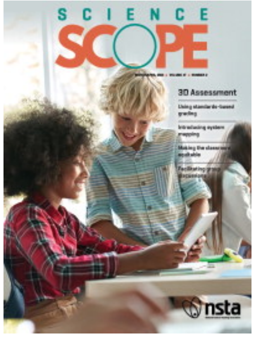

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From Windy Day Stories to Wind Farms of the Future:

Leveraging Student Resources to Make Sense of Phenomena With Data Puzzles

BY JONATHAN G. GRIFFITH, MELISSA BRAATEN, ANN DUBICK, AND ANNE U. GOLD

ABSTRACT

This article introduces the Data Puzzles instructional framework as a means to engage middle school students in the exploration of wind energy and its potential for future wind farm locations across the United States. By eliciting and leveraging student resources through an opening scenario that prompts personal experiences with wind, teachers can effectively connect students to abstract science phenomena and facilitate sensemaking. The Data Puzzles framework combines authentic scientific data sets with the Ambitious Science Teaching pedagogical practices to support students in constructing knowledge and addressing contemporary phenomena.

KEYWORDS: Climate Change; Phenomena; Earth & Space Science; Environmental Science; General Science; Pedagogy; Learning Progression; Lesson Plans; Curriculum; Instructional Materials; *NGSS*; Three-Dimensional Learning; Crosscutting Concepts; Disciplinary Core Ideas; Science And Engineering Practices; Inquiry

Imagine walking into your middle school classroom and asking students to share where they think the United States can most effectively create wind energy. What kind of initial explanations do you think you might get? It's likely many of your students have never thought about that question or may not know why it's important to consider, and they may find themselves overwhelmed. Now imagine starting the conversation with a slightly different prompt: What was the windiest day of your life? What stories would you hear from your students? How could you then use these student stories to support students in connecting to an abstract science phenomenon, like creating wind energy?

Some students may describe being on a beach, and others may talk about hiding behind bushes to get out of the wind. These student resources (ideas, experiences, language) can be used by the teacher throughout the rest of the lesson as students explore the relationship between surface roughness and wind speed as they seek to identify suitable locations for the construction of future wind farms across the United States.

Eliciting and leveraging student resources is a key aspect of sensemaking, a learning process that happens when people are actively trying to figure out how something works and, perhaps, determine possible solutions for problems (Brown 2019; Schwarz et al. 2021). Sensemaking is a cognitively demanding form of learning because it requires people to connect observations with ideas, to evaluate and reconcile any differences between ideas, and to eventually work toward developing explanations for how and why something happens (Odden and Russ 2019). Because all learners make sense of new events through the lens of what they have experienced in the past, it's essential that teachers elicit these student resources *before* students are asked to engage with science concepts in the context of complex new phenomena. The Data Puzzles instructional framework provides scaffolding for teachers to do just that (see Online Resources to view the freely available framework and accompanying lesson collection).

Data Puzzles instructional framework

Data Puzzles are a series of free, open-source lessons that combine classroom-friendly data sets with the research-based instructional practices of Ambitious Science Teaching to support students in making sense of contemporary science phenomena (see Online Resources). Data Puzzles (referred to in Data Puzzle resources as the "investigative question") are centered around a driving question about phenomena such as the rapid warming in the Arctic (*Arctic amplification*) or the impact of rising temperatures on high alpine plants (*ecological tipping points*). Data Puzzles incorporate authentic scientific data sets that allow students to address the investigative question. Aligned with the *Next Generation Science Standards* (NGSS Lead States 2013), Data Puzzles are designed to foster inquiry-based thinking, sensemaking, and data interpretation, and to connect students to a scientist and their field of study.

The implementation of a Data Puzzle takes about three class periods. The Data Puzzles framework

(Figure 1) provides scaffolding for teachers to work with students' ideas over time as they construct knowledge that they will apply to answer an investigative question. Data Puzzle resources (teacher guide, slide deck, student worksheet, answer key) guide teachers and students through science investigations utilizing the four Ambitious Science Teaching pedagogical practices:

