ACTIVITY 3

Scientific Uncertainty in Data

COMPUTER INVESTIGATION

ACTIVITY 3

Scientific Uncertainty in Data

ACTIVITY SUMMARY

The concept of scientific uncertainty is further developed with the introduction of scientific error and true value. Students explore regional air quality data from online sources and begin to identify possible sources of scientific uncertainty in data. They compare data from crowdsourced applications to data from higher-quality sensors provided by government sites. Students are asked to analyze data, draw conclusions, and discuss the role of probabilistic reasoning in making determinations about air quality.

ACTIVITY TYPE
COMPUTER 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.
2. Uncertainty in data is often a result of errors. Scientific errors can be random or systematic and can lead to conclusions that are less likely to be correct.

NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:
Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. (*Science and Engineering Practice: Analyzing and Interpreting Data*)

CONCEPTUAL TOOLS

VOCABULARY DEVELOPMENT

scientific error
the difference between a measured or observed value and the true value of a quantity

true value
the actual number that would be found if the measurement could be made without error

TEACHER BACKGROUND INFORMATION

Scientific Error and True Value

When one single measurement is compared to another single measurement of the same thing, the values are usually not identical. Differences between single measurements are due to scientific error. Scientifically accepted values are scientists' current best approximations or descriptions of nature. As information and technology improves and investigations are refined, repeated, and reinterpreted, scientists' understanding of nature gets closer to describing what actually exists.

In science, a true value refers to the actual, exact value of a quantity being measured, while a scientific error represents the difference between the measured value and that true value. A scientific error is how much a measurement deviates from the actual value due to limitations in the measuring process or instrument used. The true value is often considered theoretically perfect and cannot be precisely known in practice due to inherent limitations in measurement.

scientific error = measured value – true value

Comparing Air Quality Data

Different apps and websites employ different formulas to transform initial air quality sensor data into estimates of current and future forecasts of air quality. In the United States, the larger circles displayed on the Environmental Protection Agency's (EPA) *AirNow* map, which represent data from government monitoring stations that operate across the country, are generally considered the most accurate data source. *AirNow*'s fire map includes data from PurpleAir sensors (represented by small circles on its map) as does Watch Duty, a nonprofit app for tracking fires. Differences in the instruments, calculations, and processing means that the air quality index reported by the same sensors can vary from map to map. *AirNow* data is tracked and published on an hourly basis by the EPA. PurpleAir sensors are less accurate than the government sensors but are used more widely. They report data every two minutes, producing what the company describes as a real-time map of air quality. With an increasing global focus on air quality, new companies—such as BreezoMeter and Ambee—are working on new approaches to air quality monitoring such as using satellite data, weather information from satellites, and traffic reports in addition to data from government monitoring stations and PurpleAir sensors.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 3.1 "Air Quality Index (AQI)"
- VISUAL AID 3.2 "Some Sources of Scientific Uncertainty in Data"
- VISUAL AID 3.3 "Scoring Guide: Analyzing and Interpreting Data (AID)"
- ITEM-SPECIFIC SCORING GUIDE: Activity 3, Build Understanding Item 2

FOR EACH PAIR OF STUDENTS

- COMPUTER WITH INTERNET ACCESS

FOR EACH STUDENT

- STUDENT SHEET 3.1 "Analyzing Crowdsourced Air Quality Data"
- STUDENT SHEET 3.2 "Writing Frame: Evidence and Trade-Offs (E&T)" (OPTIONAL)
- SCORING GUIDE: Analyzing and Interpreting Data (AID) (OPTIONAL)

The number of air quality sensors varies with location. PurpleAir at https://map.purpleair.com relies on crowdsourced data and provides information from many parts of the world. Other potential sources of local air quality data include IQAir and OpenAQ. You may want to investigate other sites that provide air quality information for your region. For example, SAMHE (Schools' Air Quality Monitoring for Health and Education) at https://www.samhe.org.uk provides resources in the United Kingdom and has collaborated with the Stockholm Environment Institute to create a SAMHE web app.

