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How Teachers Envision Using Data Visualization Discussion Tasks in Classroom Instruction

Abstract. A growing number of teaching materials invite students to discuss the complex mathematical, contextual and social aspects of data visualizations. Orchestrating such discussions can be difficult as it requires teachers to balance a variety of learning goals and student perspectives. This paper examines how teachers interact with data visualization discussion tasks—specifically, those that engage visualizations' social complexities—as they consider using them in their own classrooms. Drawing from semi-structured clinical interviews with six U. S.-based teachers as they reviewed discussion tasks called Data Story Bytes, we explore: How did these teachers envision using these data visualization discussions in their classrooms? And, What mathematical, contextual, and/or social aspects of visualizations did teachers emphasize when engaging with the discussion task materials? We found that all teachers envisioned using data visualization discussions as lesson openers or routine activities, but they differed in their overall emphasis on the visualizations' mathematical, contextual, or social aspects. Despite these differences, certain types of discussion prompts were associated with certain response patterns across all teachers, suggesting these task structures can help guide teachers to address multiple intended goals. Our findings represent a first step in understanding whether and how socially-oriented data discussion materials may be enacted in classrooms, and what additional design features and supports may be needed to help teachers do so productively.

Keywords: data literacy; data visualization; data talks; data discussions; data science education

Working with data has long been recognized as a core component of scientific and mathematical practice (CCSS, 2010; NGSS, 2013; OECD, 2013). More recently, there are increasing calls for educators to introduce students to data science, emphasizing large, contextually-embedded datasets that are often with the use of computational visualization and analysis tools (IDSSP, 2019; GAISE II, 2020; NASEM, 2023). As complex data visualizations become commonplace in media and across disciplines, science and mathematics teachers are well-positioned to prepare students to critically analyze these diverse informational and rhetorical tools (Edelson & Gordin, 1998; Finzer, 2013; Gray, et al., 2016; Lim et al., 2023). This involves teaching not only the mathematical aspects of data visualizations, but also how contextual and social factors shape the creation, analysis, and display of data (V. Lee, et al., 2021; Philip, et al. 2013; Gebre, 2022).

Recently, several approaches have been developed for teachers to engage students with data visualizations through classroom discussion. These come from a variety of disciplines (e.g. statistics, Arnold et al., 2022; Bargagliotti & Franklin, 2021; mathematics, Rubel et al., 2021; social studies, Taurence et al., 2022; and science, Engledowl & Wieland, 2021; H. Lee, et al., 2022) but share key features. For example, most encourage students to find personal connections with a visualization, and to consider how the data were collected and for what purposes.

Though data visualization discussions are growing in popularity, still little is known about how they might fit into classroom instruction. Supporting meaningful classroom discussions can be challenging (Levrini et al., 2019; Nathan & Knuth, 2003; Smith & Stein, 2018); these challenges may be further exacerbated since teachers may come from different fields and data visualizations involve interdisciplinary, open-ended, and socially complex content (e.g., Nipyrakis et al., 2024; Philip, et al., 2016). In this paper, we seek to better understand how

teachers navigate the multiple foci (e.g., mathematical, contextual, and social) that these discussion protocols are intended to support, what student differences they anticipate may emerge during classroom discussion, and what additional supports they need to enact socially-oriented data discussions in the classroom.

Background

Not a decade ago, the *New York Times* in collaboration with the American Statistical Association introduced the popular "What's Going on in this Graph?" column ("WGOITGraph?"; Gonchar & Schulten, 2017). The bi-weekly feature encourages teachers and students to discuss data visualizations from news articles using well-known questions: "What do you notice? What do you wonder? What is going on in this graph?" Starting in 2020, a new question was introduced which, with minor adjustments, still appears in the feature today: "How does this relate to you and your community?"

The popularity of the WGOITGraph? feature, and its evolution over time, reflects a broader educational movement to engage students more deeply with data visualizations. "Data Talks" about socially-relevant data visualizations have become popularized (e.g., Boaler, LaMar, & Williams, 2021; Flavin & Suh, 2024; Mazzacane, Wiersma, & Seshaiyer, 2023), and emerging policy recommendations emphasize how mathematics, context, and ethics intertwine in data use (see NCTM, NSTA, ASA, NCSS, and CSTA joint statement; 2024). In this section, we focus on materials that support "data talks" and identify common themes across several such materials, including one we developed called Data Story Bytes.

Analyzing Visualizations for their Mathematical, Contextual, and Social Aspects

One of the most well-known frameworks[i] for encouraging discussion about data displays is Friel and colleagues' (2001) "levels of graph comprehension" (p. 129), which include (a)

"reading the data" to extract information; (b) "reading between the data" to identify relationships or trends; and (c) "reading beyond the data" to make inferences or predictions. Whereas Friel and colleagues's graph comprehension framework highlighted mathematical aspects of data displays that all guides continue to emphasize, it was soon extended to include more explicit attention to data construction and context–what Shaughnessy (2007) called "reading behind the data."

This increased focus on context is evident in later guides from statistics and science, which ask students to consider the validity of data, asking "is this conclusion justified?" and "is this result different from what I expected?" (Pfannkuch, et al., 2010). Others seek to help students better connect data visualizations to their real-world contexts. For example, Bargagliotti and Franklin (2021) ask students how available resources such as photos, articles, and opinion pieces might prompt them to notice new patterns in a related visualization. In science education, materials scaffold students' understanding of data visualizations as a form of scientific evidence, asking questions such as "What do you think caused these patterns?" or "What evidence [from the graph] was used to write your claim?" (Griffith et al., 2024 Schultheis & Kjelvik, 2015).

Most recently, data visualizations concerning important civic and socio-scientific issues such as inequality in Gapminder (Engel, 2019), or climate change (Lanouette, et al., 2024; Lore et al., 2023) have become more common in the classroom. Some of these efforts are rooted in historical movements to integrate social justice into mathematics instruction (see, e.g. Skovsmose, 1994; Gutstein, 2007); they also resonate with the recent "civic statistics" movement (Podworny et al., 2022; Gal, et al., 2023; Ridgway et al., 2022). For instance, Rubel and colleagues' (2021) "Reformat, Reframe, and Renarrate" framework suggests that reading data visualizations should involve interrogating the decisions that underlie the collection, display, and communication of data. Building on this framework, Kahn and colleagues' (2022) "Notice,

Wonder, Feel, Act and Reimagine" extends the common notice/wonder questioning routine to include social and affective dimensions, asking questions such as "Whose perspectives are represented and whose are ignored?" and "What might you learn from reaching out to others about information presented in this data visualization?"

As attention to data literacy across the curriculum grows, similar frameworks and guides are emerging from a broader range of disciplines. Taurence and colleagues (2020), in history and social studies education, call for more integration of data visualizations as a way to examine racial injustice. Gray's "ways of seeing data" (2022) draws from the practice of art criticism to examine how social, cultural, and historical "ways of seeing" shape the construction and interpretation of data, particularly during the critical transitions from world to data, from data to visualization, and from visualization to interpretation.