- Each Data Puzzle lesson begins by eliciting students' ideas about an opening scenario (e.g., prompt, demonstration, video) that encourages students to think about a certain science concept in the context of their own lives before they explore this same concept in the context of the science investigation presented in Data Puzzle.
- In the Identifying Important Science Ideas practice, students read and discuss the Puzzle Plot, an interactive text that features a scientist and important science ideas relevant to their work in the context of an investigative question (e.g., Why might the Arctic be warming faster than the rest of the world?). Students are challenged to make connections between their own resources (ideas, experiences, language) and the details of the science investigation featured in the text. Students are guided to use their prior knowledge and evidence from the Puzzle Plot to form an initial prediction to answer the question that the scientist featured in the Data Puzzle is investigating.
- In the Supporting Ongoing Changes in Thinking practice, students test their initial predictions against a scientific data set curated by the scientist featured in the Puzzle Plot. Careful reflection of the patterns and relationships in the data set provides the evidence students use to revise their initial predictions for the investigative question.
- Last, students are tasked with constructing an evidence-based explanation to finalize their ideas about the investigative question.

This article describes the Data Puzzles framework in the context of the Wind Farms of the Future Data Puzzle. This lesson scaffolds students' understanding of local and regional wind patterns to identify locations that may be suitable for the construction of

FIGURE 1: The Data Puzzle framework integrates the four core practices of Ambitious Science Teaching into each sensemaking resource.

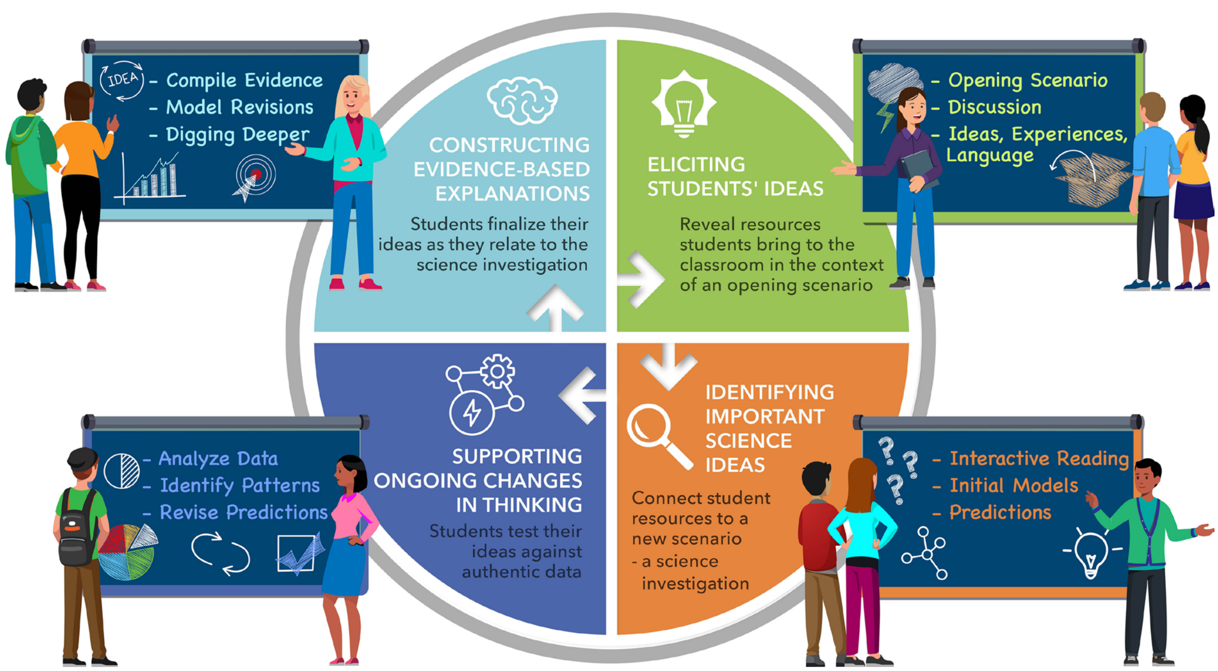


Figure modified from Ambitious Science Teaching.

future wind farms across the United States (MS-ESS3). We emphasize the ways in which student resources were used by a teacher and students as they worked through the Data Puzzle lesson (see Online Resources for additional lesson materials, including the teacher guide, which makes explicit connections to the *NGSS*).

Overview of the Wind Farms of the Future Data Puzzle

The rise in atmospheric carbon dioxide, the result of humans burning fossil fuels, is correlated to the rise in global temperatures (IPCC 2023). To stop or slow this warming trend, we must transition to renewable energy such as wind. But where should new wind farms be constructed? Dr. Julie Lundquist, an atmospheric scientist at the University of Colorado Boulder, is the featured scientist in the Wind Farms of the Future Data Puzzle. The puzzles challenges students to explore the relationship between surface roughness and wind speeds as they seek to understand why some areas across the United States are windier than others.

