ACTIVITY 2

Scientific Models and Scientific Questions

DATA ANALYSIS

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ACTIVITY SUMMARY

Students examine additional types of models and further explore the role of models in science. They identify how multiple scientific questions can be investigated with a single scientific model and how a single scientific question can be investigated with more than one model. Students discuss the role that models play in answering questions and how different types of models are best utilized for addressing different types of questions.

ACTIVITY TYPE
DATA ANALYSIS

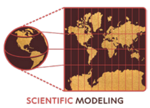
NUMBER OF
40–50 MINUTE
CLASS PERIODS
2–3

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.

NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:
Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. (*Science and Engineering Practice: Developing and Using Models*)

CONCEPTUAL TOOLS



VOCABULARY DEVELOPMENT

species distribution

the pattern of occurrence of a species within a geographic range

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 1.1 "Interpreting Graphs" (OPTIONAL)
- VISUAL AID 2.1 "Developing Communication Skills" (OPTIONAL)
- STUDENT SHEET 9.3 "Developing Scientific Questions" (OPTIONAL)

FOR EACH GROUP OF FOUR STUDENTS

- SET OF SCIENTIFIC QUESTION CARDS (4 CARDS)
- SET OF SCIENTIFIC MODEL CARDS (4 CARDS)

FOR EACH STUDENT

- STUDENT SHEET 2.1 "Investigating Scientific Models"
- STUDENT SHEET 1.3 "Unit Concepts and Skills" (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 (10 MIN)

1 **Introduce the idea of a scientific question.**

- This activity introduces scientific models and scientific questions. Ask, What do you think the difference is between a question and a scientific question? Help students develop the idea that a scientific question should be testable and answered with observable natural phenomena, while a general question is broader (for example, it may be about opinions, beliefs, or topics that cannot be measured or observed through an investigation). Scientific questions are more focused and objective. Ask, Can you brainstorm a list of scientific questions vs. general questions?

EXAMPLES OF SCIENTIFIC QUESTIONS	EXAMPLES OF GENERAL QUESTIONS
What causes cells to age?	Which is the best sports team in the league?
How do plants convert light into chemical energy?	What are you doing for lunch tomorrow?
What determines a molecule's boiling point?	Who is your favorite singer?
How fast is the universe expanding?	Is this room hot?
What causes coral bleaching?	What is the meaning of life?

- If you need to further support students' understanding of scientific questions, you may also want to refer to Student Sheet 9.3, "Developing Scientific Questions," found in Activity 9.

2 **Review the term *species distribution.***

- The Introduction in the Student Book describes a change in the climate classification of New York City. Specifically, it is referring to a macroclimate—long-term atmospheric conditions over a large geographic area. You may wish to have students investigate the macroclimate of your local area to find out if there have been changes over time.

- Use the Introduction to introduce the term *species distribution*—the pattern of occurrence of a species within a geographic range. Support students, particularly emerging multilingual learners, in sensemaking and language acquisition by adding the term *species distribution* to a word wall and providing an example as needed. For more information on a word wall, see Appendix 1: Literacy Strategies.

PROCEDURE SUPPORT (30 MIN)

3 **In Procedure Part A, students examine and summarize four scientific models.**

- There are four Scientific Models presented in the Student Book. In Procedure Part A, students generate multiple scientific questions that could be investigated by a single model. In Procedure Part B, students develop the idea that a single question can be investigated by multiple models.
- Each student will read and analyze one model and share their understanding with their group members. The models vary in their difficulty, and you may wish to assign models accordingly. Scientific Models 1 and 3 require interpreting a visual graphic, Scientific Model 2 requires interpreting a map, and Scientific Model 4 requires interpreting a graph (and may be the most challenging). Note that in Scientific Model 1, the reference to positive and negative impacts on the population of other species refers to mathematical effects and is not intended to imply good or bad effects.
- Depending on your student population, you may wish to review how to interpret graphs using optional Visual Aid 1.1, "Interpreting Graphs."
- Provide each student with a copy of Student Sheets 2.1,"Investigating Scientific Models."
- Support students, particularly emerging multilingual learners, in sensemaking and language acquisition by adding a few more words to the word wall. Students, particularly those examining Scientific Model 2, may have questions about a species distribution and its relationship to migration. If needed, clarify that the term *migration* is the movement of animals from one region to another, often seasonal. For example, many bird species have a long-distance migration pattern from breeding ranges in the United States and Canada to wintering grounds in Central and South America. All the areas that have the living (biotic) and nonliving (abiotic) conditions for the species to survive would be a part of its potential range. *Range shifts* are defined as changes in the distribution limits of a species, generally along altitude or latitudinal lines. *Species distribution* refers to how a species is spread throughout its range, for example, in tight groupings in one area or evenly throughout. For more information on a word wall, see Appendix 1: Literacy Strategies.

