

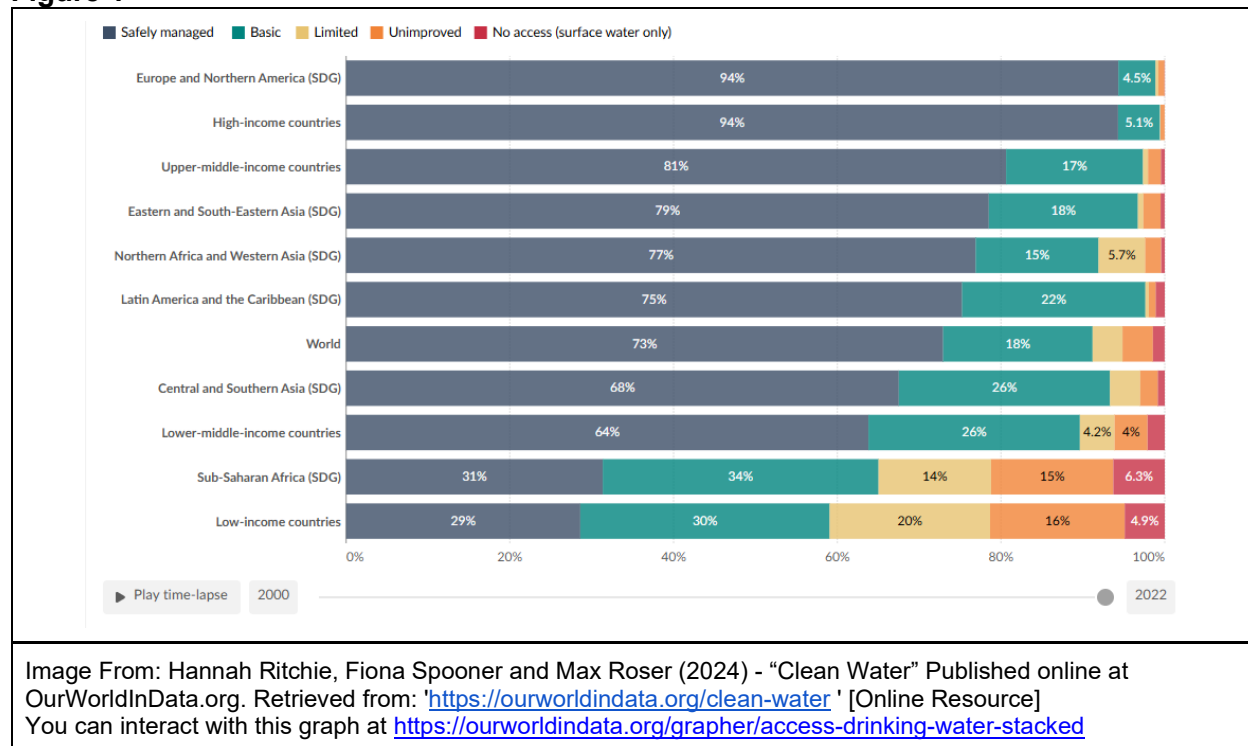
Making Sense of Data Visualizations: A Toolkit for Supporting Student Discussions

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Data visualizations offer “an alternative venue for teaching core statistical topics and an opportunity to emphasize statistical thinking over calculations.”
Nolan & Perrett, 2016, p. 268

Visualizations are increasingly used in popular news and media outlets to communicate information to various audiences and provide visuals to support claims or arguments with data. While simple bar graphs, histograms, pie graphs, scatterplots and line graphs (trend lines or time series graphs) were once the standard displays used in media, today’s advanced technological capabilities have led to many new ways to visualize data. Such visualizations often use color, shape, size, animation and geographic or spatial location to represent aspects of data or statistical measures such as an average, proportion, or ranking. The *Share of the Population using Drinking Water Facilities, 2022* graph in Figure 1 appears in Ritchie and colleagues’ online article, [“Clean Water”](#), to discuss the United Nations Sustainable Development Goal to achieve universal and equitable access to safe and affordable drinking water for all by 2030. In this visualization, the authors use a colored segmented bar graph to show the level of water management within each country grouping. Color and movement are added to help the viewer better understand the data and to be able to show changes over time.

