ACTIVITY 9

Probabilistic Modeling

MODELING

A firefighting helicopter releases a water drop over a wildfire.

9: PROBABILISTIC MODELING

GUIDING QUESTION

How can probabilistic reasoning be used to predict an outcome?

INTRODUCTION

Many factors affect air quality, some of which are unpredictable. For example, in the summer of 2017, a wildfire started near Brian Head, Utah. The fire quickly grew from 20 to 202 hectares (50 to 500 acres) in just 3 hours. Fortunately, the town had used probabilistic reasoning to plan for wildfire risks and had partially cleared 4 hectares (10 acres) of nearby forest to reduce fire spread. This strategy saved many homes, even as the fire spread almost 28,000 hectares (70,000 acres) in the opposite direction. A year later, resident Lynn Mulder said, "Circumstances including wind changes and the immediate responses of firefighting agencies and the availability of aircraft were vital, but we believe that this small area of clearance saved the town."

Predicting outcomes can be difficult when information is incomplete or uncertain. To help, scientists use probabilistic models. A probabilistic model is a tool that uses patterns in data to predict the likelihood of different outcomes. These models are often computer programs that can process large amounts of data. The computer programs then use probabilistic reasoning to predict the most likely outcomes, sometimes using artificial intelligence (AI). In this activity, you will investigate how a probabilistic model can help predict the spread of a fire.

National Oceanic and Atmospheric Administration (NOAA) researchers test a new AI fire monitoring and modeling technology at a research facility in Colorado.

CONCEPTUAL TOOLS

MATERIALS LIST

FOR EACH PAIR OF STUDENTS

- 2 NUMBER CUBES
- SET OF 8 COLORED PENCILS

FOR EACH STUDENT

- 2 STUDENT SHEETS 9.1 "Map of Koheegee Park"
- 2 STUDENT SHEETS 9.2 "Modeling Wildfire Spread"
- 2 STUDENT SHEETS 9.3 "Data from the Wildfire Model"

PROCEDURE

PART A: SIMULATING A WILDFIRE

1 With your partner, read the following fictional scenario.

PROBABILISTIC MODELS HELP STOP WILDFIRE SPREAD

A firefighter monitors a controlled burn.

A team at the Department of Forest and Fire Protection in Meso City has worked with local fire scientists to develop a new probabilistic model they say will help fight wildfires in Koheegee Park. The model was developed to predict how and where a wildfire will spread, using factors such as vegetation, wind patterns, and local geography. The team hopes to use the model to direct firefighting resources and prevent small fires from burning out of control. Rangers also plan to use the model for forest management. By knowing which areas of the forest are most vulnerable to fires, they can perform controlled burns to remove dry vegetation. Controlled burning is a form of forest management that burns off underbrush, dead trees, and other dry vegetation in order to reduce wildfire risk and maintain forest health.

2 Imagine that a wildfire has just started in the middle of Koheegee Park. As a fire scientist at the Meso City lab, your job is to predict how the fire will spread over the next 8 hours, using the Wildfire Model.

   a Examine the map on Student Sheet 9.1, "Map of Koheegee Park," and the location of the three fuel sources within the park. Label the fire on this student sheet as Fire A.

   b On Student Sheet 9.2, "Modeling Wildfire Spread," draw your prediction of the general area you think the fire will spread the most over the next 8 hours and list the factors that you considered when making your prediction. Label the fire on this student sheet as Fire A.

3 With your partner, read the guidelines for conducting the Wildfire Model in Table 9.1.

4 With your partner, conduct the model by using the information in Table 9.2 to determine:

   a the probability of each wind direction.

   b the probability of each wind speed.

   c the fuel type that is least likely to spread a fire.

HINT: You may want to revisit the Science Review on probability found at the end of Activity 1.

5 With your partner, use the Wildfire Model to simulate fire spread for Hours 1–8. For each hour, you will:

   a complete each action in the order listed in Table 9.2.

   b record the wind direction, wind speed, and fuel sources on Student Sheet 9.3, "Data from the Wildfire Model." Label the fire on this student sheet as Fire A.

   c track the spread of the fire on an hourly basis by coloring squares on the map on Student Sheet 9.1. Use the colors indicated in the first column of Student Sheet 9.3 to represent the fire spread during each hour.

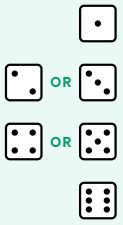
6 On Student Sheet 9.2, sketch the shape and direction that the fire spread after Hour 8 and describe the factors that had the greatest influence on the spread of the fire.

7 Share your results and your wildfire map with the class.

TABLE 9.1
Wildfire Model

- Every round represents 1 hour.
- The fire will start in the middle square on the map (with the fire icon) prior to Hour 1.
- Once a square catches on fire, it will continue to burn all 8 hours (throughout the model).
- The fire cannot spread onto squares that are already burning.
- The fire cannot spread across the river (except when strong winds cause a firestorm).

TABLE 9.2
Conducting the Wildfire Model

FACTOR	ACTION
Wind direction	The fire spreads 1 square in the direction of the wind **from every burning square.** Roll a number cube to determine the wind direction:  → **N** OR → **E** OR → **S** → **W**
Wind speed	Roll a number cube for the wind speed:  → 5 mph No additional spread from wind.  → 15 mph The fire spreads 1 more square in the direction of the wind **from every burning square.**  → 30 mph Firestorm! The fire spreads 3 more squares in the direction of the wind **from every burning square**. If the fire reaches the river, it crosses to the other side because embers are blown by the strong winds. The river does not count as a square.
Fuel source	Some fuel sources spread fire to surrounding areas. **For every burning square,** the fire spreads as follows: **Trees** → The fire does not spread to any additional squares. **Grasses** → The fire spreads 1 additional square in the direction of the wind. **Dry vegetation** → The fire spreads 1 additional square in every direction.

