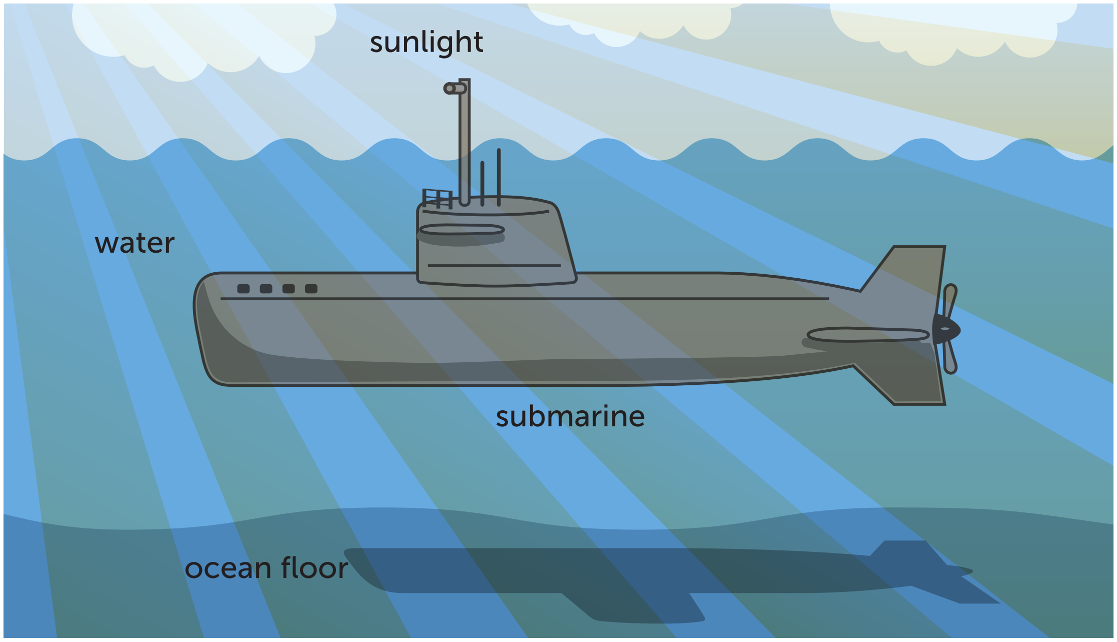

Think about the parts of the phenomenon, the purpose of each part, and if the part will perform an action in your program. Then, consider if the action depends on a variable. If it does, describe how the part, action, and variable are related. Here, you are describing the mathematical relationships you may illustrate in your model.

Parts Objects in the model	**Purpose** Role of the object in the system	**Action** Something the object might do	**Variable** A characteristic of the object that may determine if/how the action occurs	**How does the variable determine whether the object will do the action? Describe the relationship or equation.**
Ex: Lake	*Ex: storing water*	*Ex: Evaporate*	*Ex: Temperature*	*Ex: If the temperature is greater than 100 degrees C, the lake will evaporate*
Submarine	Traveling in the water	The submarine is going to sink, float, or neither in the water.	Density of the submarine The mass of the submarine: • What it's constructed of • How many people/ how much "stuff" its carrying The volume of the submarine	Density = mass/volume The volume of the submarine remains constant. The submarine can add mass by increasing the amount of water in its ballast tanks. This increases the density of the submarine. If the density is greater than the density of the water, it will sink. The submarine can lose mass by decreasing the amount of water in its ballast tanks, filling with air instead. This decreases the density of the submarine. If the density is less than the density of the water, it will float.
Water	Medium for submarine to travel	Might move/have a current Might be more or less dense based on the depth	Density of water Temperature of the water Salinity of the water Motion of the water Depth of the water	The density of water is 1 g/mL. The density of water changes with temperature and salinity. Ocean currents move objects Deeper water can be more dense due to increased pressure.
Sunlight	Affects water currents and temperatures	Might warm shallow water Might cause a current	Hours of sunlight Intensity of sunlight	Changes in water temperature cause convection currents.
Ocean floor features (subduction zones, rifts)	Affects ocean currents and temperatures	Areas of thinner crust could warm the water.	Depth of crust Temperature of water near crust	Changes in water temperature cause convection currents.

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In order to explore how a submarine sinks or floats in water, it is most important to determine the density of the submarine compared to the density of the water. If the submarine is more dense than water, it will sink. If it is less dense, it will float.

The density of the submarine is determined by mass/volume. There are factors that affect mass and volume that are determined when the submarine is constructed, such as how big it is and what it is constructed of. These will be excluded from our model because they are not easily modified. The mass of the submarine can be modified by adding people to the submarine or adding water to the ballast tank. This will be a variable that can be modified in the model.

There are factors that can modify the density of water (e.g. salinity, temperature, sunlight, ocean floor features), but these variations are slight and therefore we will exclude from the computational model, keeping the density of water at a constant of 1 g/mL.