Figure 1



Other examples of interactive components in a data visualization include using multimedia such as audio or video clips (e.g., [audio integrated into a visualization on the number of collapsed houses in Egypt over time](#)) to enhance the sensory experience with the data. Making sense of these complex visualizations has become a critical component of data literacy needed by all to make informed decisions for one's personal life and to be able to contribute through civic engagement.

Data Visualizations in Classrooms

Graphs have been an integral part of classrooms for many years; however, often these graphs are not as complex as seen in media nor used to describe social and scientific phenomena. These complex visualizations allow the focus of classroom discussions to go beyond just understanding the structure of a graph and statistical measures to also considering the ways data are being collected and used in the media. In "[A Call for Humanistic Stance Toward K-12 Data Science Education](#)", Victor Lee and his colleagues advocate for adopting a humanistic perspective around data which advocates for developing students' data literacy skills on structure of data visualizations, the methods of data collection and processing, and critical reflection on factors like how attributes are measured, who is included or excluded in the data, and potential biases that influence data collection, processing, or visualization. Ultimately, a key aspect of data literacy is knowing that our understanding of data is shaped by our personal, cultural and sociopolitical experiences.

In the past decade there have been several approaches used to ignite classroom discussions about data visualizations. One such approach is to apply a "notice and wonder" teaching strategy to data visualizations. This approach was popularized by The [New York Times' Learning Network "What's Going on in this Graph?"](#) column, which began in September 2018. In each release, a data visualization is chosen from a recent article in The New York Times and students are invited to start conversations with four prompts:

- What do you notice?
- What do you wonder?
- How does this relate to you and your community?
- Create a catchy headline that captures the graph's main idea.

Classrooms use these questions to structure conversations around the visualizations. The visualization along with students' comments and more information about the graph are archived for future use.

Others have used popular data visualizations with students through a strategy of "slow reveal". The idea behind [slow reveal graphs](#), as shared by Laib and collaborators at [SlowRevealGraphs.com](#), is to start with only a part of the visualization and then deliberately reveal additional parts (e.g., scale, axis labels) of the visualization. This helps to draw students' attention to different aspects within the visualization and allows them to grapple with the information it provides. This can be done in many different disciplines, including social studies classes as discussed by Taurence and colleagues in their article, "[Revealing the Power of Data Visualizations in Social Studies Through Slow Reveal Graphs](#)."

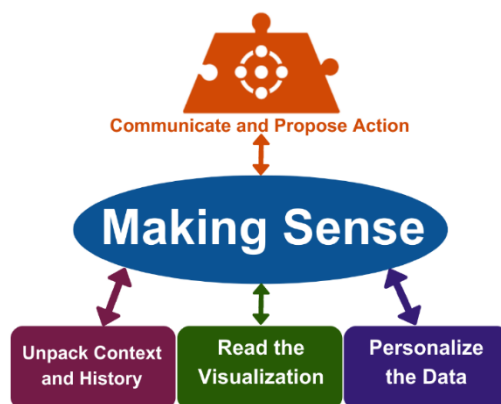
Supporting Discourse about Data Visualizations

When learners are engaged in doing data investigations themselves, they are actively involved in all the processes that lead to making visualizations of data and using those visualizations to support claims, communicate results, and propose actions, a process described by Hollylynn Lee and colleagues in their 2022 *Statistics Teacher* article, "[Digging](#)

[into Data: Illustrating a Data Investigation Process.](#) When people see data visualizations made by others, there may be significant sense making that is needed to really understand what the data represent and the story that is being communicated. Different authors have suggested different aspects or considerations that may support students in making sense of complex data visualizations. For example, in [“Notice, Wonder, Feel, Act, and Reimagine as a Path Toward Social Justice in Data Science Education,”](#) Khan and colleagues emphasize a need to “feel, act, and reimagine” how data are used to understand social and scientific issues. In [“Data Story Bytes: Examining Healthy Food Through Data,”](#) Hollylynne Lee and colleagues suggest exploring multiple aspects of a data visualization such as contextual and historical aspects, making personal connections, considering the experiences of others, and imagining how to extend learning about the social or scientific phenomena.

