ACTIVITY 1

Investigating Probabilistic Reasoning

CARD-BASED INVESTIGATION

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ACTIVITY SUMMARY

In the context of air quality and its potential health effects, students use probabilistic reasoning to determine the most likely causes of various respiratory illnesses. Students compare the symptoms of four fictional students to the information in a respiratory symptom chart. They explain their reasoning and begin to identify the limits of the data. Additional information allows students to reassess their findings. The concept of scientific uncertainty as well as false positives and false negatives is introduced.

ACTIVITY TYPE
CARD-BASED INVESTIGATION

NUMBER OF 40–50 MINUTE CLASS PERIODS
1-2

KEY CONCEPTS & PROCESS SKILLS

1 When there is scientific uncertainty in data, probabilistic reasoning is a method for determining the likelihood of different outcomes on which to base a decision.

NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:
Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (*Science and Engineering Practice: Analyzing and Interpreting Data*)

CONCEPTUAL TOOLS

VOCABULARY DEVELOPMENT

false negative
a type of error when something is incorrectly identified as absent but is actually present

false positive
a type of error when something is incorrectly identified as present

particulate matter (PM)
microscopic particles suspended in the air that are so small that they can be inhaled

PM2.5
particulate matter in the air that has a diameter of 2.5 micrometers (μm) or less, also known as fine particles

probabilistic reasoning
a way of making predictions or drawing conclusions based on how likely something is to happen, especially when there is not enough clear data

scientific uncertainty
an understanding that there are limits to data and conclusions about the natural world, and additional data and/or investigations can lead to increased surety or new questions

trade-off
a desirable outcome given up to gain another desirable outcome

TEACHER BACKGROUND INFORMATION

Probabilistic Reasoning

Probabilistic reasoning is a method of scientific inference that uses probability theory to analyze and interpret data, particularly when dealing with uncertainty or incomplete information. Unlike traditional deductive logic, which assumes absolute truth, probabilistic reasoning acknowledges that many scientific observations are subject to variability and randomness. Scientists can make informed conclusions based on the likelihood of different outcomes rather than absolute certainty. One key aspect of probabilistic reasoning is that prior knowledge can be combined with new data to calculate the probability of a hypothesis, enabling scientists to continuously refine their understanding as more evidence becomes available.

Probabilistic reasoning is commonly used in everyday situations. People intuitively consider the available evidence, think about uncertainties, and estimate the chance that something is true. Science is based on the very same process but requires the use of rigorous, established methods before a conclusion can be reached. Although there are more, three of these methods are described in this unit: (1) reducing the scientific uncertainty of data, (2) quantifying the remaining uncertainty afterward, and (3) using confidence levels when analyzing data. Together, these methods are designed to increase one's certainty in the accuracy of data from scientific studies and the conclusions that can be drawn from that data. Probabilistic reasoning is widely used in scientific fields such as genetics, medicine (diagnostic testing), climate science (predicting weather patterns), particle physics (interpreting experimental results), and ecology (modeling species distributions).

Air Quality

Air pollution occurs in many forms but generally refers to gas and particulate contaminants in the atmosphere. The most common air pollutants are particulate matter (PM), ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. These pollutants can harm health and the environment and cause property damage. Primary pollutants are released directly into the air, while secondary pollutants result from primary pollutants reacting with other substances in the air. Ozone and acid rain are examples of secondary pollutants. Particulate matter can be both a primary and a secondary pollutant.

Ground-level ozone can cause health problems (such as lung irritation) in contrast to ozone high in the stratosphere, where it is protective of health since it blocks incoming solar UV radiation. (The hole in the ozone layer was an environmental issue discovered in the 1980s—by banning human-emitted chlorofluorocarbons (CFCs), the hole recovered and is one of the most successful global environmental efforts.)

In the United States, the Clean Air Act, first enacted in 1963, is the federal law that regulates air emissions. It also authorizes the Environmental Protection Agency (EPA) to regulate outdoor air pollutants by developing criteria based on human and environmental health. The EPA also raises awareness of indoor air pollution, which involves exposures to particulates, carbon oxides, and other pollutants carried by indoor air or dust. Examples include household products and chemicals, off-gassing of building materials, allergens (mouse droppings, mold, pollen), and tobacco smoke.

PM2.5 and Human Health

Health studies reveal a strong association between particle pollution exposure and health risks. Health effects include cardiovascular effects, such as cardiac arrhythmias and heart attacks, and respiratory effects, such as asthma attacks and bronchitis. Exposure to particle pollution can result in increased hospital admissions, emergency room visits, absences from school or work, and restricted activity days, especially for those with preexisting heart or lung disease, older people, and children. The health effects of wildfire smoke can range from eye and respiratory-tract irritation to more serious disorders, including reduced lung function, exacerbation of asthma and heart failure, and premature death.

The size of particles is directly linked to their potential for causing health problems. Fine particles (PM2.5) pose the greatest health risk. These fine particles can get deep into lungs, and some may even get into the bloodstream. Exposure to these particles can affect a person's lungs and heart. PM10 particles have diameters that are generally 10 micrometers (μm) and smaller and, therefore, include PM2.5 particles but also include some larger particles such as dust.