In advance of this lesson, visit sites that you will use to gather data, such as the PurpleAir website and the United States' *AirNow* Fire and Smoke Map website at https://fire.airnow.gov Familiarize yourself with data available for your state or region. Since air quality data availability varies widely by region, you may find it helpful to gather and assess your local data by using the procedure steps in the Student Book to complete Student Sheet 3.1 in advance of the lesson. If there is no data available for your location, consider selecting a nearby region, another region of interest, or assigning student groups to investigate different areas of the world.

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 MIN)

1 **Present the story found in the Introduction.**

- The story of the development of the PurpleAir website found in the Introduction can be shared with the class in multiple ways. Read the introduction 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 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 independently.

PROCEDURE SUPPORT (30-40 MIN)

2 **Use Visual Aid 3.1, "Air Quality Index (AQI)," to review the Air Quality Index.**

- Support students, particularly emerging multilingual learners, in sensemaking and language acquisition as they read the information in the Air Quality Index provided in Procedure Step 1. Circulate around the room and check in with students as they use the strategy to decode scientific ideas and construct meaning as they read. You may wish to use Visual Aid 3.1, "Air Quality Index (AQI)," to review that the AQI is a measurement from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 or below (green) represents good air quality, while an AQI value over 300 (maroon) represents hazardous air quality. Color is used to denote the different levels and make it easier to understand.

3 Students explore a website providing crowdsourced air quality data, such as PurpleAir.

- Inform students that they will use crowdsourced data to investigate one measure of air quality: PM2.5 levels.
- Have students familiarize themselves with your chosen website by first spending a few minutes exploring. Ask students to share what they observe, such as the types of features the site has and the type of information that is provided.

4 Support students in selecting a geographical area for gathering data.

- The number of sensors varies greatly by location. For some parts of the world, a few sensors may be found across a large geographical area of hundreds of kilometers (miles). In other places, a few sensors may be found in a neighborhood of just a few blocks. Help students navigate the size of the area being considered.
- If needed, demonstrate how to select an appropriate area. Depending on where you live, you may find it helpful to designate a boundary such as a city (e.g., New York City), a county (e.g., Los Angeles County), a state, or even an entire country.

5 In Part A, students gather evidence about regional air quality from crowdsourced sensors.

- Distribute one copy of Student Sheet 3.1, "Analyzing Crowdsourced Air Quality Data," to each student. Review how to complete Table 1 by either filling in a row as a class or by modeling sample data. A sample student response is shown at the end of this activity.
- You may wish to assign pairs to work with another pair of students. Pairs can compare their data and conclusions. If students need more support, you might suggest that they discuss the following questions in their groups:
  - Did the other pair find similar data as you?
  - Did the other pair have similar or different ideas about air quality based on the data?
  - Did the other pair have any data or ideas that made you change your thinking?

  Students should recognize that more sensor data reduces scientific uncertainty and increases the likelihood that the air quality determinations are closer to the true value.
- Circulate and assist students as needed.
- Students complete the "Crowdsourced Data" column of Table 2. They then compare their two air quality determinations for an area with many sensors based on: (1) the range of data [found in Table 1] with (2) an average of five data points [found in Table 2]. If the data are similar, there is likely less scientific error in the data and, therefore, reduced uncertainty. If the data are different, the data based on an average is more likely to be closer to the true value than the range because taking the average reduces the effect of differing data points (which may be a result of scientific error).