We designed a discourse framework for **Making Sense of Data Visualizations** (Figure 2) which brings together these different ideas into one framework while also aiming to communicate how these elements may work together to support classroom discourse around complex data visualizations. This framework consists of three coordinating elements -- **Unpacking Context and History**, **Reading the Visualization**, and **Personalizing the Data**-- and leads to considerations of how a data visualization that was created by others could be used to communicate an important message and lead to further action by an individual or a community. These three coordinating elements support students’ sense making of the data visualization and allows students to move from understanding the data visualization to action from the visualization (Communicate and Propose Action) through examining further questions or being able to articulate a data-based point of view. This diagram (Figure 2), which reads from the bottom up, helps to communicate how these three aspects (**Unpack Context and History**, **Read the Visualization**, **Personalize the Data**) work together to lead to sense making.

Figure 2



Unpacking the Context and History includes identifying the context or phenomena for the data. Students should discuss what they already know about the context and any historical perspectives related to the context. Also, they should discuss who created the visualization, why it was created and consider who or what is being represented or left out of a data visualization.

Reading the Visualization entails carefully attending to structures in the visualization like scale, axes, and color, as well as understanding what was being measured and any computed statistics that are being displayed, such as averages or proportions. Additionally, reading the visualization involves noticing unique cases or groups with similarities, as well as overall trends and patterns.

Personalizing the Data requires prompting students to think about how they and others may be represented in the data, or if they or others are not represented in the data. Data visualizations may also evoke an emotional response (e.g., surprise, happiness, empathy,

disappointment) that can contribute to students' sense making and lead them to consider biases or promote an urge to act on an issue.

After making sense of a data visualization, the viewer is then able to **Communicate and Propose Action** through making arguments supported by the data visualization, proposing next steps for further investigation, or advocating for personal or community-based actions. There are bidirectional arrows between the different elements in the diagram to communicate that making sense of a visualization is not a step-by-step process and that classroom conversations may move between and integrate these elements as learners work together to consider and process a visualization.

Applying the Making Sense of Data Visualizations Framework

The following sections provide questions that can be asked in a class to help lead to productive discourse in your classroom to help students **Make Sense** of a data visualization through each of the three supporting elements. While the elements are presented in the order of **Unpack Context and History**, **Read the Visualization**, and **Personalize the Data**, working to interpret the data will not be linear and discourse will naturally flow between these elements because they are not mutually exclusive.

To apply these ideas and questions, consider the graphs in Figure 3 from [March 16, 2022 for a "What's Going on in This Graph?"](#) activity. How can the **Making Sense of Data Visualizations** framework (see Figure 2) help students understand this display of record setting temperatures from weather stations across the United States?