Risk levels vary throughout a lifetime, generally being higher in early childhood, lower in healthy adolescents and younger adults, and increasing in middle age through old age as the incidences of heart and lung disease and diabetes increases. Factors that increase the risk of heart attacks, such as high blood pressure or elevated cholesterol levels, may also increase the risk from particle exposure.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 1.1 "Developing Communication Skills"
- VISUAL AID 1.2 "Understanding Conceptual Tools"
- VISUAL AID 1.3 "Complete Symptom Chart" (OPTIONAL)
- VISUAL AID 1.4 "PM2.5 and Human Health" (OPTIONAL)

FOR EACH GROUP OF FOUR STUDENTS

- SET OF STUDENT HEALTH CARDS (4 CARDS)
- SET OF STUDENT FOLLOW-UP CARDS (4 CARDS)

FOR EACH PAIR OF STUDENTS

- SET OF COLORED PENCILS (2 DIFFERENT COLORS)

FOR EACH STUDENT

- 2 STUDENT SHEETS 1.1 "Analyzing Symptoms"
- STUDENT SHEET 1.2 "Symptom Chart"
- STUDENT SHEET 1.3 "Unit Concepts and Skills" (OPTIONAL)
- STUDENT SHEET 1.4 "Writing Frame: Evidence and Trade-Offs" (OPTIONAL)

Prepare a class set of Student Health cards and Student Follow-Up cards. Note that students will not receive both sets of cards at the same time. You may wish to create stacks of Student Follow-Up cards for each fictional student so pairs can independently collect the appropriate Student Follow-Up card during Procedure Step 7.

Preview an approximately 9-minute video titled *Probabilistic Thinking* produced for the college course Sense and Sensibility and Science, from which this high school course is adapted. Note that the script was written and narrated by 2011 Nobel Prize in Physics winner Dr. Saul Perlmutter.

TEACHING NOTES

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

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

GETTING STARTED (5–10 MIN)

1 **Elicit students' prior knowledge about air quality.**

- One approach to eliciting students' prior knowledge is to create a class list of words and phrases that students associate with air quality. Students may have personal experience with and prior knowledge of issues related to air quality. Engaging students about their experiences can create a stronger foundation for learning. Support students, particularly those with varied life experiences, in sharing their prior knowledge of and personal experiences with this issue. Specifically validate funds of knowledge—not just textbook knowledge but also family or cultural insights, practices, and personal histories—by eliciting students' observations and experiences as assets to building understanding. Throughout this unit, encourage students to respond to any topics or questions that arise to which they feel a personal connection—during small-group or class discussions, when students respond to relevant Build Understanding items, and/or when they write reflections in their science notebooks.

TEACHER'S NOTE: Some topics in this unit may require particular care and sensitivity, depending on students' individual experiences. For example, some students may have severe asthma or have experienced loss due to wildfires (a topic raised multiple times in the unit).

2 **Read the Introduction and the Guiding Question (*How do you make predictions with incomplete information?*), either as a class or individually.**

- Connect students' prior knowledge and ideas about air quality to the information provided in the Student Book Introduction. Student ideas most likely will include a greater breadth of topics related to air quality than is addressed in the Introduction. You may want to ask, What are you most interested in learning? Student responses will vary but may include wanting to know the exact effect of air pollutants on health, an assessment of their local air quality (which will be further investigated in Activities 3 and 4), or what causes poor air quality. Point out that the Introduction sets the stage for the general focus of this unit.

- Review the highlighted terms provided in the Introduction, as well as the relative size of the particulate matter of 2.5 micrometers (μm), as needed. These terms are defined at the start of the activity but are developed conceptually over the course of this and the following activities. It is not necessary to spend significant time reviewing the meaning of these terms at the start of the activity; instead, support students to develop meaning during the activity procedure and synthesis of ideas.

- Support students, particularly emerging multilingual learners, in sensemaking and language acquisition by reviewing the terms in this activity and supporting the construction of a word wall. At the start of this activity, record the terms *particulate matter (PM), PM2.5*, and *probabilistic reasoning*. For more information on a Word Wall, see Appendix 1: Literacy Strategies.

PROCEDURE SUPPORT (40 MIN)

3 **Present the factual article found in Procedure Step 1.**

- This activity explores the relationship between wildfires and indoor air quality. The article presented in Step 1 can be shared with the class in multiple ways. Read the article aloud to the class or have individual students read it aloud while others follow along with the text (either as a whole class or in small groups).
- Reading the article aloud can better support comprehension for many students, including neurodiverse students and emerging multilingual learners who often have more highly developed listening and oral skills than reading comprehension skills. Alternatively, students can read the article independently.

4 **Distribute a set of 4 Student Health cards to each group of 4.**

- It may be helpful to preread the cards with emerging multilingual learners before diving into the procedure.
- Explain that first, partners will read and analyze the symptoms of one fictional student and work through the activity together. Then, they will examine the symptoms of a second fictional student. The other pair in the group will complete the same process for the other two fictional students. In Procedure Step 12, both pairs will share their findings as a group.

TEACHER'S NOTE: Do *not* provide students with the Student Follow-Up cards at the start of the activity. Students will receive those cards in Procedure Step 7.

- In Procedure Step 3, provide each student with two copies of Student Sheet 1.1, "Analyzing Symptoms," (one copy for each fictional student) and one copy of Student Sheet 1.2, "Symptom Chart." Also provide each pair with a set of two different-colored pencils. Mention to students that they will use one color pencil on Student Sheet 1.2 for one fictional student and a different color pencil for a second fictional student. They can make a key on the student sheet for the color they use for each fictional student. After pairs discuss their thinking, each student can record their own ideas on Student Sheet 1.1 and 1.2. Partners do not need to agree.

- Sample student responses for all four fictional students are located at the end of this activity.
- Have student groups work together to share their ideas. To support students' discussion, you may wish to use optional Visual Aid 1.1, "Developing Communication Skills," to help guide student interactions. Visual Aid 1.1 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. You may want to address student discomfort with navigating disagreement with peers and provide additional guidance, for example, by modeling a conversation in which two individuals disagree respectfully. For more information about Developing Communication Skills, see Appendix 1: Literacy Strategies.