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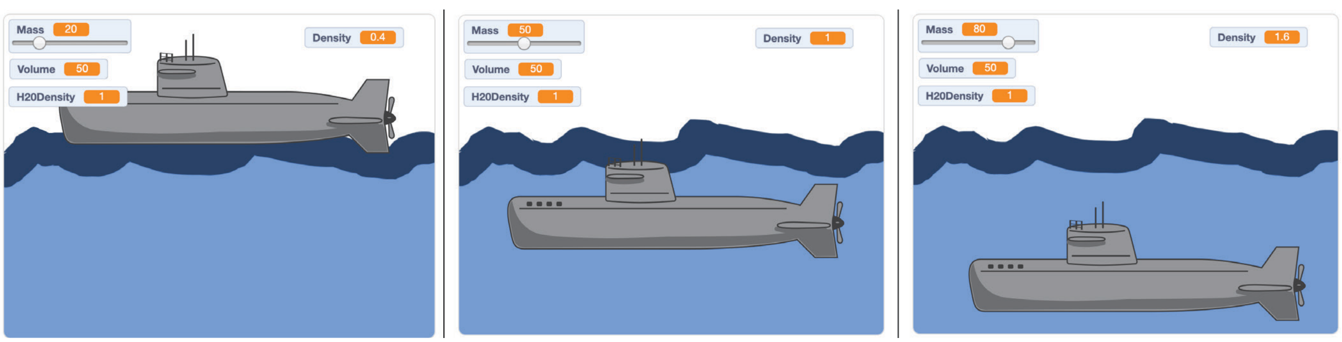
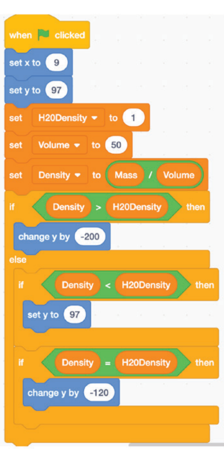
Link to Scratch model here





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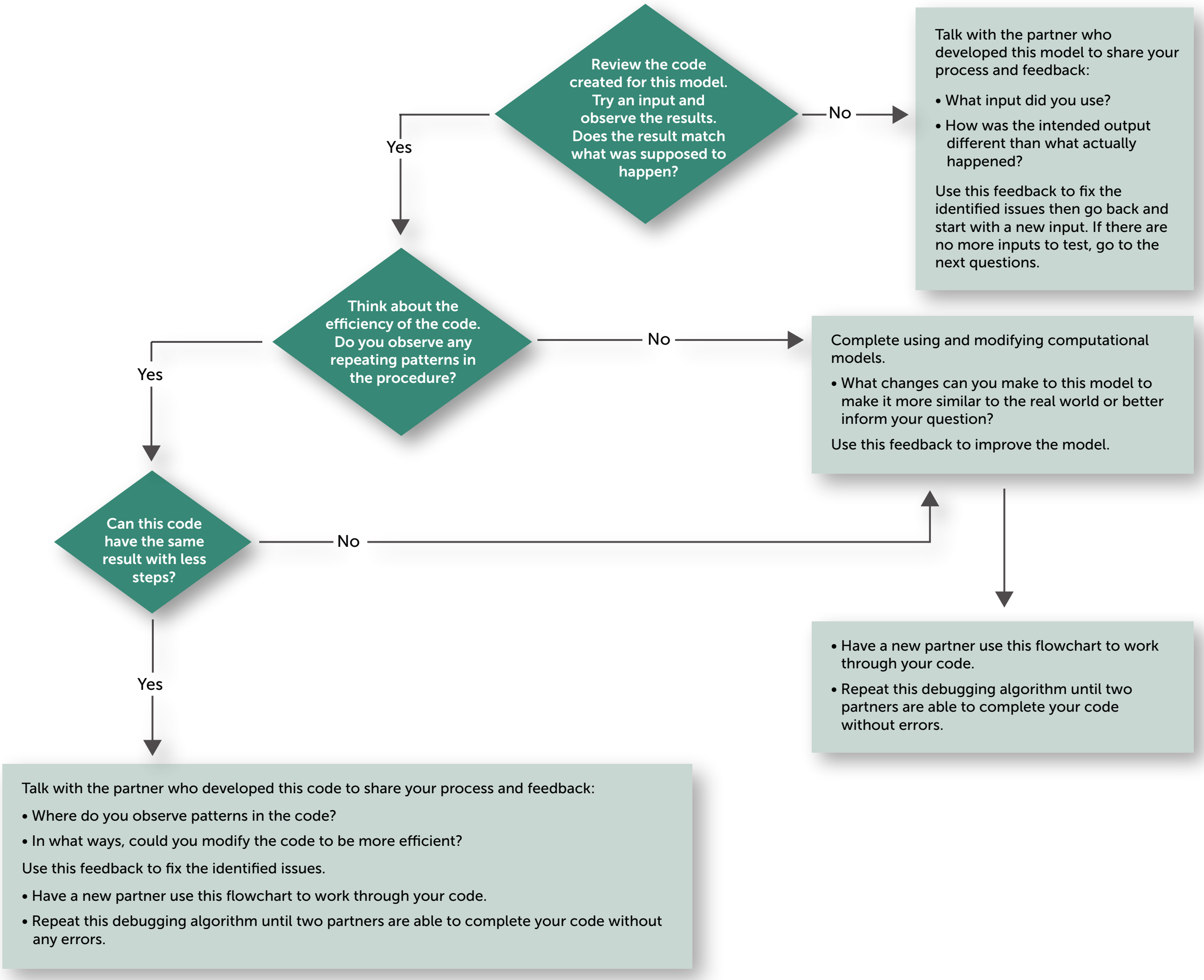