Figure 3

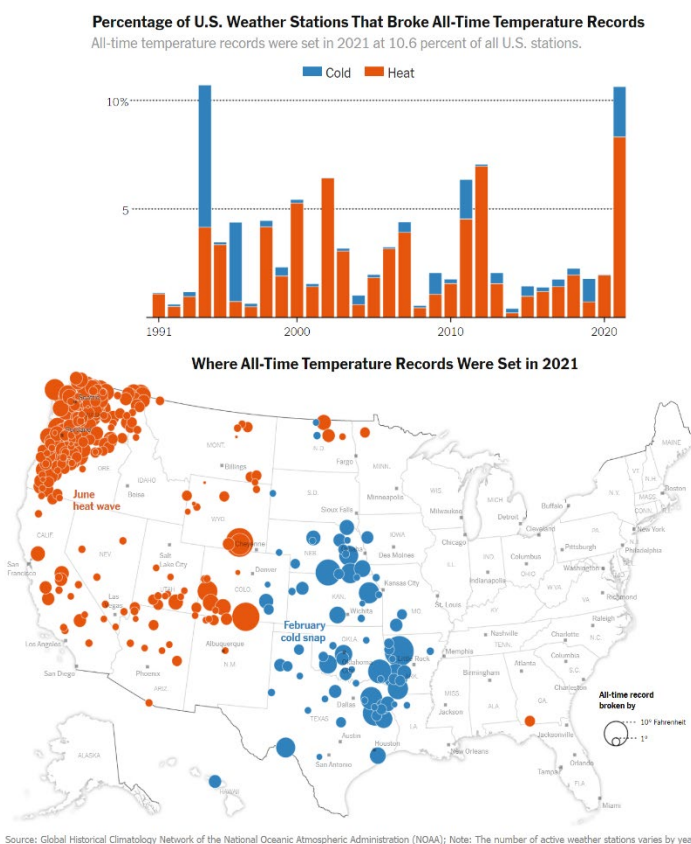


Image used with permission from The New York Times' Learning Network.

Getting Started

Making sense of a data visualization can be started by using two broad questions which provide a space for all students to be able to enter the conversation:

- What do you notice?
- What do you wonder?

After you and your students engage in an open-ended notice and wonder discussion, the conversation can then be deepened through use of focusing questions which are provided in the following sections.

Unpack Context and History

When developing meaning from a data visualization, students need to understand the context being depicted. Unpacking the context includes identifying the context and exploring knowledge of that context and its history, understanding why the visualization was created and by whom, and examining who or what is being represented or left out of the data visualization. Sometimes, this might require using outside resources to better understand the context and its history. These questions push students to make connections between the visualization, its message, and the real world.

- What is the context? What do you know about the context?
- How, when, why, and by whom were data produced/collected?
- Who created and/or published this visualization, and why? Who might be the intended audience for this visualization?
- What did the creators possibly assume about their audience?
- Are there any privacy or ethical concerns with the data?
- Who or what is left out, or perhaps misrepresented?
- What are contextual or historical reasons for patterns you see?
- What would be different if the data had been collected by different people or in a different time period?
- Can you find the original article or data source and better understand what was communicated and the data collection process?

Specifically, for the “Percentages of U.S. Weather Stations That Broke All-Time Temperature Records” visualization in Figure 3, students would need to understand the context of weather and temperature records. A teacher may pose questions such as: What is the context being represented in this data visualization? or What do you know about weather events from 1991-2021? Such questions can help students understand that the graph is trying to communicate about broken temperature records and have students engage with what they know about the weather during this time.

Read the Visualization

Traditionally within mathematics and statistics, students are asked to develop skills in making sense of graphs and representations by considering the variables, how those variables are measured, type and scale of graph, and the trends. Reading the visualization encompasses these skills, however, it also pushes students to apply the skills to new situations and non-traditional representations. Additionally, reading the visualization and the examining questions associated with it, involves noticing trends and patterns within the visualization and attributing meaning to those trends.

- What was observed/measured in the data?
- How can measurement units be expressed in everyday terms?
- How are specific measurements or statistical calculations represented?

- How are space (axes, locations on a map, size and layout, etc.) and symbols (dot, shape, color, number) used to represent data? Is there a key or legend?
- What does this visualization tell you about *specific* observations (e.g., people, items, areas)?
- How are extremes (highest, lowest) represented, if at all?
- Can you find different *clusters* or groups of observations? What does it mean for them to be similar to one another but different from others?
- What does the visualization tell you about the *general* pattern or trend in the data?