5 **When students are ready for Procedure Step 7, have them collect the appropriate Student Follow-Up card for their fictional student.**

- Students record updated recommendations (even if it remains the same) and reasoning.
- In Procedure Step 10, students are asked to assess how sure they are of their diagnoses, using a scale of 0–100%, where:

0% = there is no chance their diagnosis is correct
50% = their diagnosis is just as likely to be wrong as it is to be correct
100% = they are absolutely sure that their diagnosis is correct

You may need to support students to understand that they are making an estimate based on the available evidence. Their estimates will vary, though estimates should likely be above 50% (they have enough evidence that they are not simply guessing) but below 100% (there is not enough evidence to make a definitive diagnosis).

SYNTHESIS OF IDEAS (20 MIN)

6 **Highlight the idea that students made determinations about student health despite uncertainty in the data.**

- Use Student Sheet 1.1 to discuss comments and questions that students had about the evidence. Ask students to share some of the questions they had for the fictional students. Highlight these questions as an example of identifying uncertainty in the data.
- Review the concept of scientific uncertainty by having students think of a time when they were uncertain about a decision they had to make. Then ask, What did you do to deal with the uncertainty? Students' responses may vary but should include information about what was uncertain, how it was managed, and what affected the decision. Contrast the usage of uncertainty in examples from everyday life, as mentioned here, with the concept of scientific uncertainty used throughout the unit. Remind students that the term *uncertainty* has a more specific meaning in science. Scientific uncertainty is not about being unsure, but about an understanding that there are limits to data

and conclusions about the natural world, and additional data and/or investigations can lead to increased surety or new questions. This is an essential part of scientific work and includes reasoning about the probability that conclusions drawn from limited unclear data are likely to be true.

- Ask, Do you have enough information to diagnose a student and feel 100% sure of your diagnosis? Point out that students were able to make diagnoses with some level of surety despite the limited data. In some cases, this could lead to an incorrect conclusion; communicate that it is okay to be wrong in their conclusions. In science, confidence in an explanation grows with increasing amounts of relevant, accurate, and reliable evidence.

- Discuss which factors, such as additional symptoms or information about a student's environment, can reduce uncertainty in their diagnoses. In the case of medicine, doctors have access to additional data—including medical knowledge, access to many medical tests and test results, and awareness of the frequency of different illnesses in the community. Use Build Understanding item 2 to introduce false positives and false negatives—even in the process of gathering additional data, errors can be introduced.

- You may wish to share optional Visual Aid 1.3, "Complete Symptom Chart," which provides additional symptoms for the respiratory illnesses that were investigated in the activity, as well as Respiratory Syncytial VIrus (RSV). You may wish to discuss how common certain symptoms are for a particular illness and/or how variable illness can be. For example, many of the symptoms are common in cases of COVID–19, yet many people have few or no symptoms. Nonetheless, it is possible to make diagnoses with some level of certainty.

- Students may want to talk about their own experiences by responding to questions such as, How similar were the student's actions to your own when you had similar symptoms? What do you think the follow-up should be for each patient after their symptoms went away or were treated? Allow students to share their experiences as appropriate. Engaging students about their experiences can create a stronger foundation for learning. Specifically validate funds of knowledge (not just textbook knowledge, but also family or cultural insights, practices, and personal histories) by eliciting students' observations and experiences as assets to building understanding.

7 Revisit the article presented in Step 1.

- Have students share their growing understanding of the relationship between air quality and human health. Ask, Did the student health data support the title of the article: "Increase in Wildfires May Affect Respiratory Health?" Why or why not? Have students support their responses with evidence. For example, a student may agree with the headline because it was possible that Student 4: Ali had asthma that was triggered by poor air quality. Students may also note that taking a patient's history can provide insight into illness, such as when Student 3: Tara appeared to have an allergic reaction to flowers. Other students may disagree because there was limited data provided in the activity with regard to the specific role of air quality in illness. You may wish to ask students to describe the type of evidence that could be gathered to address this question and brainstorm the type of studies that might be conducted.

- Highlight opportunities for metacognition—thinking about and understanding one's own thought processes—here and throughout the unit. Research has found that students show greater improvements in their learning when they are given opportunities to determine and evaluate their own learning. Ask, In what ways could knowing about your thinking process influence your decision-making skills? Encourage students to share their ideas. Some students may note that being more aware of their own thinking may make them more likely to expand their own ideas or make them more likely to change their minds. It may also help to enhance their skills at communicating their ideas.

8 **Use optional Visual Aid 1.4, "PM2.5 and Human Health," to review air quality and its potential impacts on human health.**

- You may wish to use Visual Aid 1.4 to review how this size of particulate matter can interact with the human respiratory system.
- You may also wish to provide additional context or information regarding air quality and other air pollutants. This unit will focus solely on PM2.5.

9 **Introduce the concept of trade-offs and how it applies to health-care decisions associated with air quality.**

- Introduce the idea that decisions about solutions to scientific and engineering problems often involve trade-offs. In Build Understanding item 3, students make a decision about the construction of an urgent care asthma center. Decision-making in the context of trade-offs includes the following key ideas:
  - Decisions often involve trade-offs.
  - Identifying trade-offs involves analyzing evidence.

The concept of trade-offs is used throughout the units in this curriculum, especially as part of the decision-making focus.

- A trade-off is a desirable outcome given up to gain another desirable outcome. In a decision involving trade-offs, something positive (or desirable) is given up to gain another positive (or desirable) outcome. Since many decisions involve trade-offs, students should understand that a perfect choice that maximizes all goals is often not possible. It is possible, however, to recognize and analyze the trade-offs associated with each decision.
- Provide an example of a trade-off. For example, when choosing to purchase a disposable or reusable water bottle, there are several benefits and trade-offs to consider. A consumer who chooses the disposable water bottle may want a cheap option that doesn't need to be cleaned or maintained. Disposable bottles are also easily shared with others, since they are not expected to be returned. However, in choosing the disposable water bottle, the consumer is contributing to environmental problems, such as increased energy use and higher amounts of solid waste in landfills if the bottle is not recycled. A consumer choosing to purchase a reusable water bottle may do so to save money over time, to save bottles from ending up in a landfill, and—by their example—to encourage others to purchase reusable bottles. However, this option has trade-offs as well, such

as the increased upfront cost of the reusable bottle and the need to clean and maintain the bottle. Neither choice is ideal, and both choices have positives and negatives. Identifying the trade-offs helps clarify the reasoning that is being applied to make a decision.