The Data Story Bytes Discussion Protocol

We developed Data Story Bytes ("DataBytes" for short; H. Lee et al., 2022) during the COVID-19 pandemic for use in science classes whose typical inquiry activities were no longer feasible given instructional constraints. DataBytes were a direct response to our teacher partners' requests for short, collaborative, meaning-making exercises that engaged students with data visualizations. They include three levels of specificity: a four-part questioning framework for engaging with the mathematical and social dimensions of data (Figure 1a); a guide featuring a set of generic questions that can be applied to any visualization to move a classroom discussion through the four parts of the framework (Figure 1b); and a collection of discussion tasks with sets of questions designed to be used with specific data visualizations (Figure 1c). The DataBytes generic questioning guide is in Appendix A and available online at https://bit.ly/wds-databytes. Tasks for eight visualizations are available in PDF and Google Slides format, with instructions in

both English and Spanish to support multilingual learners. Some have extension activities that allow students to analyze the visualization's dataset within the Common Online Data Analysis Platform (CODAP).

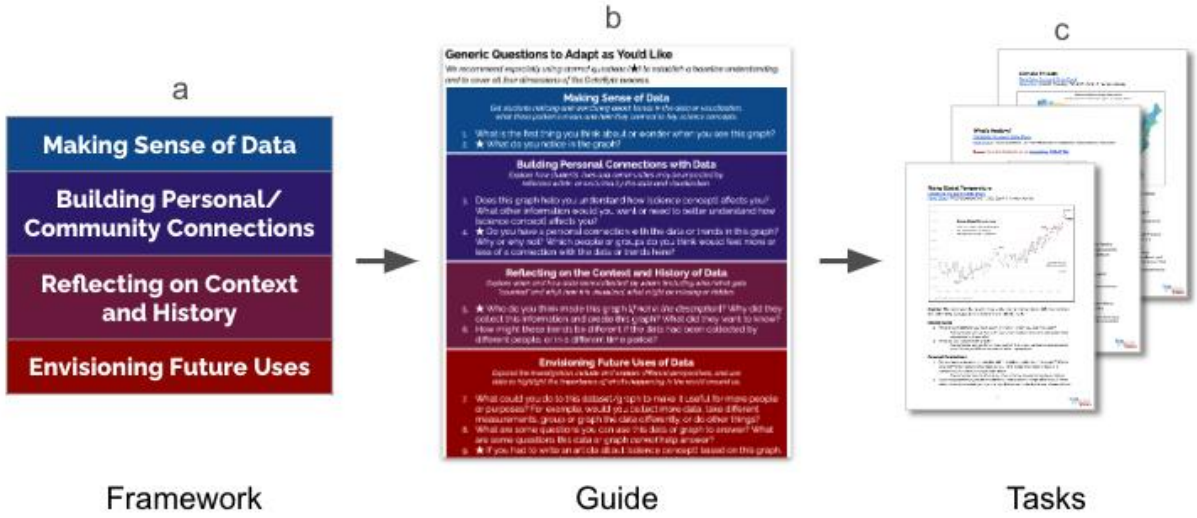


Figure 1. Our materials include (a) a general framework highlighting four key foci; (b) a guide with generic questions for any data visualization; and (c) specific discussion tasks with tailored questions for selected visualizations.

Inspired by a syncretic theory of literacy (Gutierrez, 2008), DataBytes are designed to emphasize social aspects of data by surfacing potential similarities or tensions between students' experiences and the patterns and narratives highlighted in visualizations. Our goal is to position students as "historical actors" (Gutierrez et al., 2016, p. 154) who consider how they might (re)purpose texts such as data visualizations to design better futures. For example, one of the tasks used in this study, "Is Sushi 'Healthy'?" uses a graph that appeared in an original *New York Times* article (Quealy & Sanger-Katz, 2016) and was featured in a 2017 WGOITGraph? Activity (The Learning Network), to examine perceptions of the nutritional value of various foods. Often students and teachers engaged with this task notice that their own favorite foods are missing from the visualization. This leads them to question how food items were selected, what groups of people the visualization represents, and what changes might make the visualization more

inclusive.

Common Features Across Socially-Oriented Data Discussion Materials

We organized questions from several visualization discussion guides and tasks, to highlight correspondences with the four DataBytes framework categories (see Table 1). We limited our analysis to materials that explicitly highlight social (also described as "human," Kahn et al., 2022; or "critical," Taurence et al., 2022) aspects of data visualizations.

Table 1. Common prompt types across Socially-Oriented Data Discussion Frameworks

Making Sense of Data	How does the visualization account for race, gender, class, and place and their intersection?	Does the line gradually climb, or is the change sudden and drastic?	What do you notice? What do you wonder?	What information or data is being represented in the visualization?	What does this plot show? What information is this plot conveying?
Building Personal/ Community Connections	How does the data or context connect to interpersonal relationships or to relationships with nonhuman others and the planet?		What impact does this have on you and your community?	What kinds of visual cultures and practices are implicated or reflected in the data visualization? Where do these come from?	
Exploring Context and History	Who might have been involved in the collection, production, interpretation, analysis, visualization, and communication of the visualization?	Why did the author create this? Who was the audience? What was going on at the time?	When was the data collected? Where was the data collected?	What design decisions have been taken? What are their consequences?	What purpose might the Georgia Department of Public Health have had in manipulating the plot in this way?
Imagining Future Uses of Data	How can you use the data or data visualization to challenge and inform, inspire, or support political action?	Should there be reparations for the Tulsa Race Massacre?			Why might the COVID-19 case rates be higher in counties with mask mandates than those without?

While not all these questioning frameworks include questions aligned with each DataBytes category, each category was represented by at least three. There are other notable differences in orientation across materials. Kahn and colleagues' (2022) framework, grounded in feminist and non-western epistemologies, focuses on affect and more-than-human impacts. Taurence et al (2022), grounded in critical race theory, emphasize racial injustice and oppression in society as it may be evidenced or reproduced through data visualizations. Engledowl and Weiland's (2021) guide is designed specifically to interrogate visualizations that misrepresent patterns and trends that are politically consequential.

Nevertheless, the alignments presented in Table 1 suggest that it may be productive to treat socially-oriented data discussion materials as a class of tasks. To the extent that DataBytes serve as an example of this class, understanding teachers' responses to DataBytes can shed light on ways in which teachers might approach socially-oriented data discussion materials more generally.

Theoretical Framework

Teachers' reception of DataBytes and other socially-oriented data visualization discussion materials must be understood within a context of ongoing reform efforts in mathematics and science education. These efforts draw from constructivist and sociocultural theories to suggest students learn through activities that are collaborative, authentic to the discipline, and relevant to their lives. Despite consensus about the need for such reforms, they have been difficult to implement. Teachers significantly shape how reform-based curricula are enacted (Remillard & Heck, 2014), and some studies suggest they may routinize or simplify otherwise high-quality activities (Stein et al., 2009; Kang et al., 2016).

To maintain disciplinary depth and support all students, teachers need to clearly identify their intended learning goals and be able to notice and respond to student thinking in service of those goals (Cengiz et al., 2011; Robertson et al., 2016). When working with socially-oriented data visualizations, this includes balancing a sense of clarity around learning goals amidst interdisciplinarity and the complex student ideas that may emerge (Deitrick & Wilkerson, 2017; V. Lee et al., 2022). It also includes attending to students' thinking about the role of race, bias, and ethics in the construction, interpretation, and communication of data (Philip et al., 2016; Bailey & McCollough, 2023).

