ACTIVITY 5

The Role of Models in Science

READING

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ACTIVITY SUMMARY

A reading summarizes important unit concepts about scientific modeling and the role of systems, assumptions, limitations, orders of understanding, and revision in constructing a model. The use of models to study the changing distribution of lobsters off the east coast of Canada and the United States provides real-world examples of ecological research. The potential use of conservation strategies in addressing species change is highlighted.

ACTIVITY TYPE
READING

NUMBER OF
40–50 MINUTE
CLASS PERIODS
1

KEY CONCEPTS & PROCESS SKILLS

1 Scientific models are constructed to explain phenomena and make predictions. They represent aspects of the natural world that are too small, too large, too complex, or too difficult to observe or explain directly.

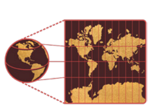
2 Different scientific questions about a single system may be best addressed by different scientific models, or one model may be used to answer multiple questions.

3 Models are developed based on observations of a system. When modeling a complex system, it is often useful to identify how a system's parts interact and to describe the limitations of the model based on the scientific question being investigated.

4 Models can be made more accurate through an iterative process that can involve testing it, refining it based on new evidence, adding or deleting relevant factors, or modifying the relationship between factors.

5 When constructing a model, it is helpful to distinguish those factors that have a greater impact on the question being studied from those with a lesser impact. This framework for differentiating among factors is known as *orders of understanding.*

CONCEPTUAL TOOLS



NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:
Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. *(Science and Engineering Practice: Developing and Using Models)*

VOCABULARY DEVELOPMENT

assisted migration

when humans deliberately move species from one location to another

components

factors, relationships, and processes of a system that are being represented in a model

predictive model

a tool to forecast the future

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 5.1 "Read, Think, and Take Note Guidelines"
- VISUAL AID 5.2 "Scoring Guide: Developing and Using Models (MOD)"
- ITEM-SPECIFIC SCORING GUIDE: Activity 5, Build Understanding Item 4

FOR EACH STUDENT

- 3-5 STICKY NOTES
- STUDENT SHEET 1.3 "Unit Concepts and Skills (OPTIONAL)
- SCORING GUIDE: Developing and Using Models (MOD) (OPTIONAL)

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in pink.

GETTING STARTED (5 MIN)

1 **Use the Introduction in the Student Book to set the context for the activity.**

- Let students know that, in the Student Book Introduction, they will be reading about how modeling is being used in the seafood industry.

PROCEDURE SUPPORT (30-40 MIN)

2 **Review the Read, Think, and Take Note Guidelines to support students in completing the reading.**

- This reading summarizes key concepts of the unit and provides additional examples of modeling in current ecological research. The Read, Think, and Take Note strategy provides an opportunity for students to record their thoughts, reactions, and questions on sticky notes as they read. The notes serve to make concrete the thoughts arising in their minds and then serve as prompts to generate conversation or write explanations. You can use Visual Aid 5.1, "Read, Think, and Take Note Guidelines," to review this literacy strategy. If your students are unfamiliar with the strategy, it can be helpful to demonstrate with a short passage of simple text, such as the Introduction to the activity. For more information about the Read, Think, and Take Note strategy, see Appendix 1: Literacy Strategies.

- Support students, particularly emerging multilingual learners, in sensemaking and language acquisition as they read the text. For example, students may need help in interpreting the last sentence of the first paragraph in the "Models and Decision-Making" section ("The models estimated that even with changing ocean temperatures, using this strategy would have reduced population decline in southern New England from 78% to 57%."). Circulate around the room and check in with students as they decode scientific ideas and construct meaning as they read.