- Develop some examples of trade-offs in students' lives by brainstorming with the class a list of decisions they make every day that involve trade-offs. Choose one and talk through the associated trade-offs of deciding one way or another. This practice will familiarize students with ways to identify and consider trade-offs in this and subsequent activities.

- Optional Student Sheet 1.4, "Writing Frame: Evidence and Trade-Offs," provides additional support for students responding to Build Understanding item 3b in which they apply the concepts of evidence and trade-offs. A Writing Frame can support learners, particularly emerging multilingual learners, in decoding scientific ideas, constructing meaning, sensemaking, and language acquisition. This strategy, which has been deemed effective for emerging multilingual learners, was built on and adapted from strategies for English-proficient learners. You may wish to provide students with the Writing Frame to compose their responses or simply as a reference or checklist to help them organize how they will respond. Consider posting an enlarged version of the writing frame on a classroom wall for students to refer to now and in future assessments. For more information on a Writing Frame, see Appendix 1: Literacy Strategies.

TEACHER'S NOTE: The Writing Frame for this unit is identical in all activities, despite different issues being addressed. The sample student response is specific to the issue raised within an activity.

10 Discuss the conceptual tool of probabilistic reasoning.

- Discuss the role of probabilistic reasoning as a tool in a student's scientific toolkit. The scientific toolkit is intended to be a set of conceptual tools that can be applied to everyday life. With each new unit, students will add conceptual tools to their toolkits. Depending on your student population, you may wish to use optional Visual Aid 1.2, "Understanding Conceptual Tools," to review the use of the word *tool*, which is defined as an implement used to carry out a particular function. The word is commonly used to refer to construction tools such as hammers, levels, and tape measures. In a science classroom, examples of scientific tools include beakers, graduated cylinders, and microscopes. In this unit, scientific tools and technology are used to gather evidence—students consider conceptual tools, such as probabilistic reasoning, as a way of exploring the application of science to everyday life.

- You may want to help students distinguish the meaning of the term *probabilistic reasoning* from the term *probability*. The meaning of *probability* is a mathematical measure of the likelihood that a specific event will happen. A basic review of the concept of probability is found in the Science Review at the end of the Student Book activity.

- Use Connections to Everyday Life items 4 and 5 to review when it is useful to use probabilistic reasoning. You would not use probabilistic reasoning when you have complete confidence about the outcome of a situation. When dealing with well-defined, deterministic scenarios in which every piece of information is known and leads to a single, definite conclusion, there is no need to calculate probabilities as the outcome is already fully predictable.

- As students build understanding about the importance of probabilistic reasoning, they will build a conceptual tool about this idea in their minds and develop skills to utilize it at various points in the unit. You may wish to use optional Student Sheet 1.3, “Unit Concepts and Skills,” to help students organize their learning. This organizer is designed to help students reflect on their understanding of the conceptual tool, consider how they have used it to analyze problems throughout the unit, and how it may influence their decisions about unit topics.
- While a completed sample unit organizer is provided in this activity, students will not be able to complete it at this time; the ideas in the sample student response will be built over the course of the unit. At the end of this activity, students can add initial ideas about probabilistic reasoning.

EXTENSION (10 MIN)

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

In this extension, students review how scientists manage uncertainty and use probabilistic reasoning by watching the video *Probabilistic Thinking* narrated by Nobel Laureate Saul Perlmutter. After showing the video, hold a class discussion on the advantages and disadvantages of using probabilistic reasoning in everyday life.

SAMPLE STUDENT RESPONSES

BUILD UNDERSTANDING

The Build Understanding and Connections to Everyday Life items are intended to guide your understanding. Some of these items may be discussed with a partner, be part of a class discussion, or require an individual written response. Your teacher will guide you as to how these items will be used in your class.

1. **Doctors, like other scientists, try to identify and reduce sources of uncertainty in science.**

   a **What factors caused you to be uncertain about your diagnoses?**

   Limited information about a student, their symptoms, and the disease, as well as not being able to get additional test results.

   b **What factors caused you to reduce uncertainty in your diagnoses?**

   Information about a disease's symptoms, having more information about a student's symptoms, and knowing about other factors that could be affecting a student's health.

2. **Examine the data in the following table.**

TABLE 1.1
Evaluation of Over-the-Counter COVID-19 Tests, 2021

BRAND	PERCENT OF POSITIVE COVID-19 CASES CORRECTLY IDENTIFIED	PERCENT OF NEGATIVE COVID-19 CASES CORRECTLY IDENTIFIED
1	49.4%	100%
2	44.6%	100%
3	45.8%	97%
4	54.9%	100%

   a **A false positive is a type of error when something is incorrectly identified as present—for example, a positive COVID-19 test result when someone does not have COVID-19. A false negative is a type of error when something is incorrectly identified as absent but is actually present—for example, a negative COVID-19 test result when someone does have COVID-19. Based on Table 1.1, are over-the-counter COVID-19 tests more likely to result in a false positive or a false negative? Explain your reasoning.**