We conceptualize data visualization discussions as *tasks*, or "unit[s] of disciplinary work that [are] assigned to students to intellectually engage them in science or mathematics" (Tekkumru-Kisa et al., 2020, p. 607). Tasks lend insight into how high-level reform goals are translated into curricula, and how those curricula are further translated by teachers into classroom instruction. In our case, the abstract goal of teaching the complexity of data visualization has been embodied within the design of data visualization discussions as a general task type, with DataBytes representing a particular task. We seek to understand more about how teachers envision these task types translating into classroom activities. In this way, our study provides insight into how data discussions can maintain high quality across their curricular and instructional levels, *before* they become too hastily scaled or mandated.

Research Questions and Methods

To explore how teachers engage with socially-oriented data visualization discussion materials as potential tasks in science or mathematics classrooms, we ask:

RQ1. How (if at all) do teachers envision using socially-oriented data visualization discussions, and what support might be needed to do so effectively?

RQ2. What foci (e.g. mathematical, contextual, and/or social reasoning) do teachers emphasize when exploring a socially-oriented data visualization discussion guide?

We leverage an interview-based multiple case study design (Stake, 2006), to illuminate relationships between practical goals (classroom teaching) and the theorized supports and goals highlighted in the protocols (e.g., that certain prompt types that might inspire certain types of student reasoning). The quintain of the study is teachers' engagement with DataBytes as a socially-oriented data discussion task. We consider each teacher as an instrumental case, contextually embedded within the realities of their classrooms and students as they consider the potential use of new materials in their teaching.

Data Collection

We conducted one approximately hour-long, semi-structured clinical interview with each participant. They were introduced to the DataBytes framework, selected and reviewed one DataBytes discussion task for a specific data visualization, and answered questions about how they might use similar questioning guides and tasks in their own classrooms.

Participants

Six in-service classroom teachers from the U. S. participated in the study (Table 2), from a variety of school types including public, private, and charter schools. They were recruited from contact lists of educators interested in data science education. Participants reported different levels of comfort and experience working with data in their courses. The majority taught in middle school and worked with ethnically and socioeconomically diverse student populations. They were relatively experienced, ranging from 3 to 25+ years of teaching.

Table 2. Information about Study Participants

	Currently Teaching	Years Exp.	Self Identification	Sector, State	Teacher-Description of Student Population

T1	8th Math & Science	7	Latina	Charter, CA	Latine, first-generation & migrant families
T2	6th Science	10	white Female	Public, CA	Majority Latino & white; 41% free/reduced lunch
T3	7th Math	10+	multiracial Black/White	Public, CA	Majority Black & Latino
T4	7th/8th Math	3	White	Charter, CO	~50% white; 40% Black; 10% Hispanic/other
T5	HS Math (prior 6th)	25+	White/ Jewish Male	Private, CA	High income; culturally diverse
T6	6th Science	10+	White Male	Public, NC	80% African American, w/Latino, white

Interview Protocol

Participants were asked to describe themselves and their teaching context, with focus on prior teaching experience and the demographic and instructional features of their schools. Next, we introduced the general DataBytes discussion protocol, including the four question categories of Making Sense of Data; Building Personal/Community Connections; Reflecting on Context and History; and Imagining Future Uses.

We asked participants to choose one of two specific discussion tasks concerning nutrition or global climate change to focus on in more depth for the remainder of the interview (Figure 2). The nutrition task featured a visualization titled “What’s Healthy?” (The Learning Network, NYT, 2017), with photographs of foods positioned as points on a scatterplot. The x-axis representing the percent of “Americans” who reported the food as healthy, the y-axis featuring the percent of “Nutritionists” who reported the food as healthy. A dotted line was plotted at y=x. The global climate change task featured a visualization called “Rising Global Temperature” (The Learning Network, NYT, 2019), a connected scatterplot of the difference between the mean global temperature for each year from 1880-2018 and the mean temperature from 1880-1899. Both the y-position and the color of each plotted point indicated a relatively colder (blue), typical

(white), or warmer (red) temperature. Links to view the images on the New York Times site are in the reference list.

Participants were then asked to think aloud as they worked through the selected guide, which featured several prompts that addressed different aspects of the selected visualization through the lens of the four question categories (Appendix A). We encouraged them to first answer question prompts as themselves, then to reflect on how they might imagine their students would respond to those same prompts. Finally, we asked teachers to describe overall strengths and weaknesses of the tasks, supports needed to do it well, and how they might use such a task in their own classrooms. The full interview protocol can be found in Appendix B.

Data Sources

Interviews were conducted online and video-recorded using Zoom, with the DataBytes materials projected via screenshare. The recordings were used to generate text transcripts for interpretive coding, described below. Videos were referenced in instances where the text transcript was not sufficient to infer meaning (e.g., when participants gestured to items projected on the screen).

Data Analysis

Analysis followed an iterative process consistent with qualitative multiple case study methods. This included (1) open coding and the development of a codebook; (2) generating case-specific, structured interpretive memos; and (3) generating a cross-case report to summarize similarities and differences across cases.

Phase 1: Coding

We first identified the different ways teachers referenced or described the data visualization (e.g. its patterns, messaging, content) as they worked through the DataBytes task.

As is typical with theory-driven ground-up analysis (e.g., Chi, 1997; Clarke, Friese, & Washburn, 2017), codes were developed collaboratively by the first two authors through iterative tagging and sharing with other members of the research team for feedback. During this process, we also identified teachers' references to different student needs, perspectives, or knowledge while using the DataBytes task. This process eventually yielded 18 subcodes across four code categories—Mathematics, Context, Social, and Student Differences. The full list of codes, including example excerpts from interview transcripts, is provided in Appendix C. After the codebook was finalized, codes were systematically applied to transcripts at the level of teacher turns-of-talk.

Phase II: Generating Analytic Case Memos

Next, we generated a set of analytic memos for each teacher participant. Each specified the teachers' background and school context, their justification for participating in the study, and their general reflections on the DataBytes materials. The memos summarized patterns that emerged from analytic coding of each interview (e.g., frequency and distribution of codes across interview sections); narrative descriptions connecting these code patterns to teachers' navigation of the tasks; and a list of the differences in student knowledge, perspectives, or experience that teachers mentioned.

Phase III: Generating the Cross-Case Analysis

Finally, we compared interpretive coding results and case memos across participants to identify similarities and differences across cases, as they related to our research questions. A final cross-cases analysis report described the dominant code and subcode categories for each teacher; summaries of how the teachers described potential use of the tool in their classrooms; and all student differences mentioned during the interview. It described similarities and

differences across findings, and featured transcript excerpts and analytic notes that shed light on why particular code relationships may have emerged what they could mean for teacher practice.

Results

We present our results in three parts. First, we describe ways in which teachers envisioned using tasks like DataBytes in their classrooms, and the types of supports that they believe would be most helpful in doing so. Next, we present an analysis of general trends in teachers' emphasis on mathematical, contextual, and social aspects of the visualizations as they reviewed the four sections of the DataBytes tasks. Finally, we present three qualitative cases to explore similarities and differences in those general trends in more detail.