PART B: CONTAINING THE FIRE

8 Imagine you have a chance to fight a wildfire starting at the same location in Koheegee Park as you did in Procedure Part A. Your goal is to minimize the spread of the fire. Use your knowledge of the Wildfire Model and the map of Koheegee Park to decide where to send resources to stop the fire.

- **a** Label your second copies of your student sheets as Fire B.
- **b** On your second copy of Student Sheet 9.2, sketch your prediction of the general area you think the fire will spread the most in 8 hours and list the factors you considered when making your prediction.
- **c** Repeat Procedure Step 5 for Hour 1, recording the data on your second copy of Student Sheet 9.3 and tracking the spread of the fire by coloring squares on your second copy of Student Sheet 9.1.
- **d** **Before completing any actions for Hours 2–8**, you may send a firefighting helicopter to make a water drop onto one square of fire. Fire cannot spread into or out of this square in all future hours. Choose the square (on Student Sheet 9.1) where you would like to have the water drop and mark it with an X.
- **e** Repeat Step 5 for Hours 2–8 and then repeat Step 6 after Hour 8.

9 Compare your results with the results from another pair of students. Determine:

- in which direction the fire moved the most.
- what factor(s) most influenced the outcome.
- how the different factors interacted in a way that caused the fire to spread.

BUILD UNDERSTANDING

1. Based on the Wildfire Model from this activity, make a recommendation to Koheegee Park Rangers about what areas would benefit from controlled burning. Support your reasoning with evidence from the model.

2. Kairoba City is north of Koheegee Park, while Meso City is east of Koheegee Park. According to the Wildfire Model, which city is more likely to have poor air quality as a result of the fire in Koheegee Park? Explain your reasoning.

3. Consider the factors that contribute to wildfire in the model.
   - **a** What are some ways that the model is realistic?
   - **b** What are some other factors that could affect wildfire spread that are not included in the model?
   - **c** How is the Wildfire Model an example of a probabilistic model?

4. Suppose you want to use the Wildfire Model to plan water drops to contain a fire in Koheegee Park. You have numerous helicopters and can drop water on as many locations as you want. However, each water drop costs $2,000 and can be dangerous to firefighting crews that will need to navigate difficult weather conditions and terrains.
   - **a** A probabilistic wildfire model predicts a fire to spread south of the park. People there are warned, and firefighters are sent to assess the situation and do a water drop if needed. When they arrive, there is no fire. What might be one consequence of this false positive?
   - **b** Describe how a probabilistic wildfire model could result in a false negative and what one consequence of this false negative could be.

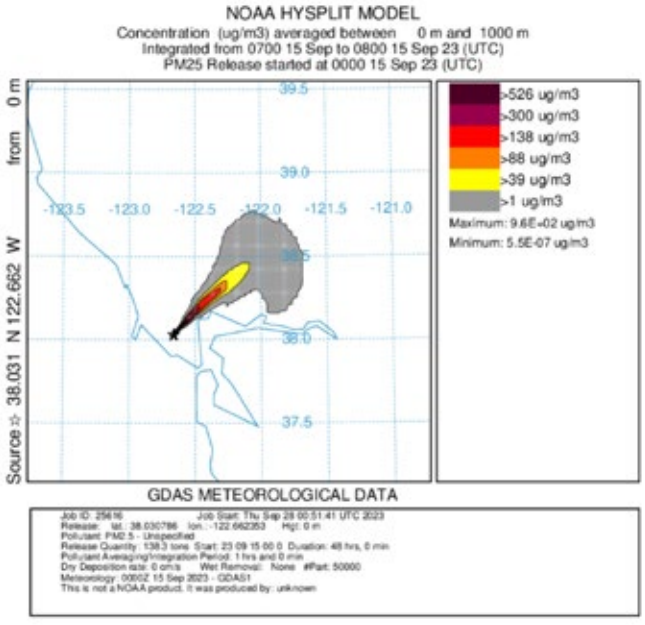
5. Imagine 2 different wildfire models are being tested to make predictions about local wildfires. Model A predicts that a fire at a particular location will burn between 1,000 and 2,000 hectares (2,471–4,942 acres) under certain wind and weather conditions and has a 95% confidence level. Model B predicts that a fire at the same location will burn between 1,000 and 2,000 hectares under certain wind and weather conditions and has a 90% confidence level. Explain which model you would prefer to use when making wildfire predictions for this area and why.

CONNECTIONS TO EVERYDAY LIFE

⑥ Probabilistic reasoning is a key component of several decision-making systems, including those used in AI tools. For example, an image-generating AI tool learns to make images by looking at millions of images in a database. It finds patterns in the data it is given and uses those patterns to project how things should look. A problem arises because the data the AI learns from can be unbalanced or biased. For example, if most of the pictures the AI learns from show only certain types of people (such as men as doctors and women as nurses), the AI might recreate those stereotypes in its images. Discuss with your class whether this represents random error, systematic error, or both in the AI image-generator system.

EXTENSION

The spread of smoke can also be modeled using probability. Evaluate where smoke from a controlled burn spreads over an 8–hour period in your own local area, using National Oceanic and Atmospheric Administration's (NOAA) online HYSPLIT computer model.



KEY SCIENTIFIC TERM

probabilistic model