Using the example weather data visualization in Figure 3, teachers would want to build on aspects students already attended to but need to extend or dig deeper to make sense of the data visualization. For example, they might ask: What does orange and blue represent in this visualization? Why are so many of the bars in the top bar graph mostly orange? In which years did more than 5% of the weather stations record a new temperature record? What does the size of the circles mean in the map of 2021 records? What was your experience with extreme temperatures in 2021?

Personalize the Data

Making personal connections or “seeing” yourself in the data can also support students’ ability to make sense of a visualization. This requires prompting students to think about where they and others are represented in the data, or if they or others are not represented in the data. Personalizing data may also evoke an emotional response that can contribute to meaningful discussions for students. Often, questions asking students to find themselves in the visualizations are good entry points to starting to make sense of the visualization. The following questions ask students to think about how the visualization and its patterns affect them or other groups of people.

- How do you relate to the data or patterns in this visualization?
- How does this visualization make you feel?
- What does this visualization tell you about what many people may experience? How is that different from your experiences?
- How would any patterns, trends, or extreme values represented affect you or your community?
- Which people or groups do you think would feel less of a connection with the data or patterns here? What connections could they have to the context, data or patterns?
- Who is most affected by the patterns or data represented here? How are they affected?
- What information do you need to understand how this visualization affects you or your community?

Questions about personalizing the data often serve to engage students who are struggling to get started. For example, a teacher could ask about the weather visualization example in Figure 3: Were you or anyone you know part of the heat wave in the northwest or the cold snap in the central United States? How does this visualization make you feel?

Communicate and Propose Action

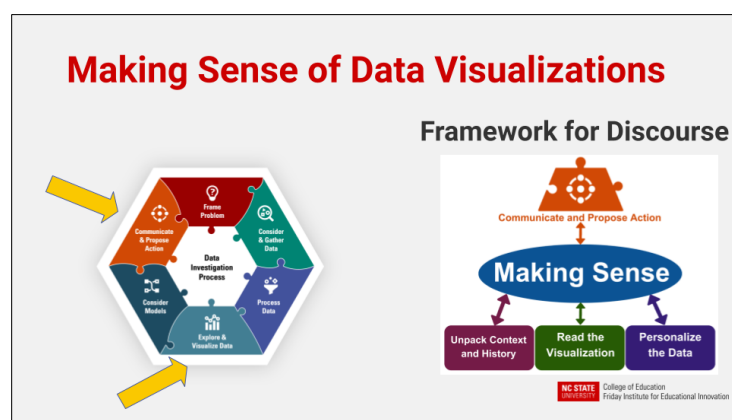
Communicate and Propose Action is the culmination of making sense of a visualization. Now that students have come to data-based conclusions, what do these conclusions propel them to do? The following questions support students to think about next steps after making sense of a data visualization.

- If you had to write an article based on this visualization, what would the headline be? Why?
- What could you do to this visualization to make it more useful for yourself or others who

- might not be included here? Explain.
- What do you need to communicate about limitations, constraints, and potential biases in these data?
- Are you moved to take or refrain from action? How would you propose/communicate that to others?
- What else does this visualization make you want to know? Would you collect more data, group or graph the data differently, take different measurements, or focus on certain parts of the data?

To better understand this framework and its implementation in the classroom, Hollylynne Lee discusses the use of this framework in a video (Figure 4) as she illustrates making sense of the “Percent of US Weather Stations that Broke All-Time Temperature Records” visualization (shown in Figure 3).

Figure 4



You can [watch this video online](#) [5:24 min].

As you watch the video, reflect on your use of **Unpack Context and History**, **Read the Visualization**, and **Personalize the Data** as you made sense of the data visualization about record setting temperatures in the U.S. What questions would you ask your students?

Conclusion

We hope that the **Making Sense of Data Visualizations** framework (Figure 2) helps you to unpack and support sense making of data visualizations. This framework not only supports students practically through asking appropriate questions but also works to connect students to the data and support understanding that data are collected, interpreted, and acted on by people who bring varied perspectives and experiences to the sense-making process. Equipping students with the skills to interpret data in their lives enables them to make informed personal decisions and actively participate in their communities. The resources provided in the toolkit below will further support your use of this approach in your classroom.