Part I: Teachers' Perceptions of DataBytes as a Classroom Activity

There was relative consistency in how teachers envisioned data visualization discussions fitting into their curricular routines. All six teachers described them as a potential opening or closing activity that could complement a longer unit of study. Four (T1, T3, T4, and T5) mentioned they already used notice/wonder prompts or similar discussion routines in their classrooms, and sought additional focus on the social dimensions of visualizations. Three teachers (T1, T2, T3) mentioned that DataBytes or similar prompts could form the basis of an assessment, and two (T4, T6) suggested they might use them on a regular basis to help students develop general competency in reading and reasoning about diverse types of data displays and associated mathematical concepts such as percents and proportions. Several mentioned that they appreciated that the questions could be easily adapted for use with other visualizations beyond the specific ones presented. Some noted that they would likely use the task materials as a "menu" from which they would select a subset of questions.

In terms of student differences, all six participants expected that their students would approach the discussions with a variety of experiences of the topics presented. They described this diversity as a positive feature of the activity that could allow students to learn from one another and engage in authentic discussion. However, some participants (T2, T5, T6) mentioned that they or their students might be less comfortable engaging in discussion-based activities in the classroom without clear learning goals for the discussion and establishing a culture of civil discourse and community building.

The participating teachers also suggested that additional language and/or graph reading supports would be helpful for enacting socially-oriented discussions in their classrooms. For example, T1 and T4 mentioned that in addition to having the materials translated into other languages, offering sentence starters and vocabulary guides might help multilingual students develop comfort and precision in discussing data visualizations. T2, T3, and T4 and T6 all mentioned a need to support students' graph reading skills. Suggestions included having students draw a prediction of what a graph might look like before sharing the visualization, using a slow-reveal method (which gradually adds detail about scale and variables to contextualize the trends shown), or presenting multiple visualizations of the same data at different levels of complexity.

Part II: Patterns in Teacher Reasoning

Across teachers, there was considerable diversity in number of times they emphasized mathematical, contextual, or social aspects of the data visualizations throughout the interview. Table 3 displays the three main categories of reasoning codes identified in teachers' responses as they reviewed the four different components of the DataBytes tasks. Each of the three main code categories was highly represented for at least one participant: Mathematics codes were most

frequently represented in T4's interview; Context codes in T1, T5, and T6's interviews, and Social codes in T2 and T3's interviews.

Table 3. Proportion of feature codes and subcode representation per participant. The most highly represented code and subcode for each participant are indicated in bold font.

	VIZ	TREND	VAR	MEAS	PER	SUBJ	OTH	EVID	PROV	CUR	MULTI	EMO	INEQ	CRIT
T1	8%	13%	3%	8%	8%	8%	8%	13%	11%	8%	3%	3%	0%	8%
	Total≅32%				**Total≅47%**					Total≅21%				
T2	2%	10%	4%	2%	10%	6%	0%	8%	2%	6%	14%	2%	14%	18%
	Total≅18%				Total≅27%					**Total≅55%**				
T3	5%	5%	3%	8%	5%	3%	5%	3%	3%	3%	24%	4%	8%	24%
	Total≅22%				Total≅19%					**Total≅59%**				
T4	11%	13%	5%	11%	8%	3%	11%	13%	3%	11%	3%	0%	3%	8%
	Total≅41%				Total≅38%					Total≅22%				
T5	2%	12%	6%	6%	12%	8%	4%	16%	8%	6%	10%	2%	4%	2%
	Total≅29%				**Total≅44%**					Total≅27%				
T6	8%	13%	5%	8%	5%	**23%**	5%	13%	5%	3%	0%	10%	0%	3%
	Total≅34%				**Total≅49%**					Total≅17%				

To highlight how these patterns are related to specific question types, Table 4 indicates the count of teachers for whom each code and subcode was represented at least once as they engaged with each segment of the DataBytes tasks. Despite differences in teachers' overall emphasis during the interview, we find these sections of the protocol were consistently associated with certain types of data reasoning. For example, the Making Sense section was associated with references to mathematics and context codes; the Personal/Community Connections section was associated with context codes, Context and History with context and social codes, and Future Uses with all three codes.

Many of these emergent associations reflect the intended function of the DataBytes framework: to elicit and encourage integration of different dimensions of data reasoning over time. Examining the subcodes further illustrates that certain prompt types were associated with specific types of data reasoning. For example, the Making Sense section of the tasks were

associated with teachers describing trends (TRND) in the visualizations ("[…] there's a lot of correlation here, like there's a lot of agreement. It seems like to follow kind of, generally, follows a trend line of Americans and nutritionists agreeing on what things are healthy and to what degree they are, but there are some outliers there and looking at those outliers is interesting") [T2].

The Personal/Community Connections section functioned similarly as intended, and was associated with mentions of how personal (PER) and subject matter (SUBJ) knowledge, and the connections between these two aspects, informs one's interpretations of a visualization. For example, Teacher 3 highlighted historical and hereditary differences in diet and food sensitivity when asked to reflect on personal and community connections to the Nutrition visualization, remarking "I feel like this does not tell me anything […] about how diet and nutrition affect me. […] Milk, for example, like in some places people grow up healthy happy and strong drinking milk, as they report here and other places, not so much." [T3]. Teacher 5 similarly noted how connecting personally experiences to subject matter can help reframe what might be perceived as small changes in global temperature ("Trying to think like one degree Celsius in temperature outside, am I going to change my clothes probably not") to broader impacts on climate ("…if you connected to the natural disasters, living in California, the wildfires […] a student that knew about the polar ice caps or the polar bears or environment, other environmental issues due to rising global temperature then they'll probably have more of a personal connection."

The Context and History section was especially associated with mentions of data provenance (PROV), and with the ways in which datasets can reflect different perspectives (MULTI) or the use of particular measurements and calculations (MEAS, TREND). For example, Teacher 6 said of the U. S. National Aeronautics and Space Administration (NASA),

"Anytime you put a NASA stamp on something I mean, that's pretty credible information. […] had [the data] been collected in a different time period we'd probably look at things like the technology used to collect this information, if there were any error or fault."

Table 4. Count of participants (out of 6) whose responses reflected each code at least once per task segment.

	VIZ	TREND	VAR	MEAS	PER	SUBJ	OTH	EVID	PROV	CUR	MULTI	EMO	INEQ	CRIT
Making Sense	4	6	4	2	3	4	1	1	1	1	3	0	2	2
	Total=6				Total=4					Total=3				
Personal/Comm. Conxns	0	2	1	1	6	6	3	6	0	1	5	3	2	3
	Total=3				Total=6					Total=5				
Context and Hist.	1	4	1	4	1	3	2	4	6	4	5	0	1	3
	Total=4				Total=6					Total=6				
Future Uses	4	5	4	6	1	2	4	5	1	4	2	0	3	4
	Total=6				Total=6					Total=5				

Overall, teachers engaged more frequently with the social features of the visualization as they progressed through the DataBytes task, and their discussions reflected different social subcodes over the course of the interview. The Personal/Community Connections and Context and History prompts were associated with discussions of how students may adopt different perspectives (MULTI) toward the visualization—for example, because of the cultural nature of foods, or the political debates regarding climate change. The Context and History prompts were associated with more mentions of how certain design decisions are reflected within the visualization (CUR). Moving to the Future Uses set of prompts was associated with more explicit teacher attention to the role of power (CRIT) in the collection and visualization of data. For example, participants who interacted with the nutrition visualization questioned who counted as "nutritionists" and how nutrition was defined; those who interacted with the climate change visualization began to elaborate on the disproportionate impact of climate change on certain regions and communities.