6 In Part B, students gather evidence about regional air quality from higher-quality sensors.

- Inform students that they will use data from a site that provides data from higher-quality sensors to continue to investigate PM2.5 levels. They will look for data in the same area of the map with many sensors that they investigated in Procedure Steps 5 and 6.
- Have students use data from higher-quality sensors, such as the Fire and Smoke Map at *AirNow*, to complete Table 2 on Student Sheet 3.1. *AirNow* is a partnership of the United States Environmental Protection Agency (EPA); National Oceanic and Atmospheric Administration (NOAA); National Park Service; National Aeronautics and Space Administration (NASA); Centers for Disease Control and Prevention (CDC); and tribal, state, and local air quality agencies.
- Students should compare air quality findings for the same location from high-quality sensors with crowdsourced data. If the data are similar, there is reduced uncertainty, and the air quality determination is probably closer to the true value. If the data are different, the air quality determination based on the higher quality sensor data is likely to be closer to the true value (have less scientific error) because it is collected from sensors that are more accurate and reliable. Given limited data and variability among sensors, making a determination of air quality requires making predictions or drawing conclusions based on likelihood—i.e., probabilistic reasoning.

Sample Student Response, Procedure Step 9

There were more data points for the crowdsourced sensors, but the crowdsourced data had a greater range of values. This means that there was probably more error in the individual sensor readings. We calculated that the same average air quality from both the crowdsourced sensors and the higher-quality sensors. The true value was probably close to this number because it was a result of averaging data from two different types of sensors. We used probabilistic reasoning because we don't know the true value for sure, but we had enough data that we can be pretty sure.

SYNTHESIS OF IDEAS (20 MIN)

7 Discuss the sources of uncertainty in data, using Visual Aid 3.2.

- Use Build Understanding item 1 and Visual Aid 3.2, "Some Sources of Scientific Uncertainty in Data," to discuss sources of scientific uncertainty in data. Have students share their responses to Build Understanding item 1 and discuss how the limitations of their data correspond to the categories described on Visual Aid 3.2.
- Ask, What are some ways to address these different sources of scientific uncertainty? Sample student responses are shown in the following table. You may want to use student responses to foreshadow the possibility of errors in measurement or experimental design (systematic error) or the possibility of random errors, which are formally introduced in the next activity.

missing	*gather additional data (increase sample size)*
unreliable	*gather additional data (increase sample size), compare to other data sets, test measurement equipment*
conflicting	*gather additional data (increase sample size), test measurement equipment, design additional investigations*
confusing	*gather additional data (increase sample size), compare to other data, calculate average*

- Help the class build a common vocabulary to describe sources of uncertainty: *missing*, *unreliable*, *conflicting*, and *confusing*. For example, students may be referring to missing data when describing not having enough data or highlighting areas with few sensors.

8 Discuss the strengths and limitations of crowdsourced data.

You can build on the strengths and limitations of different data sources by having a class discussion about the use of crowdsourced data. Crowdsourcing makes it possible to collect a much larger amount of data from a larger geographic area over more time than a team of professional scientists or even volunteers can do on their own. It also means that more people can be part of the process of science, contributing and learning from one another. One disadvantage is that the data may be of lower quality and reliability since the people collecting it are not all trained in common methodologies. Such data sets might also be vulnerable to people trying to influence the conclusions made from the data (i.e., trolls). It is only possible to gather data from places where people are participating and making observations that they think are worth adding, so scientists have to be careful in interpreting the data; there might be missing data in places without much participation or when observations by untrained people are determined not to be relevant.

9 Use Build Understanding item 2 to assess students' ability to analyze and interpret data.

- Build Understanding item 2 is an Analyzing and Interpreting Data assessment item. This first opportunity can be used to introduce your students to the optional Scoring Guide: Analyzing and Interpreting Data (AID). As this is the first opportunity for students to review the Scoring Guide, you may wish to have them work in pairs or small groups to discuss and/or write their responses, using the Scoring Guide to help develop their responses. See Appendix 2: Assessment Resource at the end of the Teacher's Edition for more guidance and information on using the Scoring Guide with your students.

- Do not share the item-specific version of the Scoring Guide (Item-Specific Scoring Guide: Activity 3, Build Understanding Item 2) with students as it provides specific information on how to respond to the item prompt. Review the Item-Specific Scoring Guide to support scoring this specific item.