Surface roughness is a measure of how much "stuff" there is on the landscape and how tall it is; this can include mountains, buildings, trees, rocks, and even people. Typically, areas with less stuff (low surface roughness) will have higher wind speeds because there is less friction or drag exerted on the moving air mass (wind). Students use the Global Wind Atlas (see Online Resources) to discover that areas with low surface roughness are the same areas that have the highest wind speeds. Using what they have learned about the relationship between surface roughness and wind speeds and the understanding that higher wind speeds create more power, students then propose areas across the United States that are most suitable for the construction of wind farms in the future.

Lesson sequence

Practice: Eliciting students' ideas

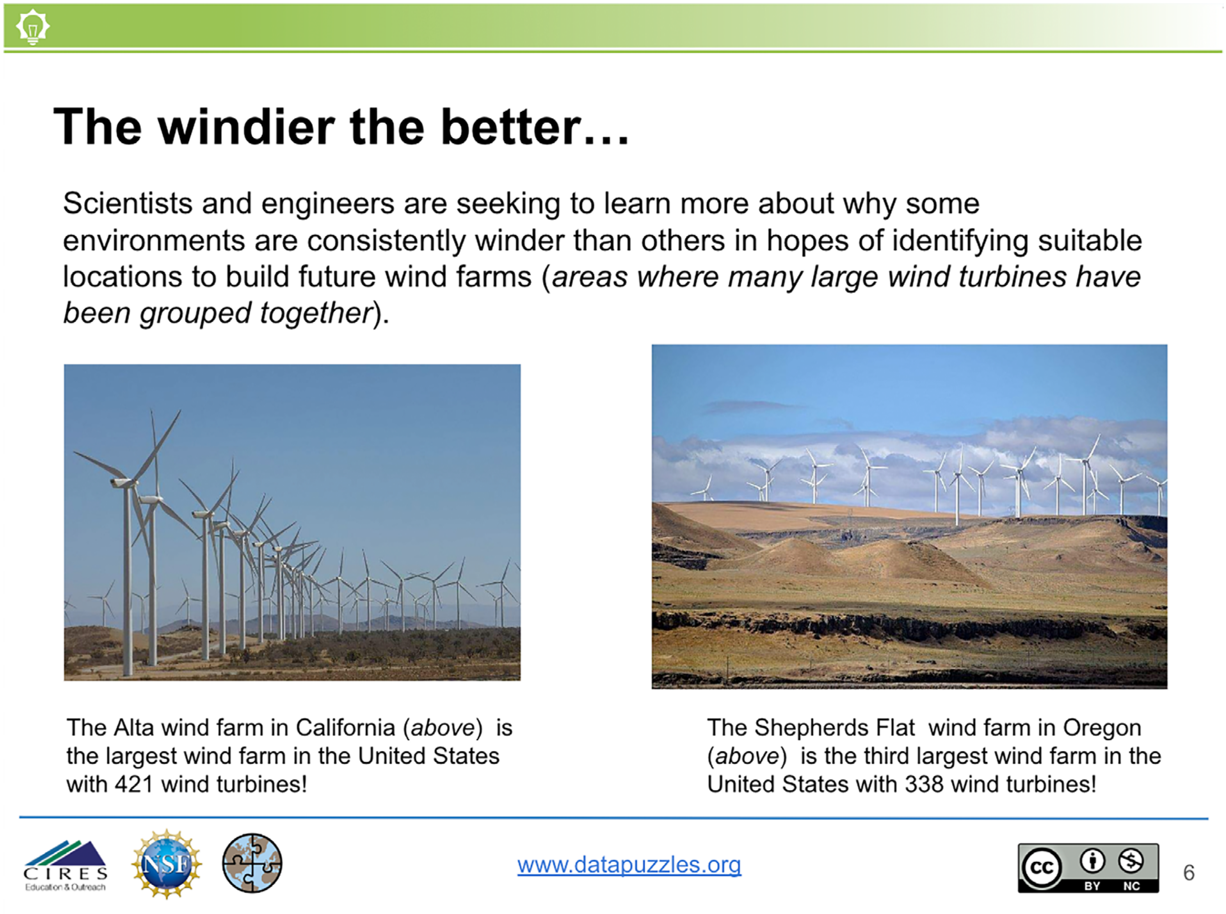
The Wind Farms of the Future Data Puzzle begins by asking students to reflect on the windiest moment of their lives. *Where were they? Is it usually windy there? What did they do?* Students in our 8th-grade pilot classroom responded to these prompts, in groups of two to four, on a large piece of butcher paper in the middle of their tables and enthusiastically discussed their wind stories with one another (Figure 2). After a few minutes, the teacher facilitated a whole-class discussion in which students shared their windiest moments.