- Add the terms *assisted migration*, *components*, and *predictive models* to the word wall and provide examples as needed. For more information on a word wall, see Appendix 1: Literacy Strategies

SYNTHESIS OF IDEAS (20 MIN)

3 **Review important ideas about models and their use in science.**

- You may wish to use questions (such as *In general, what do scientific models represent? How are models used in science? What are some ways of revising a scientific model? Why do scientific models have limitations?)* to do a quick post-reading assessment of student understanding and elicit the following main ideas:
  - In science, models are used to represent systems, or parts of systems, in order to study and communicate ideas about those systems.
  - In science, models help scientists make predictions about how systems will behave under given conditions.
  - A scientific model can be refined and revised based on testing it by comparing it to real-world systems, refining it based on new data, adding or deleting factors, and modifying the relationships between factors.
  - All models have limitations because they are simplified representations. As a result, they cannot include every aspect of the real world. While models help explain how things work together, they may oversimplify complex systems or fail to predict unexpected outcomes.
- Highlight the idea that in scientific study, the size and scope of a system is defined by the question being investigated. For example, an astronomer studying black holes may investigate the structure of the galaxy, while an ecologist gathering data on local tick populations may be focused on a local forest ecosystem. Systems thinking is the ability to recognize, describe, and model a complex phenomenon in its structure, behavior, and function (as a system). Systems-thinking skills include identifying system organization, analyzing system behavior, and system modeling. Students build these skills over the course of this unit.

4 **Use optional Student Sheet 1.3, "Unit Concepts and Skills," to highlight the important aspects of scientific models.**

- You may wish to have students revisit optional Student Sheet 1.3, "Unit Concepts and Skills," and add information about assumptions, limitations, and components. Again, help students think metacognitively by asking questions. For example, ask, What determines which factors are worth including in a model? Students should recognize that the question being investigated helps determine the model and the key elements to be included in the model.

5 **Assess student growth using the Item-Specific Scoring Guide for Build Understanding item 4.**

- Remind students of the Developing and Using Models (MOD) Scoring Guide. You may wish to project Visual Aid 5.2, "Scoring Guide: Developing and Using Models (MOD)" for your students to review each level and clarify your expectations.

- Do not share the item-specific version of the Scoring Guide (Item-Specific Scoring Guide: Activity 5, Build Understanding Item 4) with students as it provides specific information on how to respond to the item prompt.

- Remind students that you expect to see them demonstrate growth in their development, use, and analysis of models, and they may want to review their responses to the assessment in Activity 3 (Build Understanding item 4). You may also want to let students know that they will have one more opportunity in the unit to be assessed (Activity 10, Build Understanding item 1).

- Sample responses for Levels 1–4 are provided in the Build Understanding section that follows. Review these responses to get an idea of what is expected for each level alongside the Item-Specific Scoring Guide. See Appendix 2, Assessment Resource, at the end of the Teacher's Guide for more guidance and information on using the Scoring Guides and assessment system with your students.

- Depending on your students, you may want to have them provide feedback on one another's work for revision prior to turning in the work to you for scoring. Alternatively, consider having students turn in a rough draft to you for feedback and revision.

- To conclude the activity, evaluate whether your students are able to answer the Guiding Question, *How do scientific models represent a system?* Use this as a chance to revisit and summarize the key concepts and process skills of the activity.

SAMPLE STUDENT RESPONSES

BUILD UNDERSTANDING

1. **Dr. Wahle and his team are modeling how warming waters near the Arctic will affect lobster populations in the Northwest Atlantic. What are two sources of uncertainty in the model's predictions?**

   The rate of global environmental change is one source of uncertainty. Another source of uncertainty is the impact that factors that are not included in the model might have on the results.

2. **Look back at Figure 3.1: Gulf of Maine Food Web Model in Activity 3.**

   a. **What factor is missing from this food web model?**

   Lobsters.

   b. **What do you think is the effect of not having this factor in the model? Explain your reasoning.**

   The feeding relationships in the food web model are less accurate and can result in incorrect outcomes when using the model to make predictions.

3. **Imagine that the "bottle biology" model shown in Figure 5.4 represents a pond ecosystem.**

   a. **Identify which parts of the real-world system are included and which parts are excluded from the model.**

   The included parts are plants, water, soil, air, snails, and the pond bottom (rocks and leaves). The model does not include larger species such as fish or frogs, the physical space of a pond ecosystem, and weather and other environment changes.

   b. **Now imagine that the same model is intended to represent planet Earth. Identify which parts of the real-world system are included and which parts are excluded from the model.**

   It includes air, water, land, and some of the living parts of Earth (plants and animals). It does not include weather, climate, long-term geological change, and other species (including people).