- Visual Aid 3.3, "Scoring Guide: Analyzing and Interpreting Data (AID)," can be used to assess Build Understanding item 2. Point out the scoring levels (0–4) and review the criteria for each score. Explain that the scores are based on the quality of students' responses and reflect student growth

over time. The scores do not correspond to letter grades. A Level 4 response is complete and correct. A Level 3 response is almost complete and mostly correct, but possibly missing minor details or containing small errors. At first, many students will write Level 2 responses, and they should strive to achieve Level 3 or Level 4 responses. Let students know that you would like them to improve by at least one level as they progress through the unit. As a class, discuss what a Level 4 response to Build Understanding item 2 would include. You may develop a Level 4 exemplar as a class or share with students the Level 4 responses from the provided sample responses. To help students better understand the three levels, discuss how they are different and ask students for ideas about how to improve from Level 2 to Level 3 and from Level 3 to Level 4.

- For some students, you may wish to support a specific level of growth—this can be particularly helpful if students have an Individualized Educational Plan (IEP), a 504 plan, or other specific educational goals. Growth from a Level 1 to a Level 2 may indicate significant progress for a student and should be recognized as such. Additionally, assessments can be a good opportunity to have students evaluate one another's work and provide initial feedback for revisions prior to submitting their responses to you.

- Sample responses for Levels 1–4 are provided in the Build Understanding section. 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 Edition for more guidance and information on using the Scoring Guides and assessment system with your students.

10 Support student responses with a writing frame.

Students apply the concepts of evidence and trade-offs in Connections to Everyday Life, item 4. For students who need support organizing and writing their responses, you may wish to provide optional Student Sheet 3.2, "Writing Frame: Evidence and Trade-Offs," to compose their responses. Students could also use Student Sheet 3.2 only as a reference or as a checklist as they write their responses. A sample student response for this student sheet is shown at the end of this activity. For more information on a Writing Frame, see Appendix 1: Literacy Strategies.

11 Revisit the Guiding Question.

Finish the activity by revisiting the Guiding Question. Ask, What are some sources of scientific uncertainty in data? In this activity, students were introduced to the concepts of scientific error and true value. They investigated sources of error in data, such as missing, unreliable, conflicting, and/or confusing data, and possible ways in which these errors could be addressed to gather data which is closer to the true value. Use responses to the guiding question to formatively assess the key concepts and process skills related to being able to identify ways in which data may be uncertain. In Activity 4, students design an experiment to explore local air quality data and formally address random and systematic errors.

EXTENSION (10 MIN)

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

The Extension provides an opportunity for students to examine air quality data in other regions of the world and over longer periods of time. Data about air quality for different communities across the United States and the world can raise questions of geography, climate, and equity. Students may find areas with much better or worse air quality or identify areas that have many or few sensors. They may notice that parts of Asia, such as some cities in India, have some of the worst air quality in the world. In many countries, wood is still the primary energy source for cooking, and vehicle emissions are high. Students may observe patterns of poor air quality during the periods when the majority of people are cooking or traveling to and from work. Sources of uncertainty in the data are likely to mimic the same categories that were raised in the activity—missing, unreliable, confusing, and conflicting data—and could be addressed in a similar way.

SAMPLE STUDENT RESPONSES

BUILD UNDERSTANDING

① **Review your analysis of local air quality data from both sites.**

a List two possible sources of scientific uncertainty in air quality data.

Data can be missing, like in areas with fewer sensors. Data can also be conflicting, like when there were large differences in readings from nearby sensors. Data caused uncertainty because we could not tell if the difference was because of actual differences in air quality or if there was a problem with one of the sensors.

b Brainstorm how each source of scientific uncertainty could be reduced.

Missing data can be addressed by installing additional sensors in areas without data. Conflicting data can be addressed by taking additional measurements and also checking equipment to make sure it is working correctly.