After several stories were shared, the students "turned and talked" with a neighbor to discuss the following question: *Do you think that there are certain environments or landscapes (e.g., forests, grasslands, open water) that might be windier than others?* Students noted that beaches, mountain tops, and flat land seemed to be areas with high wind speeds. But why?

Next, students read aloud from the slide deck (Figure 3) and discovered that scientists (including featured scientist Dr. Lundquist) and engineers are asking the same question: *Why are certain areas windier than others?* Students noticed that both wind farms described in the slide deck had been constructed in relatively flat areas with little vegetation, observations many referenced in later discussions as they worked to make connections between wind speeds and surface roughness.

FIGURE 2: Students record their windy day stories on a large sheet of butcher paper.

FIGURE 3: Screenshot from the Wind Farms of the Future slide deck used to connect and segue from student experiences about a windy-day event to the research conducted by the featured scientist, Dr. Lundquist. Images from Wikimedia Commons.



At this point, students were ready to learn more about the mechanisms driving global climate change and the kind of wind-related research questions Dr. Lundquist is investigating in hopes of informing policymakers on where to best place wind farms to best harness wind energy and maximize the production of renewable energy.

Practice: Identifying important science ideas

In this section of the lesson, students are ready to incorporate new and relevant scientific concepts to support their sensemaking. Students in our pilot class watched a short video on steroids, baseball, and climate change (see Online Resources) that uses an intuitive analogy of comparing steroid use in baseball players to illustrate the scientific concept of global warming. Simply put, the more steroids a baseball player takes, the greater the chance that player will hit a home run because the steroids have made them stronger. Carbon dioxide and other greenhouse gasses act as steroids of Earth's climate system. The more carbon dioxide humans pump into the atmosphere through the burning of fossil fuels, the more Earth's temperatures will rise. Produced by the National Center for Atmospheric Research (NCAR), this video highlights the need to transition to renewable, clean energy sources like wind power and sets the stage for students to think about wind turbines (see Online Resources).

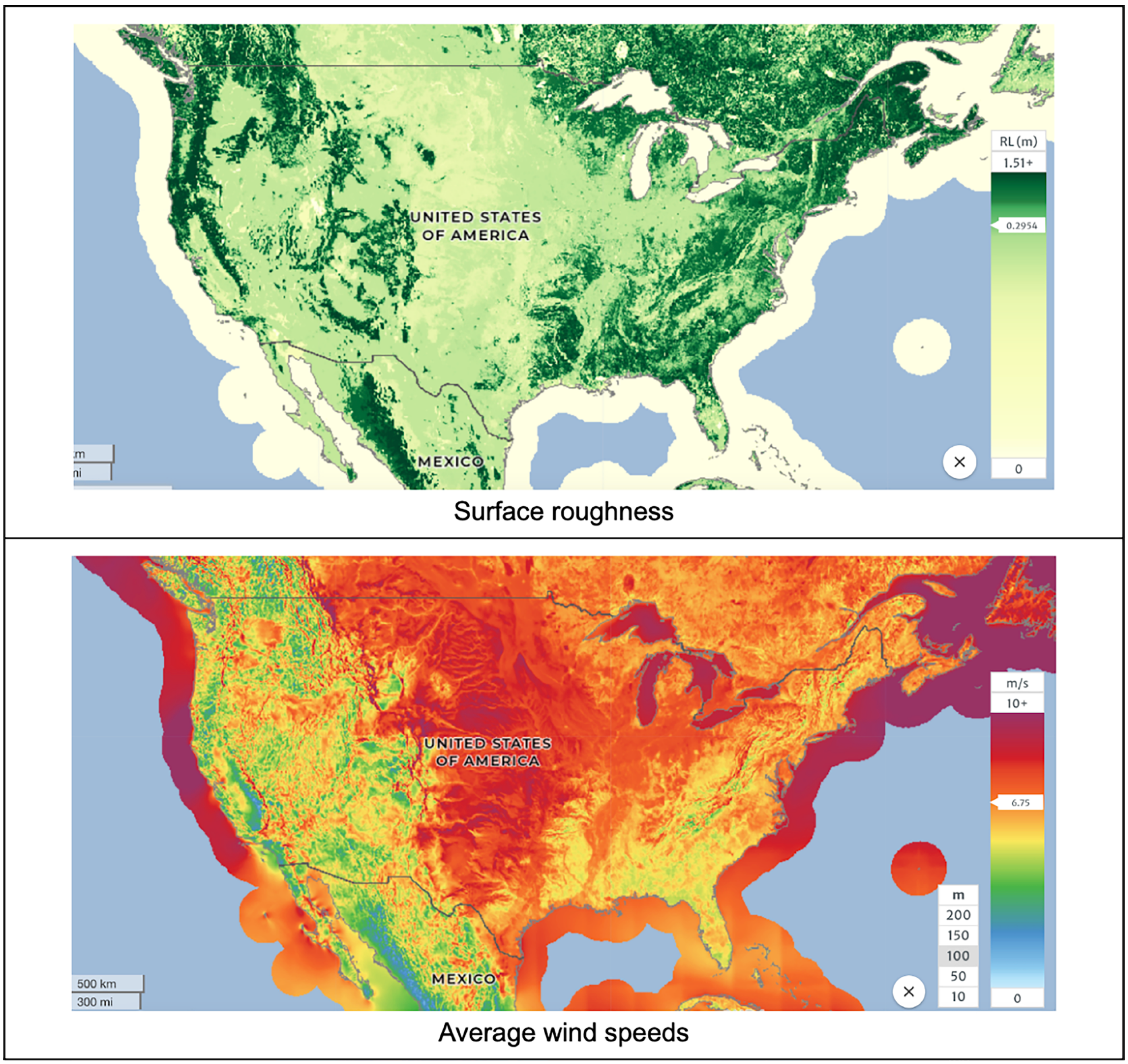
Armed with this new background knowledge, students read the Puzzle Plot text in pairs or groups of three. A differentiation strategy that other Data Puzzle pilot teachers have used is to give students the option to read the Puzzle Plot individually or to follow along as the teacher reads it aloud. As students read, they underlined similarities they found between the reading and the experiences (resources) elicited through the opening scenario prompt.