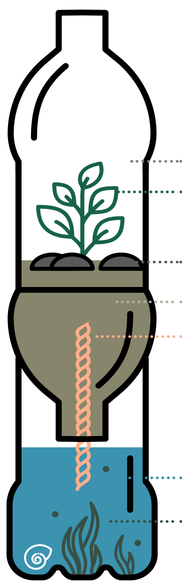


FIGURE 5.4
A "bottle biology" model

c **Which system—a pond ecosystem or planet Earth—is better represented by this bottle biology model? Explain your reasoning.**

Student responses can vary. The focus of a response should be on an explanation supporting their system selection.

I think that the bottle biology model better represents the pond ecosystem because it is missing fewer factors. When the bottle represents Earth, it is missing global processes, which are an important part of Earth's system.

④ **MOD Scoring Guide**

Climate conditions in the upper Midwestern United States have moved about over 300 kilometers (200 miles) north in 2 decades. The climate typical of southern Minnesota from 20 years ago is now in northern Minnesota. In 2016, the United States Forest Service conducted an experiment in assisted migration at Minnesota's Cutfoot Experimental Forest. They planted seedlings of 8 tree species from seeds collected up to several hundred kilometers farther south. There were 4 native species, while the other 4 species were not native. In 7 of the 8 species, the survival rate was 85%–90%. How would you construct a model to investigate the potential impacts of assisted migration for a species of tree?

a **Describe your model in detail and the key factors that you would include.**

b **Choose one key factor. Predict what your model would show if you changed that factor and your model was accurate.**

c **Predict what your model might show if the model was inaccurate.**

Level 4 response

a *I would use a computer model that would include temperature, rainfall, and location of new (assisted migration) tree plantings. My model would have a map that showed the trees' current range and areas where new trees might be planted. It would also show tree growth, with color-coding to show more growth or less growth. My model would include past data, current data, and predicted data based on different factors changing.*

b *One key factor is rainfall. If the model was accurate, it would show that with more rain in areas where the trees were newly planted, there would be more tree growth, and the opposite with less rain.*

c *If the model was inaccurate, the model might show less growth or no growth in areas with more rain, or it might show more growth in areas with less rain.*

Level 3 response

a *I would create a computer model with temperature, rainfall, and location of assisted migration tree plantings. A map would show the area where the trees grow and areas around it. It would also show the amount of tree growth.*

b *If I changed the amount of rainfall in the model and the model was accurate, it would show more tree growth with more rain.*

c *If the model was inaccurate, it might show less tree growth.*

Level 2 response

a *I would use a computer model, like the butterfly one, so I could change things. I would have a map that showed where the trees are. The key factor I would include is rain.*

b *If the model is good, it will show more trees growing.*

c *If it's not good, it won't.*

Level 1 response

a *I would use a computer model with a map. The key factor I would include is trees.*

b *If the model is good, it will show correct predictions.*

CONNECTIONS TO EVERYDAY LIFE

⑤ **A major online clothing retailer wants to use a predictive model to decide how many of a new style of hoodie to order for the upcoming season. If they overpredict, they waste money; if they underpredict, they lose sales. What key factors would they need to input into their model to forecast demand, especially given how fast trends change?**

Key factors may include weather, trend indicators (social media callouts, engagement with the website), and the general state of the economy.

⑥ **Imagine your school district wants to use a predictive model to help improve student success. The model uses data to predict which current freshman students are most likely to not graduate on time four years later.**

a **Identify three different types of data about a freshman student that the school might input into this predictive model.**

Attendance, grades, and number of credits taken per semester.

b **If the model predicts that a specific student has a very high chance of not graduating, this is a prediction, not a certainty. Explain why the model's prediction contains uncertainty.**

Past behavior is not predictive of future behavior. A student's grades or attendance can improve or decline for many reasons. This creates uncertainty in the model.

c **How could the prediction from this model create a useful feedback loop for school administrators to help improve the system and help the student succeed?**

If the model is even slightly accurate, it can help identify at-risk students so they can get additional support services to address attendance, grades, or course credits. This will reduce the likelihood that they will not graduate on time.

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Read, Think, and Take Note Guidelines

Stop at least three times during each section of the reading to mark on a sticky note your thoughts or questions about the reading.