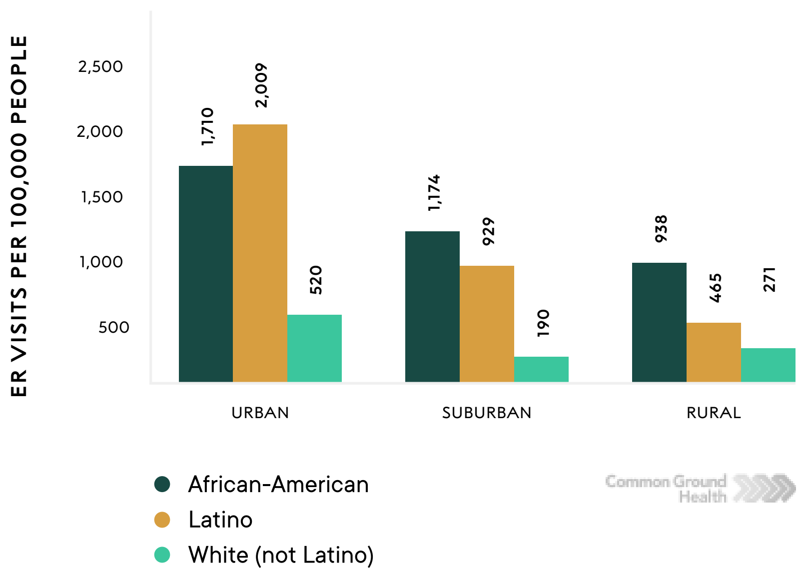
A false negative is more likely because COVID-19 is incorrectly identified as being absent when it is actually present. The range of correctly identified COVID-19 tests are from 44.6% to 54.9%. This means that about half of the people with COVID-19 would have a positive test result, while the other half would have a negative test result, even though they had COVID-19.

b Imagine that you were feeling unwell and had symptoms similar to those of COVID-19. You take an over-the-counter COVID-19 test, and the test result is negative. Use probabilistic reasoning to explain whether or not you should go to a friend's birthday party.

I should go to my friend's birthday party because it is extremely likely that I do not have COVID-19. Based on the data, over-the-counter COVID-19 tests are 97%-100% reliable if a person does not have COVID-19.

③ Examine the graph in Figure 1.2, which provides data about emergency room visits for a three-year period.

FIGURE 1.2
Emergency Room (ER) Visits for Asthma
in New York Finger Lakes Region, 2014–2016



a What can you conclude about the likelihood of emergency room visits for asthma?

From 2014–2016, people in urban areas are more likely to have emergency room visits for asthma than those living in suburban and rural areas. In every region, African-American and Latino populations are more likely to have emergency room visits for asthma than white populations.

b Imagine your state has the funds to build one urgent care asthma center. Would you recommend they build it in an urban, suburban, or rural area? Support your answer with evidence and identify the trade-offs of your decision. A trade-off is a desirable outcome given up to gain another desirable outcome.

I would recommend they build it in an urban area because the number of ER visits for asthma there is the highest. Since asthma interferes with breathing, it is important to have immediate care. My evidence is that the combined number of visits in the urban area was 4,239 compared to 2,293 in the suburban area and 1,674 in the rural area. Since more people live in an urban area, more people would have access to immediate care. The trade-off is that people in rural areas may be farther from any medical care and may experience more severe effects without immediate treatment.

CONNECTIONS TO EVERYDAY LIFE

④ **Which of the following are examples of probabilistic reasoning? Explain.**

a estimating the chance of getting stuck in a traffic jam based on the time of day

b deciding on where to have dinner based on your favorite food and the cost of the meal

c a basketball player calculating the odds of making a shot based on their past performance and the current situation on the court

d a doctor considering the likelihood of a specific disease based on a patient's symptoms and test results

e selecting a concert to attend based on which concert venue is the closest to where you live

f figuring out your chances of getting a job offer based on your qualifications and the competition for the position

The following are examples of probabilistic reasoning: a, c, d, and f.

a estimating the chance of getting stuck in a traffic jam based on the time of day

If a traffic jam has not yet happened, you can't know how much of a traffic slowdown might occur. You are making a prediction based on past events or experience.

c a basketball player calculating the odds of making a shot based on their past performance and the current situation on the court

A basketball player can't guarantee they will make the shot, so they have to make a prediction of how likely the shot is to be successful.

d a doctor considering the likelihood of a specific disease based on a patient's symptoms and test results

A doctor relies on information to assess and determine whether the disease is the most likely cause of illness, though there is a possibility of error based on how much or little information is available for the diagnosis.

f figuring out your chances of getting a job offer based on your qualifications and the competition for the position

You cannot know in advance if you will receive a job offer, but you can determine how well you match the requirements for the position. You can also determine the potential number of other qualified applicants to figure out if you are likely to be offered the job.

5. **Choose one example of probabilistic reasoning from item 4 and describe one action you could take to reduce scientific uncertainty in that example.**

You could reduce uncertainty in determining the likelihood of getting stuck in a traffic jam by gathering data about traffic patterns over a long period of time, such as a week or a month (or by checking traffic reports for any recent accidents).

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STUDENT SHEET 1.1 | ANALYZING SYMPTOMS | NAME

	STUDENT NUMBER AND NAME:	
Symptoms		
Most probable diagnoses	1	2
Reasoning	1	2
Two questions you'd like to ask the student		
Recommended course(s) of action		
What happened (based on Student Follow-Up card)?		
Course of action supported or not?		
Revisited diagnoses, reasoning, and level of sureness	1	2

	STUDENT NUMBER AND NAME: *Student 1: Serena*	
Symptoms	*• coughing for 2 weeks and after laughing hard or running* *• short of breath sometimes* *• feels fine otherwise*	
Most probable diagnoses	1 *Asthma*	2 *COVID*
Reasoning	1 *Coughing and shortness of breath are symptoms of asthma. Otherwise, feels fine.*	2 *Coughing and shortness of breath are symptoms of COVID, but no other symptoms of illness.*
Two questions you'd like to ask the student	*How long have you had these symptoms (from childhood or are they recent)?* *Have you taken an at-home COVID test?*	
Recommended course(s) of action	*• Avoid strenuous outdoor activities such as sports.* *• Take an at-home COVID test.* *• Wear a face mask when with others.* *• Consider seeing a doctor for a prescribed inhaler.*	
What happened (based on Student Follow-Up card)?	*Negative for COVID*	
Course of action supported or not?	*Yes*	
Revisited diagnoses, reasoning, and level of sureness	1 *Asthma because the COVID test was negative, and other symptoms suggest asthma. 80% likely it was asthma.*	2 *Might be good to check for allergies since they can trigger asthma. 15% likely it was COVID.*