After reading the Puzzle Plot, students engaged in a whole-class discussion to compare their own experiences (resources) to science ideas introduced in the Puzzle Plot. Then, students used the evidence gathered from the Puzzle Plot class discussions to make an initial prediction for the investigative question: *Where in the United States (lands and waters) should new wind turbines be constructed to generate the most energy?*

Practice: Supporting ongoing changes in thinking

In this section, students test and refine their initial predictions for the investigative question against

FIGURE 4: Screenshots from the Global Wind Atlas.



Top image: Surface roughness values across the United States (lands and waters). Areas with high surface roughness are shown in dark green. Areas with low surface roughness are shown in lighter colors. Bottom image: Wind speeds at 100-meter altitude (average hub height of most modern wind turbines) across the United States (lands and waters). Areas with high wind speeds are shown in dark red and areas with low wind speeds are shown in light blue.

surface roughness and wind speed data across the United States using an interactive map from the Global Wind Atlas (see Online Resources). Before the 8th-grade students explored the interactive map on their own, the teacher facilitated a whole-class discussion about the different colors shown in the legend, then modeled how to use the Global Wind Atlas by demonstrating how to rotate the Earth visualization, zoom in and out on the United States, and select and deselect display parameters. After modeling the Global Wind Atlas, students explored the Atlas tools and were encouraged to zoom in on locations where they had experienced their windiest day. Students were curious to discover the surface roughness (called "roughness length" in the Global Wind Atlas) and average wind speeds for beaches, neighborhoods, and even parking lots they had visited and referenced during the opening scenario. Once familiar with the maps, students looked for broader patterns between surface roughness and wind speeds across the United States (Figure 4).

As students analyzed the maps and identified patterns, the teacher circulated, prepared with several "back-pocket questions" (Table 1), a series of differentiated questions that allowed the teacher to find out what ideas students were wrestling with. The teacher either pressed students to connect the patterns they've identified back to the investigative question or redirected students to the Global Wind Atlas data set to deepen their understanding. Students struggling to make sense of the Global Wind Atlas maps were asked to focus on Georgia's coastline (their home state), where there are extreme differences in onshore and offshore wind speeds and surface roughness. Identifying and explaining these extremes helped these students become more familiar with the color schemes defined in the legend before they applied these new understandings

TABLE 1: Back-pocket questions used in our 8th-grade pilot class.