As you read, use a sticky note from time to time to:

- explain a thought or reaction to something you read.
- note something in the reading that is confusing or unfamiliar.
- list a word from the reading that you do not know.
- describe a connection to something you've learned or read previously.
- make a statement about the reading.
- pose a question about the reading.
- draw a diagram or picture of an idea or connection.

After writing a thought or question on a sticky note, place it next to the word, phrase, sentence, diagram, drawing, or paragraph in the reading that prompted your note.

After reading, discuss with your partner the thoughts and questions you had while reading.

VISUAL AID 5.2 | SCORING GUIDE: DEVELOPING AND USING MODELS (MOD)

WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students develop their own models or use established models to describe relationships and/or make predictions about phenomena and/or systems.

WHAT TO LOOK FOR:

- Response accurately represents the phenomenon and/or system.
- Response includes an explanation of relevant ideas and concepts represented by the model or a prediction based on the relationships between ideas and concepts represented by the model.

LEVEL	GENERAL DESCRIPTION
Level 4 **Complete and correct**	The student's model* completely and accurately represents the components, relationships, and mechanisms of the phenomenon/system, AND the student uses it to develop a complete and correct explanation or prediction.
Level 3 **Almost there**	The student's model* completely and accurately represents the components, relationships, and mechanisms of the phenomenon/system AND includes a mostly correct use of the model to create an explanation or prediction.
Level 2 **On the way**	The student's model* represents components of the phenomenon/system AND includes a partially correct representation of the relationships or mechanisms associated with the phenomenon.
Level 1 **Getting started**	The student's model* represents components of the phenomenon/system BUT provides little or no evidence of the relationships or mechanisms associated with the phenomenon/system.

* A model can be a diagram, drawing, physical replica, diorama, dramatization, storyboard, or any other graphical, verbal, or mathematical representation. It may include labels or other written text as required by the prompt.

LEVEL	GENERAL DESCRIPTION
Level 0 **Missing or off task**	The student's response is missing, illegible, or irrelevant.
X	The student had no opportunity to respond.

WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students develop their own models or use established models to describe relationships and/or make predictions about phenomena and/or systems.

WHAT TO LOOK FOR:

- Response accurately represents the phenomenon and/or system.
- Response includes an explanation of relevant ideas and concepts represented by the model or a prediction based on the relationships between ideas and concepts represented by the model.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 4 **Complete and correct**	The student's model* completely and accurately represents the components, relationships, and mechanisms of the phenomenon/system, AND the student uses it to develop a complete and correct explanation or prediction.	The student response: • includes a detailed description of the model and multiple relevant key factors. • provides a thorough, logical prediction of model outcomes for an accurate and inaccurate model.
Level 3 **Almost there**	The student's model* completely and accurately represents the components, relationships, and mechanisms of the phenomenon/system AND includes a mostly correct use of the model to create an explanation or prediction.	The student response: • includes a description of the model and multiple relevant key factors. • predicts logical model outcomes for an accurate and inaccurate model.

* A model can be a diagram, drawing, physical replica, diorama, dramatization, storyboard, or any other graphical, verbal, or mathematical representation. It may include labels or other written text as required by the prompt.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 2 **On the way**	The student's model* represents components of the phenomenon/system AND includes a partially correct representation of the relationships or mechanisms associated with the phenomenon.	The student response: • includes a limited description of the model and at least one relevant key factor. • predicts logical model outcomes BUT may be vague AND/OR may not describe both accurate and inaccurate model outcomes.
Level 1 **Getting started**	The student's model* represents components of the phenomenon/system BUT provides little or no evidence of the relationships or mechanisms associated with the phenomenon/system.	The student response: • includes a minimal description and at least one key factor, which may or may not be relevant or appropriate. • includes a prediction of outcomes that is vague, illogical, or not provided.

* A model can be a diagram, drawing, physical replica, diorama, dramatization, storyboard, or any other graphical, verbal, or mathematical representation. It may include labels or other written text as required by the prompt.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 0 **Missing or off task**	The student's analysis is missing, illegible, or irrelevant to the goal of the investigation.	
X	The student had no opportunity to respond.	