We were surprised that the Future Uses section was associated with what we would describe as deeper mathematical and scientific discussion of measurement (MEAS) for all six

teachers, especially since measurement was not a frequent focus during the more mathematics-oriented Making Sense section of the task. Deeper exploration of the data suggests this is because the teachers sought to build clearer and more precise connections between the situations under investigation, how those situations were measured, and how they were represented and explained in the visualization. For example, Teacher 1 clarified that "They're showing, showing the deviation, right, from the average. Which shows like when things start to shift dramatically but seeing just a straight average and seeing how that changes at a global scale, I think, would be interesting and a little more straightforward." Teacher 5 similarly remarked that "… the average doesn't tell the whole story, like if we switch the summer data for the winter […] Maybe the median, because I'm always talking [to students] about differences between average and median." When asked how they might design the visualization differently, Teacher 3 said, "I would be interested in seeing multiple graphs where the y axis is a number of different metrics on health. Like, maybe uh, calcium content, fiber content. Some way to measure bio availability of nutrients." More generally, we observed several teachers' responses begin to simultaneously attend to mathematical, contextual, and social aspects of the data visualization during the final Future Uses section of the task. (This integrative treatment of codes in response to Future Uses prompts is further highlighted in the case studies in Part III.)

There were also some infrequent patterns worth noting within the table. Few teachers mentioned social aspects of the visualization when engaged with Making Sense prompts, or mathematical aspects of the visualization when engaged with the Personal/Community Connections prompts.

Overall, these patterns suggest that it is not enough to offer data visualizations to teachers, but that orienting them to certain thematic questions, such as the thematically organized

questions distilled in Table 1, in a more structured way can more deeply support engagement with desired teaching and learning outcomes (e.g. mathematical, social, and scientific/subject matter considerations). Asking teachers to make sense of a visualization using the most common "notice/wonder" prompts did encourage some initial engagement with the visualization's mathematical substance. Asking them to consider personal and community connections, which an increasing number of teacher support materials for data visualization discussions are beginning to do, supported deeper engagement with the related subject matter and with some social considerations related to the visualization. However, asking the teachers to consider the context and history of data deepened their social engagement with the data and began to integrate this with their reasoning along other dimensions. And asking teachers to consider how the visualization it might be redesigned for future uses unexpectedly supported more intentional mathematical and subject matter engagement (as well as more specific pedagogical considerations) across our small sample.

Part III: Case Studies

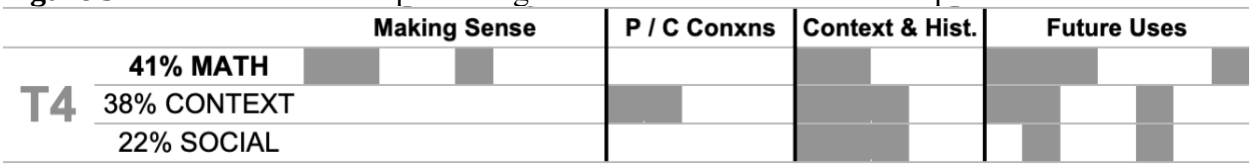
The three cases we present here were selected because together they demonstrate complementary emphases on mathematical (T4), contextual (T1), and social (T2) aspects of data visualizations. These participants also more frequently centered their students' perspective (versus their own) during the interview, which may provide more insights into their thinking about how the tasks might translate to classroom instruction.

Teacher 4: Data Visualizations to Explore Mathematics and Measurement

Teacher 4 taught 7th and 8th grade mathematics at a school that served high proportions of white (~50%) and Black (~40%) students, and focused on multidisciplinary, project-based pedagogies. T4 also described an affinity for data in their own life - they were a mathematics

major in college, and deliberately sought out data and visualizations about current events and personal hobbies such as running. They selected the Global Temperature task to review, noting that they joined the study because the recruitment materials mentioned climate-related content.

Figure 3. Timeline of codes representing T4's review of the Global Temperature discussion task.



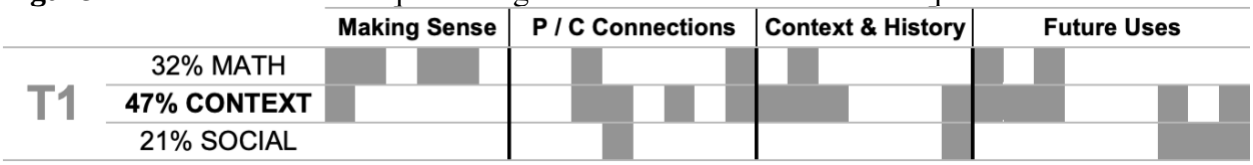
Teacher 4's interview reflected what we had originally expected from the guided data visualization discussions–a sustained engagement with mathematical aspects of the visualization, with deeper attention to context and social aspects over time (Figure 3). Throughout, they centered the ways data are being gathered and used to provide evidence for climate change. For example, during the Making Sense section, T4 said, "I wonder [...] how you calculate a temperature for the globe as a whole, like such a large thing." During the Context and History section, they noted "I would hope that if the data was collected by different people, [the trend] will look pretty similar," and expected that the Context and History set of questions would help students consider "…any sort of agenda behind the data and the graphs they're looking at."

For all teachers, the Future Uses section of the DataBytes task was associated with statements that integrated several codes, often across all three major code categories. T4 demonstrated this with their typical emphasis on the mathematical, suggesting students use the visualization for "...making predictions for the future based on what we've already seen with global temperatures. And then having students think more about impacts and especially, like, what action does this data call for us, like, what can we do to combat global warming?"

Teacher 1: Data Visualizations as Evidence for Scientific Claims

Teacher 1 was an eighth grade mathematics and science teacher at a charter school that served a majority low-income Latine student population, including students who had recently immigrated to the United States. She wanted her students to understand the growing role of data in society, and understood socially-oriented data visualization discussions as well-aligned with initiatives at her school to support culturally relevant and inquiry-based pedagogies. She also saw the DataBytes materials as useful for supporting multilingual learners. T1 selected the Global Temperature task, noting she and her students felt a strong connection to the topic through recent experiences of local wildfires and related air quality disruptions.

Figure 4. Timeline of codes representing T1's review of the Global Temperature discussion task.



Like T4, T1 engaged with the task in expected ways as she moved through the four major sections of the framework, though she demonstrated more movement between code categories than T4 (see Figure 4). Teacher 1 most frequently referenced scientific aspects of the visualization, with special attention to the causes and impacts of climate change and how social factors play a role in the collection and representation of scientific data. For example, very early on during the Making Sense series of prompts, T1 drew clear connections between mathematical aspects of the visualization and their contextual implications: "there's a lot of dips in the data and I'm curious about [...] what is causing those consistent dips over time." She focused on the impacts of rising global temperatures during the Personal and Community Connections section. When moving to the Context and History section, T1 focused on data provenance, asking: "…who worked on this data? Was it only people from the US, was it scientists globally?"