TEACHER'S NOTE: Some language in this unit may require particular care and sensitivity, depending on students' individual experiences. For example, the concept of migration may be familiar to students from other contexts, such as history (e.g., migration during the Dust Bowl or during wars) or from current global human migration.

- Have groups work together to share their understanding of each model and to develop a scientific question that could be answered by each model. To support students' discussion, you may wish to use optional Visual Aid 2.1, "Developing Communication Skills," to help guide student interactions. Visual Aid 2.1 is a tool to help students effectively participate in class discussions by providing sentence starters that students can use to initiate a conversation and express their ideas. For more information about Developing Communication Skills, see Appendix 1: Literacy Strategies.

- After group members discuss their thinking, each student can record their own ideas to complete Table 1 on Student Sheet 2.1. There does not need to be agreement among group members. Sample student responses are located at the end of this activity.

- After group members identify at least one scientific question that can be investigated for each model, each student can record the questions in the last row of Table 1 on the student sheet.

4 **Have groups share their scientific questions with the class.**

- Remind students that the scientific questions they generate should be questions that could be investigated using each model (and are not questions about the model itself).

- For each of the four models, make a list of scientific questions that students generated. For example, for Scientific Model 1, students might generate scientific questions such as: *If the polar bear population continues to decline due to climate change, is it possible that the population of subarctic seals and common eiders will begin to increase? Will reduced sea ice reduce the arctic seal population? Is there competition between the two seal species?*

- To figure out if a model can answer a scientific question, students can compare the question to the model's purpose and scope (e.g., the factors it includes). You may want to review ways in which a model can be used to address a scientific question, such as by explaining a phenomenon or predicting a future outcome.

- Ask, Can one scientific model be used to answer different scientific questions? Students should recognize that the list of scientific questions generated by the class for a single model means that the answer is yes.

5 **In Procedure Part B, hand out both sets of cards to each group.**

- Facilitate the engagement of students with learning disabilities and neurodiverse learners by providing targeted support. Consider how to best adapt the activity to the needs of your particular student population. Students who need more time processing language (such as students with dyslexia) can be provided with a copy of the cards in advance of the activity.

- There are 4 Scientific Question cards and 4 Scientific Model cards. Students are asked to identify which models could be used to answer the scientific question on each card and record their responses in Table 2 of the student sheet. It is important that students understand that more than one model can be used to investigate a particular question—there is not a one-to-one correspondence between the cards.

- Highlight the idea that a scientific question may be addressed by more than one scientific model.

6 **Have students share their own scientific questions about species distribution.**

- Have students share with the class the scientific questions they would like to have answered about species distribution. For example, students may be interested in how bird migration is affected by increasing numbers of people living in urban (vs. rural) areas.

- While student responses will vary, possible questions may include:

  What will happen to our local oak trees in the future? What effect do invasive species such as silver carp have on local fish populations such as largemouth bass? Do large-scale wildfires have a permanent effect on global air quality?

- Have students share the models they brainstormed that could help address a scientific question about species distribution, such as a computer model that could incorporate changing patterns of urbanization and its effect on the migration of birds.

- While student responses will vary, one possible response is:

  The future of our local oak trees could be modeled by creating a computer model that includes historic data on temperature, water availability, tree diseases, and soil quality. The model could exclude factors such as competition and predation, since people have planted these trees and they are also the ones who could remove them. Assuming that people are not going to plant more trees or remove the trees, the model could predict how the identified factors will change in the future and affect the future population and health of oak trees.

SYNTHESIS OF IDEAS (10 MIN)

7 **Review the relationship between scientific models and scientific questions.**

- Summarize the key takeaways: a single scientific model can be used to answer different scientific questions, and a scientific question may be addressed by more than one scientific model.

- Highlight the idea that the relationship between scientific models and scientific questions is cyclical: scientific questions are used to construct models to help explain, predict, and test ideas. Models can then generate new scientific questions as a result of simplifying complex phenomena, refining existing models, and producing data.

- Review the idea that models may be represented as drawings, graphs, equations, three-dimensional structures, or words. Other familiar examples of models include weather maps and planetary globes. Different types of models are best utilized for different types of questions.