② **AID Assessment**

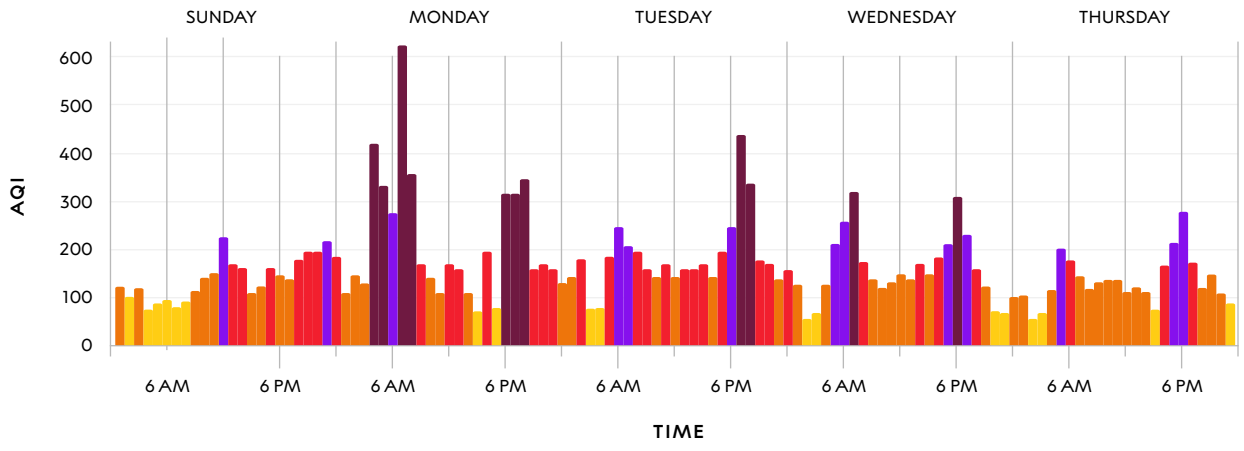
The graph in Figure 3.2 shows a week of hourly PM2.5 measurements for the capital city of N'Djamena in the country of Chad. Explain what conclusions you can make based on the data in the graph. Refer to Figure 3.1, "Air Quality Index (AQI)," in Procedure Step 1 as needed. In your explanation, be sure to include the following:

a Describe what patterns you observe in the air quality over time.

b Explain what conclusions you can make about local air quality.

c Explain at least two possible sources of scientific uncertainty, including possible scientific errors, that may have affected the data.

FIGURE 3.2
Air Quality Index (AQI) Data for Five Days in N'Djamena, Chad



Level 4 response

The worst air quality is Monday morning between 5:00 am and 8:00 am. The best air quality varies: the best air quality (moderate) compared to the other days is Sunday. I can conclude that in general, the air quality in N'Djamena is not great, since it never goes below 82 PM2.5, which is in the middle of the moderate air quality scale. There is no time when it is good (green). Also, there are many parts of the day when it is hazardous (maroon) for human health. This could be when people are commuting to and from work early in the morning and again in the evening. One source of scientific uncertainty is that we were only given 5 days of data, so it is unclear whether this pattern is always present. Another source of scientific uncertainty is that it is not clear what type of air sensors were being used. They could be low quality and not reporting accurate data.

Level 3 response

The worst air quality is Monday morning, maybe because that's when people are all driving to work and school. The best air quality is early Sunday morning. I can conclude that in general, the air quality in N'Djamena is not great because it never goes lower than 82 PM2.5, which is in the middle of the moderate range, and it's never in the good range. One source of uncertainty is that there is limited data, and it might just be showing some really bad days by chance, like maybe there was a fire on Monday somewhere in the city that affected the air quality.

Level 2 response

There is yellow air quality for a little while on Sunday and Tuesday, but there's also a lot of red, purple, and maroon times that tend to go up and down. The data is uncertain, but I think that the air quality isn't very good there.

Level 1 response

The air quality in this city isn't very good. There's lots of bad air quality. I would not want to breathe that air.

③ **Based on the data in Figure 3.2, which day would be better to be outdoors: Monday or Tuesday? Support your answer with evidence.**

It would be better to be outside on Tuesday because the air quality index does not reach hazardous levels for as many hours as it does on Monday.