When reviewing the Future Uses section, T1 brought together the ideas of data collection as a scientific process, with data representation as form of evidence for claims. She noted she would first want to work with her students to review how data can be used for different goals such as advocacy or advertising, and how it can be constructed by different people. Then, she noted, the Future Uses prompts would be helpful for students to consider "...what are the intentions behind how information is presented, which [presentations] are successful, which are not."

Teacher 2: Data Visualizations to Explore "What Counts" and for Whom

Teacher 2 was a sixth grade science teacher with 10 years of experience at a suburban, public school that served large populations of Latino (~50%) and white (~40%) students from a variety of economic backgrounds. She reported that although she held a bachelor's degree in science, quantitative reasoning was not her strength, but she understood its importance for students' learning. She saw DataBytes as a way to strengthen this aspect of her instruction. While T2 found the Climate Change task more relevant to her teaching, she elected to review the Nutrition task for personal reasons: "I'm pregnant and I think a lot about my diet, just because I know it impacts what nutrition my kid is getting."

Figure 5. Timeline of codes representing T2's review of the Nutrition discussion task.

Unlike the other two cases presented above, T2 mentioned all three code categories– mathematical, contextual, and social–very early in the interview, and maintained heavy focus on social dimensions of the visualization throughout her engagement with the task (Figure 5). This reflects a sustained focus on cultural and biological diversity over the course of the interview,

including mentions of foods people around the world eat, different people' nutritional needs, and who counts as a "nutritionist" for the purposes of the visualization. For example, T2's first observations were related to the inclusion of certain foods and food types: "...if my family's Greek and we eat spanakopita, I could see stuff on here, it has spinach which is healthy. But has a crap ton of butter. So where does that put it?" As she moved to the Context and History section of the task, she also highlighted the social construction of health, noting that "...when I was growing up, it was always margarine, and it was never butter. And now I feel like it's shifted back."

When exploring the Future Uses section of the guide, T2 revisited these questions in ways that deepened connections to the scientific and mathematical foundations of the visualization. When asked what different data might be collected, she responded "I think thinking about what healthy means and quantifying that differently [...] maybe breaking it down by macronutrients and maybe breaking it down by caloric content…" When considering what other questions she or students might want to answer through collecting and visualizing more data, she mentioned potential comparisons in the perceived nutrition of processed and unprocessed foods, and exploring the cost and availability of healthy and unhealthy foods.

Discussion

Facilitating productive data discussions requires teachers to balance a variety of complex learning objectives and student ideas, and to translate general curricular principles into the specific classroom tasks that support learning for their own students (Kang et al., 2016; Tekkumru-Kisa et al., 2020). Below, we synthesize key insights and implications of our analysis including what teachers emphasize as key learning goals when working with these tasks and

what they identify as potential benefits, challenges, and curricular support needs for enacting these tasks in their own classrooms.

Systematic Mathematical, Contextual, and Social Foci

Across teachers, we found some evidence that data discussion guides can indeed help teachers prioritize the mathematical, contextual, and social aspects of data visualizations. Certain types of questions that are commonly featured in these materials—what we describe as "Making Sense," "Personal/Community Connections," and "Context and History" questions (Table 1)—were associated with systematic emphases on the mathematical, contextual, and social aspects of data visualizations across participants. We also have some evidence that *without* certain types of questions, some of these domains may be downplayed by teachers. Even among our participating teachers who were interested in facilitating socially-oriented explorations of data visualizations, "Making Sense" questions were less frequently associated with focus on context and social factors, and "Personal/Community Connections" were less frequently associated with discussion of mathematical aspects of the visualization. We take this as evidence that explicit discussion guides of the sort explored in this study can, in fact, support balance in how teachers navigate the multiple goals of socially-oriented data discussions.

Teachers' responses to "Future Uses" types of questions were particularly interesting. These types of questions were generally less common among socially-oriented data visualization discussion guides (see Table 1), though they were especially emphasized in the work of Rubel and colleagues (2021) and Kahn and colleagues (2022). We found that these questions were especially associated with *integrative* reasoning. We found that teachers also considered more deeply how particular measures, statistical methods, or visualization techniques could better

represent the scientific connections, social impacts, or multiple perspectives related to the topic being explored.

Diversity in Teachers' Emphases

There was still, however, considerable variability in the extent to which participating teachers emphasized (or de-emphasized) the mathematical, contextual, or social aspects of visualizations as they reviewed the data visualization discussion tasks. For each of the three categories, there was at least one teacher for whom that category was most highly represented, as well as one teacher for whom the category represented less than 20% of their overall interview codes. Given our small sample of six experienced teachers who had all expressed interest in the social aspects of data visualizations, we expect there would be an even wider diversity of emphases among the more general teacher population. This, in turn, suggests that even with well-structured discussion support materials, teachers may enact those materials in very different ways for their students (Remillard & Heck, 2014; Stein et al., 2009; Kang et al., 2016).

While this study was not designed to identify the causal mechanisms that underlie differences in teachers' approach, we did find preliminary evidence that teachers' disciplinary context and their expectations for students impacted what they emphasized during the interview. For example, Teacher 4, a math teacher, framed contextual and social considerations in terms of measurement and calculation. Teacher 2, a science teacher, highlighted how discussions of nutrition would benefit from students' cultural diversity and attention individual' different nutritional needs. We also found some evidence that the topic of the visualization, and in particular the *metric* that is visualized, shapes what teachers emphasized during their review. Teachers 2 and 3, who both explored the Nutrition task, were the two participants that emphasized social aspects during their engagement with the discussion task. The visualization

featured a social metric—measures of peoples' perceptions of whether a food was healthy—which both participants emphasized was culturally defined and subject to interrogation about "who counts."

It is worth noting that the extent to which teachers engaged with these visualizations on a personal level, and connected those personal observations with discussions of content, measurement, and pattern, is pedagogically promising. This demonstrates that the framework engaged teachers-as-learners through constructivist and sociocultural principles in ways that might similarly support more inclusive and responsive *student* engagements with data visualizations in classroom contexts. We are hopeful, but note that given the preliminary nature of this study, these results are tentative and more research is needed in order to understand how such data visualization discussion tasks might be enacted in K-12 classrooms.

Implications for Design

Our interviews offer insight into how teachers envision data visualization discussions fitting into their instructional practice, and how they may interface with other classroom structures and supports. For example, all teachers suggested they would use DataBytes as a launch activity; some additionally mentioned using them as assessment or synthesis. This suggests they are expecting the tasks to unfold over shorter time periods (10-15 minutes) than the long lists of questions featured in most materials may allow.

Designers of data visualization discussion guides may wish to offer flexibility to "pick and choose" questions to adapt to shorter time periods, whilst finding ways to maintain a focus on balancing the multiple (e.g. mathematical, contextual, social) objectives of such discussions. To the extent that attending to all three objectives is necessary for thoughtful engagement with data visualizations, our study suggests some scaffolding is needed to ensure such a balance. For

example, our DataBytes generic questions guide includes “starred” questions that we encourage to be included in *all* data visualization discussions, alongside other optional and adaptable questions (see also Weiland, et al., 2024). Our identification of specific “starred” questions is meant to attune teachers and students to mathematical and social aspects of visualizations that might, if not carefully attended, mislead or misrepresent. For example, we included starred questions that connect the visualization to relevant mathematical tools and ideas; considerations of who is represented and not represented in the dataset; and questions about the dataset’s origins. When constructing tasks connected to specific datasets, we encourage designers to develop prompts that further specify the specific mathematical and social understandings that reflect these attentions (e.g. separating trend from noise; reviewing axes and units of measurement).