- As needed, review student responses to Student Sheet 2.1.

- Depending on your student population, you may wish to review the model in Build Understanding item 2. It is an expanded version of the models first presented in Activity 1. It is a type of model that is sometimes referred to as a feedback loop, where change in one part of a system triggers a specific response in another part of the system. As needed, explain the meaning of arrows as well as +/– signs in this type of model. You may need to explain that an increase in deaths is a negative effect.

8 **Use optional Student Sheet 1.3, "Unit Concepts and Skills," to help track important concepts of the unit.**

- You may wish to have students revisit optional Student Sheet 1.3, "Unit Concepts and Skills," and add information about scientific questions and their relationship to scientific models.
- Highlight how the activity helped students address the Guiding Question: *How are scientific models used to answer scientific questions?* Develop the idea that different scientific questions about a single system may be best addressed by different scientific models. A single system, such as a forest or a human body, is too complex to capture perfectly in one model.

EXTENSION (10 MIN)

9 **Use the Extension as an opportunity for advanced learning.**

- Students can look online to further investigate scientific models and ways in which they are being used to investigate scientific questions. Note that this unit provides examples of conceptual, mathematical, and computer models (seen later in the unit) but does not utilize physical models with which students are typically more familiar and which they may have described in the Getting Started discussion in Activity 1. You may wish to use this Extension as an opportunity to provide additional examples of physical models if needed.

SAMPLE STUDENT RESPONSES

BUILD UNDERSTANDING

1. **A team is developing a population model for bass fish in a local freshwater lake ecosystem. The team decides to focus only on two key factors: the population size of bass fish and water temperature.**

   a **Identify at least two factors of the real-world lake system that the team is leaving out of their model.**

   Possible responses include:
   water quality, predators, food availability, competition, and disease.

   b **Explain how excluding these factors might lead to an inaccurate prediction about the bass population.**

   One or more of these factors may be having a greater impact on the bass population than water temperature. Not including them in the model could result in attributing population change to the wrong factor.

   c **If the team's scientific question is *How does the bass population size change in response to changes in water temperature?*, do you agree with the focus of their model? Why or why not?**

   Yes, because then the model is looking specifically at the effect of water temperature on the population. The model can help determine if there is a relationship and, if so, what that relationship is (positive or negative).

② **The following diagram is another type of model that shows that a change in one part of a system causes a specific response in another part of the system.**

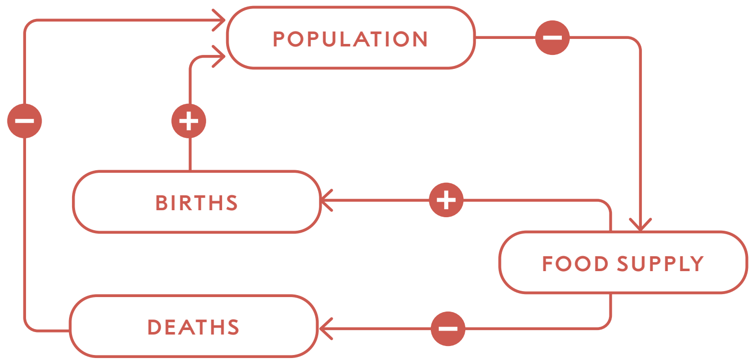


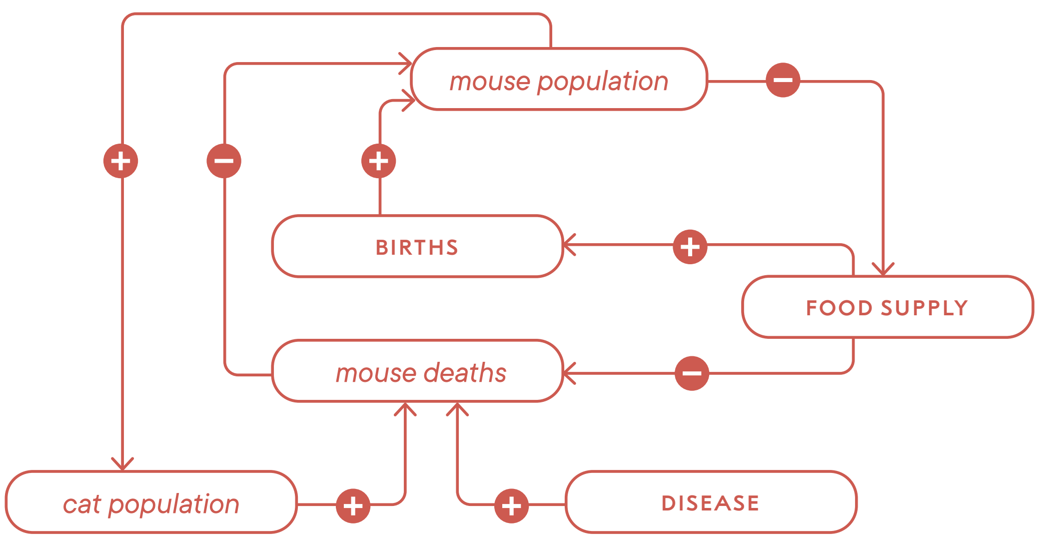
FIGURE 2.5
Population model diagram showing relationship between population, births, deaths, and food supply