CONNECTIONS TO EVERYDAY LIFE

④ **The local Air Quality Index (AQI) on the day of your team's soccer semifinals is reported as 135. A sensor near your home shows an AQI of 100. The best player on your soccer team has asthma. Would you recommend that she play in the semifinal game? Support your answer with evidence and identify the trade-offs of your decision.**

I would recommend that she not play soccer. An AQI of 135 is unhealthy for sensitive groups. Even though one sensor showed a reading of 100, the local AQI is likely based on more sensors and has less error. Since she has asthma, a respiratory illness with possible symptoms of shortness of breath and wheezing that can be triggered by poor air quality, she may be more affected by the poorer air quality than other players who do not have asthma. The trade-off is that the team will lose our best player during the semifinals, and we may not advance without her participation. People who disagree with me may say that winning the semifinals is very important, and the air quality is not hazardous, just moderate. My friend may not experience any symptoms under those conditions. Also, one local sensor gave a lower reading of 100, so the 135 might not be accurate.

⑤ **People rely on data such as air quality from scientific tools and technology to make decisions. Yet data from such technology can sometimes be inaccurate. In the case of an air quality sensor, is it worse to have a false positive or a false negative? Explain your reasoning.**

A false negative from an air quality sensor would be worse because it would incorrectly identify particulate matter as absent, but it would actually be present. If there were high PM levels or unhealthy air quality, a person relying on a sensor that provides a false negative would be misled into thinking that the air quality was better than it actually was. This might lead someone to accidentally exposing themselves to high levels of PM.

REFERENCES

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Table 1: Crowdsourced Data for (date): _____

	RANGE OF DATA	DETERMINATION OF GENERAL AIR QUALITY	DESCRIBE HOW YOU MADE YOUR DETERMINATION	REASONS FOR SCIENTIFIC UNCERTAINTY IN DATA
My state				
Area with few sensors				
Area with many sensors				

Table 2: Data from an Area with Many Sensors

	CROWDSOURCED DATA	HIGHER-QUALITY SENSOR DATA
Five measurements		
Differing data point(s)		
Average of five measurements		
Determination of general air quality		

Table 1: Crowdsourced Data for (date): *Oct 30, 2024*

	RANGE OF DATA	DETERMINATION OF GENERAL AIR QUALITY	DESCRIBE HOW YOU MADE YOUR DETERMINATION	REASONS FOR SCIENTIFIC UNCERTAINTY IN DATA
My state *Missouri*	*0-54*	*Healthy*	*Most sensors in the state are green.*	*Not many sensors in the state (missing data).*
Area with few sensors *Moberly, MO*	*15*	*Healthy*	*One sensor reading is green.*	*Most state data shows green, but there is only one local sensor (missing data).*
Area with many sensors *Independence, MO*	*8-23*	*Healthy*	*Sensor readings for nearby Kansas City are green.*	*Many more sensors, but they show different values (confusing, conflicting, or unreliable data).*

Table 2: Data from an Area with Many Sensors

	CROWDSOURCED DATA	HIGHER-QUALITY SENSOR DATA
Five measurements	*8, 20, 21, 23, 23*	*18, 19, 19*
Differing data point(s)	*8*	*none*
Average of five measurements	*19*	*19*
Determination of general air quality	*Healthy*	*Healthy*

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

There is a lot of discussion about the issue of

whether to play sports outdoors during moderate air quality.

My decision is that

I would tell my friend who has asthma to not play soccer.

My decision is based on the following evidence:

First,

an AQI of 135 is unhealthy for sensitive groups.

Second,

she has asthma, a respiratory illness with possible symptoms of shortness of breath and wheezing.

Third,

she may be more affected by the poorer air quality than other players who do not have asthma.

The trade-off(s)

is that the team will lose our best player during the semifinals and may not advance without her participation.