	STUDENT NUMBER AND NAME: *Student 2: Marcus*	
Symptoms	• *fever* • *runny nose* • *chills*	
Most probable diagnoses	**1** *COVID*	**2** *Flu*
Reasoning	**1** *Fever, runny nose, and chills are all common symptoms of COVID; no other illness on the chart has all these symptoms as common.*	**2** *Fever, runny nose, and chills are all possible symptoms of the flu, but chills only occur in some cases.*
Two questions you'd like to ask the student	*How long have you been feeling sick?* *Have you taken an at-home COVID test?*	
Recommended course(s) of action	• *Take an at-home COVID test.* • *Isolate from other people as much as possible.* • *Wear a face mask when with others.*	
What happened (based on Student Follow-Up card)?	*Stayed home and symptoms eventually went away.*	
Course of action supported or not?	*Yes*	
Revisited diagnoses, reasoning, and level of sureness	**1** *COVID still possible but no COVID test results and a quick recovery, so 50% likely it was COVID.*	**2** *Equally likely that it was flu, so 50% flu.*

	STUDENT NUMBER AND NAME: *Student 3: Tara*	
Symptoms	• *sneezing* • *runny nose* • *headaches*	
Most probable diagnoses	**1** *Allergies*	**2** *COVID*
Reasoning	**1** *Sneezing, runny nose, and headaches are all possible symptoms of allergies; she also recently received flowers.*	**2** *Runny nose and headaches are symptoms of COVID, although sneezing is rare.*
Two questions you'd like to ask the student	*Do you have any other symptoms, like shortness of breath?* *How long have you had these symptoms (did they start after receiving flowers)?*	
Recommended course(s) of action	• *Ignore the symptoms and maintain routine activities.* • *Take an over-the-counter allergy medicine.* • *Take an over-the-counter headache medicine.*	
What happened (based on Student Follow-Up card)?	*Symptoms disappeared when flowers were thrown away.*	
Course of action supported or not?	*Yes*	
Revisited diagnoses, reasoning, and level of sureness	**1** *Symptoms went away when flowers were tossed, 99% likely it was allergies.*	**2** *Symptoms of illness quickly disappeared after flowers were thrown away; 1% likelihood of COVID.*

 SAMPLE STUDENT RESPONSE FOR STUDENT 4

	STUDENT NUMBER AND NAME: *Student 4: Ali*	
Symptoms	• *short of breath* • *headaches* • *watery eyes*	
Most probable diagnoses	1 *Asthma*	2 *COVID*
Reasoning	1 *Abrupt onset of symptoms with shortness of breath common for asthma, with headaches a possible symptom.*	2 *Shortness of breath and headaches are both common symptoms, but abrupt onset makes it less likely.*
Two questions you'd like to ask the student	*Have you been spending a lot of time outside?* *Do you wear a mask when outside?*	
Recommended course(s) of action	• *Stay indoors.* • *Avoid strenuous outdoor activities such as sports.* • *Wear a face mask when outdoors.*	
What happened (based on Student Follow-Up card)?	*Ali felt fine after the wildfire ended.*	
Course of action supported or not?	*Yes*	
Revisited diagnoses, reasoning, and level of sureness	1 *Symptoms went away but asthma is still possible, and symptoms could reappear; 75% likely it was asthma.*	2 *Symptoms of illness quickly disappeared after wildfire ended; 15% likely it was COVID.*

STUDENT SHEET 1.2 | SYMPTOM CHART | NAME

SYMPTOMS	ASTHMA	SEASONAL ALLERGIES	COLD	COVID-19	FLU
Onset of symptoms	gradual or abrupt onset of symptoms	abrupt onset of symptoms	gradual onset of symptoms	symptoms range from mild to severe	abrupt onset of symptoms
Length of symptoms	can start quickly or last for hours or longer	several weeks	less than 14 days	7–25 days	7–14 days
Cough	common	rare	common	common	common
Shortness of breath or trouble breathing	common	no*	no*	common	no*
Sneezing	no*	common	common	rare	no
Runny or stuffy nose	no*	common	common	common	sometimes
Sore throat	no*	sometimes (usually mild)	common	common	sometimes
Fever	no	no	short fever period	common	common
Headaches	rare	sometimes (related to sinus pain)	rare	common	common
Chills	no	no	no	common	sometimes

* Allergies, cold, flu, and some strains of COVID-19 can all trigger asthma, which can lead to shortness of breath. People with both allergies and asthma may have a runny nose, sore throat, and sneezing.

STUDENT SHEET 1.3 | UNIT CONCEPTS AND SKILLS | NAME

UNDERSTAND		ANALYZE
CONCEPT	DESCRIPTION	UNIT EXAMPLE(S)

WHAT DECISION(S) WERE MADE OR ACTION(S) TAKEN?