`Factors such as birth rate, death rate, and food supply can affect the size of a population. For example, when there is more food (+), there can be an increase in births, which increases (+) the population.`

a **According to the model, how would an increase in population affect the food supply?**

An increase in population would cause a decrease in the food supply.

b **Revise this model to show the possible effect of at least two additional factors on a population of mice.**



c **List at least one scientific question that could be investigated by your revised model.**

Sample questions include:
If the mouse population increases, does the cat population increase at the same time? Does the density of the mouse population affect the birth rate? When the mouse population is high, does competition for food cause an increase in deaths?

CONNECTIONS TO EVERYDAY LIFE

3. **Different mapping apps provide different models of the geographic layout of Earth's surface. For example, one model, used for navigation, can tell you the best way to get from one place to another by car, foot, or public transportation as well as an estimate of how long each will take. Another model shows satellite photographs with labels to identify cities and country boundaries. Take a moment to go online to explore both of these mapping models.**

   a **What factors are included in a satellite map model but not in a navigation map model?**

   A satellite model includes geographic features such as mountains and what Earth really looks like from above.

   b **What factors do both models include?**

   Rivers, towns, large roads.

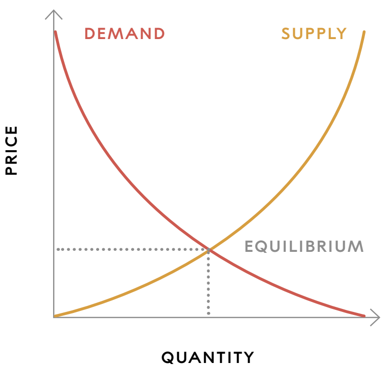
   c **Given these differences, what is one question that a satellite map model can help address but a navigation map model cannot?**

   Sample responses include:
   Which regions have more green plants vs. dry earth? How widespread are forests in this area? How does the color of deserts vary in different states?

   d **What is one question that both models address equally well?**

   What is the direct distance from London, England, to Cairo, Egypt?

4. **Other fields of study also use models. The graph to the right is one that is commonly used in economics to model the relationship between the price of goods and services based on the supply and demand for them. A clothing retailer uses it as a model to set the price for a popular vintage T-shirt.**



   a **When the supplier sets the price exactly at the equilibrium point, what is the model predicting will happen to the number of T-shirts sold?**

   The number of T-shirts sold will exactly match the supply of available T-shirts.

   b **Identify one limitation of this model.**

   HINT: Consider what might happen if the T-shirt became a viral trend on social media.

   One limit of this model is that it does not address changing demand. For example, a T-shirt that goes viral online suddenly has a high demand and sells out (there is not enough supply).

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STUDENT SHEET 2.1 | INVESTIGATING SCIENTIFIC MODELS | NAME

Table 1: Describing Four Scientific Models

	MODEL 1	MODEL 2	MODEL 3	MODEL 4
Species				
Location				
Factors included in the model				
Model prediction(s)				
Scientific question				

Table 2: Asking Scientific Questions

Scientific Question	This scientific question could be investigated by which model(s)? Explain your reasoning.
CARD A How will the distribution of a species change over time?	
CARD B What role does food availability play in the population size of a species?	
CARD C What effect does temperature have on the suitability of a habitat for a species?	
CARD D How are changes in global climate likely to affect predator–prey relationships?	