People who disagree with my decision might say that

winning the semifinals is very important, and the air quality is not hazardous, just moderate. My friend may not experience any symptoms under those conditions. Also, one local sensor gave a lower reading of 100, so the 135 might not be accurate.

AQI CATEGORY (COLOR)	INDEX VALUE	DESCRIPTION OF AIR QUALITY
Good (green)	0–50	Air quality is satisfactory, and air pollution poses little or no risk.
Moderate (yellow)	51–100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive* to air pollution.
Unhealthy for Sensitive* Groups (orange)	101–150	Members of sensitive* groups may experience health effects. The general public is less likely to be affected.
Unhealthy (red)	151–200	Some members of the general public may experience health effects. Members of sensitive* groups may experience more serious health effects.
Very Unhealthy (purple)	201–300	Health alert: The risk of health effects is increased for everyone.
Hazardous (maroon)	301 AND HIGHER	Health warning of emergency conditions: Everyone is more likely to be affected.

* According to the American Lung Association, sensitive groups include children under 18, adults over 65, people with chronic heart or lung disease, people who are pregnant, and people with diabetes. Adults who are active outdoors, including outdoor workers and frequent outdoor exercisers, can be considered sensitive because of prolonged exposure to outside air.

Missing Data

Unreliable Data

Conflicting Data

Confusing Data

VISUAL AID 3.3 | SCORING GUIDE: ANALYZING AND INTERPRETING DATA (AID)

WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students analyze and interpret data that they have collected or that has been provided to them.

WHAT TO LOOK FOR:

- Response describes patterns and trends in data.
- Response interprets patterns and trends to describe possible causal relationships.

LEVEL	GENERAL DESCRIPTION
Level 4 **Complete and correct**	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data and interprets them completely and correctly to identify and describe relationships. When appropriate, the student: • makes distinctions between causation and correlation. • states how biases and errors may affect interpretation of the data. • states how study design impacts data interpretation.
Level 3 **Almost there**	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data BUT incorrectly and/or incompletely interprets them to identify and describe relationships.

LEVEL	GENERAL DESCRIPTION
Level 2 **On the way**	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes, BUT does not interpret, patterns and relationships.
Level 1 **Getting started**	The student attempts to analyze the data BUT does not use appropriate tools, techniques and/or reasoning to identify and describe patterns and relationships.
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.

WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students analyze and interpret data that they have collected or that has been provided to them.

WHAT TO LOOK FOR:

- Response describes patterns and trends in data.
- Response interprets patterns and trends to describe possible causal relationships.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 4 **Complete and correct**	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data and interprets them completely and correctly to identify and describe relationships. When appropriate, the student: • makes distinctions between causation and correlation. • states how biases and errors may affect interpretation of the data. • states how study design impacts data interpretation.	The student response: • gives detailed descriptions of patterns in the data, including within and across days. • thoroughly describes sound reasoning and evidence for conclusions about air quality. • provides at least two sources of scientific uncertainty with a thorough explanation of reasoning, including the limitations of the available data.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 3 **Almost there**	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data BUT incorrectly and/or incompletely interprets them to identify and describe relationships.	The student response: • describes patterns in the data, including within and across days. The student response may have minor errors or limited responses related to: • describing reasoning and evidence for conclusions about air quality. • providing a source of scientific uncertainty with an explanation of reasoning and limitations of the available data.
Level 2 **On the way**	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes, BUT does not interpret, patterns and relationships.	The student response: • describes patterns in the data, including within and/or across days. The student response may have errors or limited responses/reasoning related to: • describing reasoning and evidence for conclusions about air quality. • providing a source of scientific uncertainty with an explanation of reasoning and limitations of the available data.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 1 **Getting started**	The student attempts to analyze the data BUT does not use appropriate tools, techniques, and/or reasoning to identify and describe patterns and relationships.	The student response: • describes patterns in the data that may be general or contain errors. The student response may have significant errors or very limited responses/reasoning related to: • describing conclusions about air quality. • providing a source of scientific uncertainty with reasoning.
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.	