STUDENT SHEET 1.3 | UNIT CONCEPTS AND SKILLS | NAME SAMPLE STUDENT RESPONSE

UNDERSTAND		ANALYZE
CONCEPT	DESCRIPTION	UNIT EXAMPLE(S)
Probabilistic Reasoning	*When data is unclear, it is useful to have an approach to determine the likelihood of different outcomes based on available evidence.*	*Predicting illness, determining air quality (outdoor vs. indoor, local air quality data, construction site scenario), making predictions about wildfires (fuel lab, probabilistic modeling, power line scenario)*
Scientific Uncertainty	*Uncertainty in data is often a result of scientific error. Scientific methods can reduce uncertainty.*	*PM2.5 air quality data from websites, PM2.5 air quality lab, power shut-off activity*
False Positive, False Negative	*These two types of errors can lead to incorrect decisions based on inaccurate results.*	*Questions about COVID tests, air quality sensors, smoke alarms, probabilistic wildfire models, power line sensors*
Signal and Noise	*Probabilistic reasoning can help identify the signal being investigated.*	*Outdoor vs. indoor air quality activity, computer app, ER visits graph, regional PM2.5 graph*
Systematic Error	*Can be reduced by calibrating equipment more carefully and designing investigations to control for other factors that could influence the results (confounds).*	*PM2.5 air quality lab, Harvard Six Cities Study, computer simulation, construction site scenario, power line scenario*
Random Error	*Can be reduced by taking repeated measurements and averaging across many samples*	*PM2.5 air quality lab, Harvard Six Cities Study, computer simulation, fuel lab, power line scenario*
Confidence Level, Confidence Interval, Error Bar	*Scientists communicate scientific uncertainty, using statistics to describe levels of surety and likelihood of a range of data containing a true value.*	*Harvard Six Cities Study, computer simulation, construction site scenario, probabilistic modeling*

WHAT DECISION(S) WERE MADE OR ACTION(S) TAKEN?

Evaluation of claims in articles and computer simulation, decision about power shut-offs

STUDENT SHEET 1.4 | WRITING FRAME: EVIDENCE & TRADE-OFFS | NAME

There is a lot of discussion about the issue of

My decision is that

My decision is based on the following evidence:

First,

Second,

Third,

The trade-off(s)

People who disagree with my decision might say that

STUDENT SHEET 1.4

WRITING FRAME: EVIDENCE & TRADE-OFFS

NAME SAMPLE STUDENT RESPONSE

There is a lot of discussion about the issue of

where to build an urgent care asthma center.

My decision is that

it should be built in an urban area.

My decision is based on the following evidence:

First,

since asthma interferes with breathing, it is important to have immediate care.

Second,

the combined number of visits in the urban area was 4,239, compared to 2,293 in the suburban area and 1,674 in the rural area.

Third,

because more people live in an urban area, more people would have access to immediate care.

The trade-off(s)

is that people in rural areas may be farther from any medical care.

People who disagree with my decision might say that

people who live in rural areas may experience more severe effects without immediate treatment if there is no nearby medical care in the area.

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...?