STUDENT SHEET 2.1 | INVESTIGATING SCIENTIFIC MODELS | NAME SAMPLE STUDENT RESPONSE

Table 1: Describing Four Scientific Models

	MODEL 1	MODEL 2	MODEL 3	MODEL 4
Species	*Polar bear*	*Monarch butterfly*	*Canada Jay*	*European common frog*
Location	*Arctic*	*North America*	*Northern Canada*	*Finland*
Factors included in the model	*Populations of polar bears, arctic seals, common eiders, subarctic seals, climate*	*Butterfly distribution, climate, food availability for larvae*	*Canada jay distribution, climate, wildfire patterns, vegetation*	*Habitat suitability, breeding sites, climate*
Model prediction(s)	*Less polar bear predation on Arctic seals; more predation on subarctic seals, common eiders as climate changes*	*Geographic range moves northward as average temperatures increase over time*	*Distribution directly affected by climate, distribution indirectly affected by wildfire patterns and vegetation*	*Increased suitable habitat as average temperatures increase over time*
Scientific question	*Will the arctic seal population stay the same with decreased polar bear predation and less sea ice habitat?*	*Why is there a greater likelihood of monarch butterflies in Canada with severe climate change vs moderate change?*	*Will an increase in wildfires reduce the population of Canada jays in Northern Canada?*	*How large can the population of European common frogs get if all sites are available for breeding?*

CONTINUED

Table 2: Asking Scientific Questions

Scientific Question	This scientific question could be investigated by which model(s)? Explain your reasoning.
CARD A How will the distribution of a species change over time?	• *Model 2 predicts the change in the monarch butterfly distribution over time.* • *Model 3 predicts the change in Canada jay distribution over time.* • *Model 4 predicts the change in European common frog habitat suitability over time, which is likely to affect its distribution.*
CARD B What role does food availability play in the population size of a species?	• *Model 1 predicts changes in predator–prey relationships and polar bear population size.* • *Model 2 incorporates the food availability for butterfly larvae in its model.*
CARD C What effect does temperature have on the suitability of a habitat for a species?	• *Model 1 predicts the effect of climate change, which includes temperature, on polar bears.* • *Model 2 predicts the effect of climate change, which includes temperature, on monarch butterflies.* • *Model 3 predicts the effect of climate change, which includes temperature, on Canada jays.* • *Model 4 predicts the effect of climate change, which includes temperature, on European common frogs.*
CARD D How are changes in global climate likely to affect predator–prey relationships?	• *Model 1 predicts changes to polar bear predation.*

COMMUNICATION	SENTENCE STARTERS
to better understand	One point that was not clear to me was... What if we tried...? I have an idea. We could try...
to disagree	I see your point, but what about...? Another way of looking at this is... I'm still not convinced that...
to challenge	How do you reach the conclusion that...? What makes you think that...? How does it explain...?
to look for feedback	What would help me improve is... Does it make sense, what I said about...?
to provide positive feedback	One strength of your idea is... Your idea is good because...
to provide constructive feedback	The argument would be stronger if... Another way to do it would be... What if you said it like this...?

SCIENTIFIC MODEL 1

POLAR BEARS

Model of Predicted Climate Change Effects on Polar Bear Predation in the Arctic

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 2: Scientific Modeling
Activity 2: Scientific Model Cards

SCIENTIFIC MODEL 2

MONARCH BUTTERFLIES

Species Distribution Modeling (SDM) of monarch butterflies across North America in June under three different climate scenarios

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 2: Scientific Modeling
Activity 2: Scientific Model Cards

SCIENTIFIC MODEL 3

CANADA JAYS

Model of Predicted Climate Change Effects on Canada Jay Distribution in Northern Canada

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 2: Scientific Modeling
Activity 2: Scientific Model Cards

SCIENTIFIC MODEL 4

EUROPEAN COMMON FROGS

Species Distribution Modeling (SDM) of habitat changes for the European common frog in subarctic Finland

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 2: Scientific Modeling
Activity 2: Scientific Model Cards

SCIENTIFIC QUESTION A

How will the distribution of a species change over time?

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 2: Scientific Modeling
Activity 2: Scientific Question Cards

SCIENTIFIC QUESTION B

What role does food availability play in the population size of a species?

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 2: Scientific Modeling
Activity 2: Scientific Question Cards

SCIENTIFIC QUESTION C

What effect does temperature have on the suitability of a habitat for a species?

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 2: Scientific Modeling
Activity 2: Scientific Question Cards

SCIENTIFIC QUESTION D

How are changes in global climate likely to affect predator–prey relationships??

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 2: Scientific Modeling
Activity 2: Scientific Question Cards