Classroom-Ready Resources for Your Data Visualization Toolkit

To prepare to structure conversations in your classroom, here are two resources from the InSTEPwithdata.org professional learning platform, where teachers can learn more about supporting discourse with data:

- [One page handout](#) with question prompts aligned with the Making Sense of Data Visualization framework.
- A [Google Slide Deck template](#) that includes space to insert an image and pose questions aligned with each element in the framework.

Below we provide some of our favorite data visualizations to use with students. There is a brief description of each data visualization with a link to where you can find it, potential grade band, and key terms associated with the visualization. The visualizations are grouped by topic.

Environment

Description and Source	Grade band	Key Terms
Global Temperature Anomalies - This visualization shows the yearly global temperature as compared to the average from 1850 - 2022. Source: Datawrapper River	6-8	global temperature, degrees Celsius, global warming
Global Carbon Emissions - This visualization compares the carbon emissions of 23 rich countries with all other countries. Source: The New York Times - What's Going On in This Graph	6-12	carbon emissions, global warming, climate change, carbon dioxide, income, percentages
Hotter Summers - This visualization shows the daily minimum temperatures for the summer months in the 2020s and 1960s for nine popular US cities. Source: The New York Times - What's Going On in This Graph	9-12	temperatures, climate change, global warming, multiple graphs
How we use water - This data visualization shows the average amount of water used per person each day in the United States. Source: Slow Reveal Graphs , with original source as Scholastic News.	3-5 6-8	Water, environment, pictograph, legend

Health & Wellness

Description and Source	Grade band	Key Terms
Sports & Recreation Injuries - This activity shows several different visualizations looking at the relationships between children sports and recreational activities injuries and age or location. Source: Turner's Graph of the Week	3-5 6-8	sports, recreation activities, common injuries, line graph of trends, bar graph, percents
Global Life Expectancy & Healthcare Expenditures - This visualization shows the relation between life expectancy and healthcare expenditures for countries from 2000-2017. Source: The New York Times - What's Going On in This Graph	9-12	life expectancy, healthcare, expenditures, countries, predictions
Share of the Population that is Undernourished - This visualization shows the share of people within different regions of the world that have a daily food intake that is insufficient for a healthy life over time from 2001-2022. Source: Our World in Data	9-12	health, food, undernourishment, interactive

Food and Housing

Description and Source	Grade band	Key Terms
American Fruit Consumption - This interactive visualization shows pounds of fruits consumed per capita from 1980-2016. Source: Tableau Public	6-12	fruits, pounds per capita, United States (US), percent increase/decrease, interactive
Meat Consumption - This visualization shows the kg per capita of meat consumption worldwide in 2020. Source: Statista	6-12	global map, meat consumption, kg per capita, countries
Ratios of Inequity - This visualization looks at the ratio of high-income households to low-income households by state in the U.S. in 2016 as well as trends over time. Source: Tableau Public	9-12	states, household income, inequity, social justice, ratios, interactive, multiple visualizations

International Comparisons

Description and Source	Grade band	Key Terms
International Optimism - This visualization compares the percentage of people who say the world is getting better from two different age groups. Source: The New York Times - What's Going On in This Graph	6-12	optimism, countries, scatterplot, percents
Global Success Factors - This visualization shows the results of a survey where 15- to 24-year-olds were asked about the factors that contributed to success. Source: The New York Times - What's Going On in This Graph	6-12	success factors, education, hard work, family wealth, countries, percents, variability
World Religions - This visualization shows the breakdown of people's religions for countries all around the world in 2010, while highlighting the populations of each country displayed. Source: Data Atlas of the World	3-5 6-8	religion, population, countries, continents, percents, cultures, pie graphs

References and Further Reading

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