VISUAL AID 1.2 | UNDERSTANDING CONCEPTUAL TOOLS

CONSTRUCTION TOOLS

SCIENTIFIC TOOLS

SCIENTIFIC TOOLS + TECHNOLOGY

CONCEPTUAL TOOLS

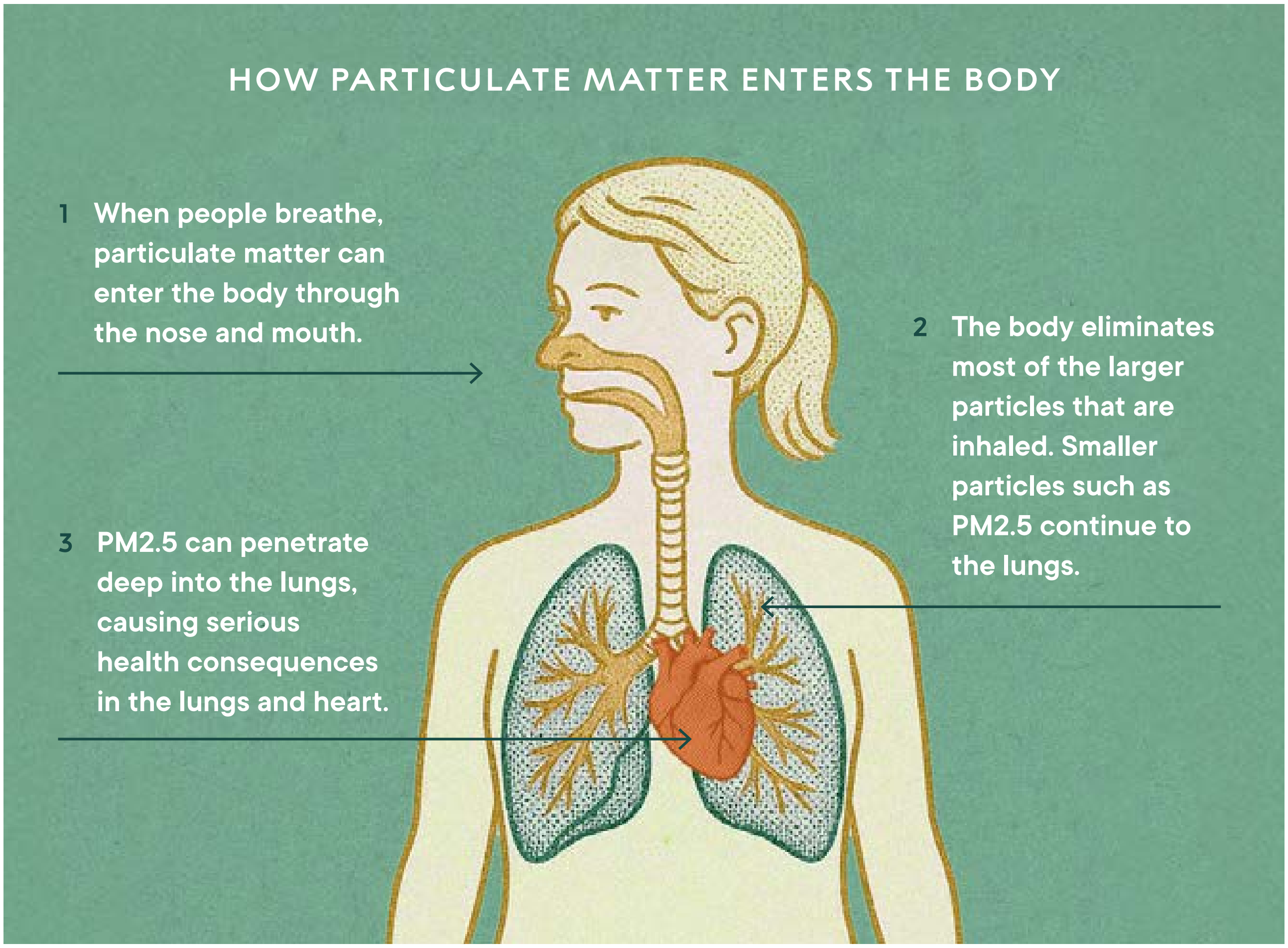
VISUAL AID 1.3 | COMPLETE SYMPTOM CHART

Symptoms	Asthma Gradual or abrupt onset of symptoms	Seasonal Allergies Abrupt onset of symptoms	Cold Gradual onset of symptoms	Coronavirus[1] (COVID-19) Symptoms range from mild to severe	Flu Abrupt onset of symptoms	Respiratory Syncytial Virus (RSV) Gradual onset of symptoms
Length of symptoms	Can start quickly or last for hours or longer*	Several weeks	Less than 14 days	7-25 days	7-14 days	7-10 days
Cough	Common (can be dry or wet/productive)	Rare (usually dry unless it triggers asthma)	Common (mild)	Common (usually dry)	Common (usually dry)	Common
Wheezing	Common	No**	No**	No**	No**	Common
Shortness of breath or trouble breathing	Common	No**	No**	Sometimes	No**	No*** (sometimes in infants)
Chest tightness/ pain	Common	No**	No**	Sometimes	No**	No**
Rapid breathing	Common	No**	No**	Rare	No**	No*** (sometimes in infants)
Sneezing	No**	Common	Common	Rare	No	Common
Runny or stuffy nose	No**	Common	Common	Common	Sometimes	Common
Sore throat	No**	Sometimes (usually mild)	Common	Common	Sometimes	Rare
Fever	No	No	Short fever period	Common	Common	Common
Feeling tired and weak	Sometimes	Sometimes	Sometimes	Common	Common	Rare
Headaches	Rare	Sometimes (related to sinus pain)	Rare	Common	Common	No
Body aches and pains	No	No	Common	Common	Common	Rare
Diarrhea, nausea, and vomiting	No	No	Rare	Common	Sometimes	No
Chills	No	No	No	Common	Sometimes	Sometimes
Loss of taste or smell	No	Sometimes	Rare	Common	Rare	No

Your symptoms may vary. If you have any cold, COVID-19, or flu-like symptoms, talk with your doctor, get tested, and stay home.

*If you are having trouble breathing and your quick-relief medicine is not helping your asthma symptoms, call your health care provider or seek medical attention immediately. **Allergies, colds, flu, and some newer strains of COVID-19 can all trigger asthma which can lead to shortness of breath, chest tightness/pain, and rapid breathing. People with both allergies and asthma may have runny nose, sore throat, and sneezing. ***This is not common but may be seen in babies 6 months or younger. [1]Information about COVID-19 is still evolving. Many people may not have symptoms.

Sources: *Asthma and Allergy Foundation of America, World Health Organization, Centers for Disease Control and Prevention.* Edited with medical review: 1/18/24 • aafa.org/rti


HOW PARTICULATE MATTER ENTERS THE BODY
1 When people breathe, particulate matter can enter the body through the nose and mouth.
2 The body eliminates most of the larger particles that are inhaled. Smaller particles such as PM2.5 continue to the lungs.
3 PM2.5 can penetrate deep into the lungs, causing serious health consequences in the lungs and heart.

STUDENT 1: SERENA

Serena has been coughing for two weeks. She usually starts coughing after laughing really hard or running to catch the bus. She sometimes feels short of breath. Most of the rest of the time, she feels fine.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 3: Scientific Uncertainty & Probabilistic Reasoning, Activity 1

STUDENT 1: FOLLOW UP

Serena took a COVID-19 test and tested negative for COVID-19.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 3: Scientific Uncertainty & Probabilistic Reasoning, Activity 1

STUDENT 2: MARCUS

Marcus has missed two days of school so far. He has a fever, runny nose, and chills.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 3: Scientific Uncertainty & Probabilistic Reasoning, Activity 1

STUDENT 2: FOLLOW UP

Marcus stayed home for three more days and began to feel better at the end of that time. His symptoms went away, and he went back to school after a week of being sick.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 3: Scientific Uncertainty & Probabilistic Reasoning, Activity 1

STUDENT 3: TARA

Tara has been sneezing and had a runny nose for the last week. She also has occasional headaches. Tara turned 18 a week ago, and her friends and family surprised her with several bouquets of flowers.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 3: Scientific Uncertainty & Probabilistic Reasoning, Activity 1

STUDENT 3: FOLLOW UP

Tara ignored her symptoms since they did not interfere with her everyday activities. The flowers wilted, and she threw them away. Her symptoms went away.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 3: Scientific Uncertainty & Probabilistic Reasoning, Activity 1

STUDENT 4: ALI

Ali was feeling fine. A large wildfire in the area resulted in high levels of particulate matter in the air. Since then, he's been feeling short of breath, had headaches, and his eyes have been watering.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 3: Scientific Uncertainty & Probabilistic Reasoning, Activity 1

STUDENT 4: FOLLOW UP

Ali stayed indoors and avoided strenuous activities such as sports. Heavy rainfall in the area helped extinguish the wildfire. Ali has been feeling fine since then.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 3: Scientific Uncertainty & Probabilistic Reasoning, Activity 1