Several teachers mentioned that additional supportive material would help them feel more prepared to enact socially-oriented data discussions in the classroom. These included strategies or resources to support students’ basic graph reading skills, language/literacy supports for argumentation and statistical vocabulary, and supports for interdisciplinary connections. Some of these can be built into revisions of existing tools in simple ways. For example, slow-reveal methods can be easily incorporated into data visualization discussions (Taurence, et al, 2022), materials can be translated into multiple languages, and specific visualization discussion can identify related standards and “text sets” (Cappiello & Dawes, 2023) across school subjects.

Additionally, some teachers noted the importance of building trusting classroom communities to avoid discomfort during discussions or resistance from students who may not be used to discussion-oriented pedagogies. Linking to well-established resources in this area such as protocols for productive conversations (SRI, n.d.) or community inquiry teaching strategies (LFJ,

n.d.) can help foster the conditions necessary for meaningful conversations about the intersections of data and society. More generally, it may be productive to consider how data visualization discussion guides or tasks may be constructed as "educative" (Davis & Krajcik, 2005), making explicit the knowledge base and pedagogical principles that underlie their design.

Next Steps

To help support teachers in navigating classroom conversations about data visualization, Thrasher and colleagues (in press) connected a data visualization questioning guide with a framework for a data investigation process (Lee et al., 2022). This illuminates differences between analyzing data oneself, and making sense of data visualizations created by others. The guide (Lee at al. 2023) has four elements that are meant to be integrated together, rather than seen as separate or linear: Unpacking Context and History, Reading the Visualization, Personalizing the Data, and Communicating and Proposing Action. Suggested question prompts build from DataBytes and others from Table 2 to provide support for teachers as they bring complex data visualizations into the classroom (Thrasher et al., in press). Others are also exploring how to translate frameworks and guidelines into more concrete classroom tasks and supports for teachers. Weiland and colleagues (2024), in collaboration with secondary mathematics teachers, have developed tools to guide teachers in selecting and designing questions for data visualizations aligned with specified learning goals.

Important next steps in empirical research are also needed. It will be important to follow teachers into the classroom to understand how they actually enact data discussion tasks, and how such tasks are taken up by students as the primary audience for this work. Another potentially productive next step would be to study whether and how teachers design their own data discussion tasks using generic guides, with attention to their selection of topic areas as well as

how deeply they engage the mathematical, contextual, and social dimensions of the data visualizations they identify. It is also important to evaluate the extent to which data visualization discussions support a variety of relevant existing and emerging student learning goals and performance expectations as defined through standards and policy documents (e.g., IDSSP, 2019; GAISE II, 2020).

Conclusion

While data discussion materials may be a promising way to engage students with the complexity of data visualizations, more needs to be understood about how they are interpreted by teachers and enacted in classrooms. We found wide variability in the level of emphasis teachers placed on mathematical, contextual, or social aspects of visualizations. This variability presents a challenge and an opportunity: data visualization discussions offer the flexibility for teacher autonomy and responsiveness to student needs, however, they require considerable background knowledge and material support to facilitate interdisciplinary and collaborative sensemaking. This also begs the question of what, if anything, might represent *essential* mathematical, contextual, and social considerations that should remain invariant when engaging students in data visualization discussions across discipline and topic, and how these essential considerations might be effectively promoted across contexts.

We also identified features that might especially support productive data visualization discussions. For example, our participants indicated they would be more confident about using data discussion materials if accompanied by certain additional pedagogical supports. We also found that one type of question that is not consistently included in discussion support materials—imagining future and alternative uses and representations of data—was associated with teachers' bringing mathematics into explicit contact with contextual or social considerations.

As others pursue future research and materials development, we ask: How can such materials be developed in ways that empower teachers to plan and orchestrate productive, relevant, and complex data visualizations? Our study suggests doing so requires attention not only to materials themselves, but also to their many potential uses and their intersections with complementary classroom supports and structures.

Declarations

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Appendix A. DataBytes Generic Questioning Guide

	Purpose	Generic Question Prompts
Making Sense of Data	Making sense of trends and relationships in the data or visualization, what these patterns mean, and how they connect to key science concepts.	• What is the first thing you think about or wonder when you see this graph? • What do you notice in the graph? What mathematical tools, ideas, or patterns to do you see represented?
Building Personal/ Community Connections	Building personal connections by considering how students' own lives and communities may be impacted by or reflected by the patterns found in data.	• Do you have a personal connection with the data or patterns in this graph? Why or why not? Which people or groups do you think would feel more or less of a connection with the data or patterns here? • Does this graph help you understand how [the context] affects you? What other information would you want or need to better understand how it may affect you?
Exploring Context and History	Reflecting on the context and history of the data, how it was collected, by whom (including what gets "counted" and why), how it is visualized, what might be missing/hidden, and what questions the data can and cannot answer.	• Who do you think made this graph? Why did they collect this information and create this graph? What did they want to know? • What could you do to this dataset/graph to make it more useful for yourself or others who might not be included here? For example, would you collect more data, group or graph the data differently, take different measurements, or focus on certain parts of the data? • What are some reasons for the patterns you see? How might these patterns be different if the data had been collected by different people, or in a different time period?
Imagining Future Uses of Data	Envisioning future uses of data and visualization to expand the investigation, include and explore different perspectives, and highlight the importance of understanding what's happening in the world around us in multiple ways.	• What are some questions you can use this data or graph to answer? What are some questions this data or graph cannot help answer? • If you had to write an article based on this graph, what would the headline be? What might be missing from that article? • What else does this activity make you want to know about?

Appendix B. Interview Protocol

Have you had a chance to complete the consent form? [link to participation consent form]

I'd like to record this interview, if that is ok with you. Please let me know at any time if you'd like to stop the recording.

- Action: **Press record within zoom**

Say:

Thank you for participating in this interview. The purpose of this interview is to learn about the potential of DataBytes (or Data Story Bytes) as a resource to facilitate critical data investigations and scientific inquiry.

If you feel uncomfortable being recorded, or if you are confused or uncomfortable with some of the questions you can skip them or just decline to answer. We are only interested in your feedback in order to improve the materials.

Data Story Bytes are a curriculum resource that allows for the incorporation of critical data investigations into classroom instruction through analysis of graphical displays based on a questioning framework. Many of these activities also include access to data for opportunities to further explore other questions of interest and data analyses beyond the presented visualization.

Prior to learning more about Data Story Bytes, I'd like to ask a few questions related to your teaching experience.

Questions

Years Teaching & Courses

1. For how many years have you been teaching?
2. Which subjects do you currently teach?
3. Which subjects do you anticipate continuing to teach?

To the best of your ability, please describe your teaching environment in terms of the following.

1. Student demographics (race/ethnicity, socioeconomic status)
2. Teacher demographics
3. Public school, private school
4. Other important factors about your teaching environment, particularly regarding the teaching process and student learning
5. Please describe your race/ethnicity.