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Computational models represent mathematical relationships between parts of a system, and are created using a computer. In this activity, you will use a computational model to collect data about a scientific phenomenon and then assess how accurate the computational model predicts phenomena in the real world.

1 Part 1: Exploring a Computational Model

Explore the computational model. Consider:

- What real-world phenomenon is this model based on?
- What settings can you change?
- What happens if you set them to one extreme or the other?

2 Part 2: Developing a Question/Connecting to the Real World

- How does this phenomenon relate to your life and/or community?
- What do you wonder about this phenomenon?
- How can this model help you to better understand this phenomenon?

3 Part 3: Using a Computational Model to Answer a Driving Question

Link to computational model:		
Question:		
Scenario 1	Scenario 2	Scenario 3
Settings:	**Settings:**	**Settings:**
Results:	**Results:**	**Results:**
Compare/contrast your results. What did you learn about your question?		
What questions do you have about your results?		

4 Part 4: Assessing Your Computational Model

1. How is this real-world phenomenon different from the model? Identify at least two factors that are not represented in the model.

2. Did the creator make any assumptions about the system when they created the model? If so, how are those assumptions affecting the model?

5 Part 5 (Optional): Modify the Computational Model

What changes can you make to this model to make it more similar to the real world or better inform your question?

Are you able to see the code used to create this model? If so, look inside! Modify the code to reflect the change you identified.

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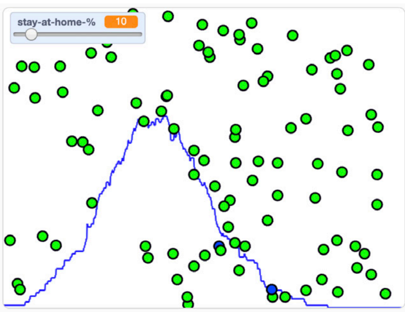
<table>
<tr><td colspan="3">Link to computational model: https://scratch.mit.edu/projects/376656449/</td></tr>
<tr><td colspan="3">Question: How does staying at home (social distancing) affect how many people are infected with coronavirus?</td></tr>
<tr><th>Scenario 1</th><th>Scenario 2</th><th>Scenario 3</th></tr>
<tr><td>Settings: 10% stay at home</td><td>Settings: 50% stay at home</td><td>Settings: 90% stay at home</td></tr>
<tr><td>Results:

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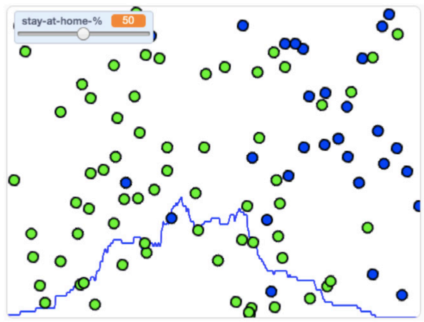
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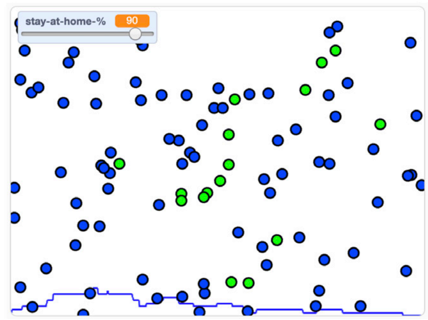
</td></tr>
<tr><td colspan="3">Compare/contrast your results. What did you learn about your question?

If at least 50% of people stay at home, then about half of the people become infected with coronavirus. If 90% of people stay at home, a much lower percent of the population gets coronavirus.</td></tr>
<tr><td colspan="3">What questions do you have about your results?

How long do people have to engage in social distancing for the disease to stop spreading?</td></tr>
</table>

4 Part 4: Assessing Your Computational Model

1. How is this real-world phenomenon different from the model? Identify at least two factors that are not represented in the model.

   - Other preventative measures for disease transmission: In the real world, there are other ways to prevent yourself from getting the virus besides staying at home. You could wash your hands, stay six feet apart, or wear a face mask.
   - Transmission rate: It is uncertain how likely someone is to contract the virus if exposed. Because so many people are asymptomatic, it is likely not 100%.

2. Did the creator make any assumptions about the system when they created the model? If so, how are those assumptions affecting the model?

Yes, the model assumes that the same number of people in the community remains constant. In reality, people travel between communities, which can affect the disease transmission rate.

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