Back-pocket questions for table talk about the Wind Farms of the Future Data Puzzle	
Teacher facilitates a whole-class discussion to help students become familiar with the graph or data set	*Identifying extremes of the data:* • What locations experience the highest and lowest wind speeds? • What locations have the highest and lowest surface roughness?
Pressing further as a teacher circulates among students while they are working with a data set	*Pattern recognition:* • What patterns do you observe? *Telling the story of the pattern:* • If you had to tell a person about the relationship between surface roughness and wind speeds, how would you communicate that? *Possible causes for the pattern:* • What do you think caused these patterns? What makes you think that? *Connecting back to the investigative question or larger phenomenon:* • How does this help us think about where wind farms should be constructed in the future?
Follow-up questions to help students think about revising their initial predictions based on new evidence.	*Metacognition—assess how thinking has changed:* • Did your initial prediction change after analyzing the data set and engaging in discussions? • Based on the patterns in the data, what can you now say more confidently about the investigative question?

to the rest of the United States. The practice concluded with students reflecting on the patterns and relationships they had identified to revise their initial predictions for the investigative question.

Practice: Constructing evidence-based explanations

In this last step, students work individually to finalize new understandings as they relate to the investigative question by constructing a written explanation. It's important to help students connect all the dots and remind them to cite data evidence from the Global Wind Atlas map, the Puzzle Plot, and even their own lived experiences in their written explanation. To support students in making these connections, the teacher facilitated the co-construction of a Gotta-Have Checklist, a public record that includes ideas and evidence that must be included in an explanation for the investigative question (Table 2). The Gotta-Have Checklist functioned as the de facto rubric for this assessment. Before turning in the assignment, students were asked to (1) review another student's explanations, checking to make sure the ideas and evidence referenced in the Gotta-Have Checklist were included, and then (2) given an opportunity to revise their explanations based on their peer's feedback.

Referencing data from the Global Wind Atlas (lowest surface roughness and highest wind speeds), students identified the Midwest and the waters just offshore the East and West Coasts of the United States as suitable locations for the construction of future wind farms. From the Puzzle Plot, students knew that wind farms could be constructed over water and were curious to learn more about the advantages and disadvantages of offshore wind farms and how many offshore wind farms already exist in the United States. Students discovered that there are currently only two offshore wind farms in the United States, but scientists, and engineers are busy planning the construction of dozens of offshore wind farms in the future!

Conclusion

This article describes how the Data Puzzles framework provides an effective scaffolding to guide teachers in eliciting student resources about an everyday event that directly connects the phenomenon to students' lives. Data Puzzles can support students' sensemaking of authentic scientific data sets in the context of a scientific investigation (phenomenon) the featured scientist(s) is working on. Utilizing a true three-dimensional pedagogical approach, Data Puzzles scaffold sensemaking about phenomena of interest to contemporary science. Classroom-friendly authentic scientific data, alongside the Ambitious Science Teaching framework, can complement science units already in use in your classroom. ●

TABLE 2: Gotta-Have Checklist co-constructed in our 8th-grade pilot class.

Ideas	Evidence
Global temperatures are rising	• Increasing atmospheric CO_2 from human activities is causing global temperatures to rise (*Puzzle Plot text*)
Transition to renewable energy (e.g., wind farms)	• Wind farms (renewable energy) should be built in areas with low surface roughness and high wind speeds to create the most energy (*Puzzle Plot text*)
Surface roughness—flat and smooth surfaces have low surface roughness	• Reference locations with the lowest surface roughness values AND actual numbers (data) from *Global Wind Atlas*
Wind speed—highest in areas with low surface roughness	• Reference locations with the highest wind speeds AND actual numbers (data) from *Global Wind Atlas*
Personal experiences with wind	• Reflect on your windiest day and consider what the surface roughness was like in the location (*Opening Scenario*)

Note: Student explanations were evaluated based on whether they included the ideas and evidence below in their evidence-based explanations.

ONLINE RESOURCES

Data Puzzles homepage—*https://datapuzzles.org/*
Ambitious Science Teaching—*https://ambitiousscienceteaching.org/*
Steroids, baseball, and climate change video—*https://www.youtube.com/watch?v=MW3b8jSX7ec*
Global Wind Atlas—*https://globalwindatlas.info/en*
Creating Gotta-Have Checklist video—*https://vimeo.com/126087021*
Wind Farms of the Future lesson materials—*https://tinyurl.com/4nzy83nj*

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