Say: Thank you. Now, I will share my screen and show you the Data Story Bytes Teacher Guide so that you can learn more about this resource. After looking at the Teacher Guide, we will go through a Data Story Bytes activity, and I will ask you some questions in order to learn about your perspective of the activity and how it may relate to the learning process.

- Action: **Share screen of Teacher Guide and explain**

Say: Do you have any questions about the teacher guide information? (respond accordingly). OK, now please choose which example Data Story Byte you'd like to go through. One is about rising global

temperatures, and the other is about "What's Healthy". I can show you the images of each of these in the Teacher Guide to help you with your choice.

Throughout the DataBytes activity we will stop after each section to answer questions about how your students might respond to the section and the framework questions. So, please keep in mind that you can answer the DataBytes activity questions from your own perspective, and then the follow up questions will ask you to think about what you think your students' experiences might be. So, go through the activity as a learner, and the follow up questions will get your perspective as a teacher.

Say: Ok, we will begin with the DataBytes activity…

- Action: Explain title page and go to slide 2

Say: Please take one minute to observe the graph and read the caption.

- Action: After one minute, go to next slide (slide 3)

Say: Here is a zoomed in view of the graph. Please take a few more seconds to look and let me know when you feel like you're done examining the graph.
(After prompt from participant)

- Action: Go to next slide (slide 4) and explain the vocabulary section.

Design
Say: Now, I will ask you a few questions about the design of what you've seen so far.
Q: What other features might you want to see on the first few slides, if any? (1)

- Action: Go to next slide (slide 4) and describe the additional key vocabulary section that has been added.
- Action: Go to next slide (slide 5)

Making Sense

- Action: Go through the first set of questions in dialogue with the participant (making sense of data) on the example data story byte.

Q: How do you think that the making sense questions might change what your students' thought about the graph versus only seeing the image and caption? (3) What about the science concept of [science concept]? (3)
Q: On a scale of 1 (not at all) to 4 (very much so), how much do you agree with the following statement: The making sense questions would help my students identify interesting and/or confusing features in the graph. (2)
Q: On a scale of 1 (not at all) to 4 (very much so), how much do you agree with the following statement: The making sense questions would help my students understand the graph or identify a question I might need to ask about the graph. (2)

Personal Connections

- Action: Go to the next slide (slide 6).
- Action: Go through the question in dialogue with the participant, then go to the next slide (slide 7).
- Action: Go through the question in dialogue with the participant.

Q: Can you describe how the personal connections questions might affect your students' interest in the data investigation and science topic of [science concept]? (2,4)
Q: On a scale of 1 (not at all) to 4 (very much so), how much do you agree with the following statement: The personal connections questions (would) make the data investigation feel more relevant to my students' lives. (2,4)
Q: On a scale of 1 (not at all) to 4 (very much so), how much do you agree with the following statement: The personal connections questions would help my students notice new things in the data/graph? (4)

Context & History

- Action: Go to the next slide (slide 8)
- Action: Go through the question in dialogue with the participant, then go to the next slide (slide 9).
- Action: Go through the question in dialogue with the participant.

Q: How might your students' perspectives of the data change as a result of considering and/or answering the context and history questions? (2)
Q: Would you say that the context and history questions would lead your students to change their thinking about the topic of [science concept] and your relationship to it?
Q: On a scale of 1 (not at all) to 4 (very much so), how much do you agree with the following statement: The context and history questions would require my students to think critically about the data presentation? (3)

Using the Data

- Action: Go to the next slide (slide 10)
- Action: Go through the question in dialogue with the participant, then go to the next slide (slide 11).
- Action: Go through the question in dialogue with the participant, then go to the next slide (slide 12).
- Action: Go through the question in dialogue with the participant.

Q: Can you explain why you do or do not feel like these questions would help your students consider other uses for the data and/or how the data relates to the science concept [science concept]?
Q: On a scale of 1 (Not at all) to 4 (Very much so) how much do you feel like these questions would help your students consider new forms of measurement, observation, or other features of data related to [science concept]?

- Action: Go to last slide (slide 13)
- Action: Go through the question in dialogue with the participant (Next Steps).

General

Q: How do you see these activities fitting in with your instruction, if at all? (1)
Q: How do you feel about the design of the activities? (1)
Q: Now that you've gone through this process, would you use these materials with your own students? How?
Q: Now that you've gone through this process, would you approach this specific graph any differently as a teacher when sharing it with your students?

Data Use & Experiences

Say: OK, I'd just like to ask you three final questions about your personal data use and experiences

- Please describe your experiences using data, in general (or for personal use) and in educational settings for students' investigations or explorations.
- How often do you use data in your classroom instruction for purposes of students' investigations or explorations?
- How would you rate your comfort level with using data, in general and/or for personal purposes?

Say: Thank you for participating in this interview… have a nice day.

Appendix C. Full List of Interpretive Codes and Subcodes applied to teacher interview data.

Categories	**Sub-codes**	**Description**	**Examples**
Mathematics: References to quantitative and statistical features of the visualization.	VIZ	Mention of specific features of the visualization.	Um. I noticed the color. The graphics are all things that I recognize. -T3, Nutrition
	TREND	Mention of trends, patterns, clusters, or other ways of describing aggregate groups or subgroups of data.	Maybe this is me, like, projecting my thinking on students, but I would imagine that it leads them towards looking for a trend, or like a statement that would kind of summarize what they're seeing overall. So in this case like. My statement was about, I see a rising trend and I'd imagine them to have similar comments about rising temperatures. -T4, Temp
	VAR	Mention of variability in the data.	On this graph there's a lot of dips and the data. And I'm curious about whether there are any, anything we can pinpoint as to why between certain years you see dips and it's consistent right it goes up and down up and down, but it is, overall, having growth. -T1, Temp
	MEAS	Mention of methods or units of measurement.	I would be interested in seeing multiple graphs where the y axis is a number of different metrics on health. Like maybe a calcium content, fiber content. Some way to measure bioavailability of nutrients. -T3, Nutrition
Context: References to context related to the visualization.	PER	Mention of one's personal experience or knowledge of the phenomenon.	So for me personally, right now, like, I'm pregnant and I think a lot about my diet. Just because I know it impacts what nutrition my kid is getting. -T2, Nutrition
	SUBJ	Mention of one's subject matter knowledge of the phenomenon.	I'm thinking about what the word global means and having that anchor of a discussion prior to looking at the graph would definitely help me understand, oh, this is not just our country, this is globally. -T6, Temp
	OTH	Mention of other external sources of information related to the phenomenon (e.g. other classes, teachers, resources).	I think this is very helpful in that it sets the stage for interdisciplinary engagement. It pushes students to think about how they would engage this data if they were sitting in an English class or history class, or a science class, I think, is really powerful. -T3, Nutrition
	EVID	Mention of using the data or visualization to formulate or support an argument about the phenomenon.	There's a correlation between how recent the years are on this graph and the, how much warmer it is. And it looks like in the most recent years, it is the highest it has ever been. Now in terms of a connection to carbon emissions. On this graph specifically there's no measurement of carbon emissions or correlation here, it just has the measurements with time passing and what's the deviation

			from the average temperature. -T1, Global Temp
	PROV	Mention of the data's ownership, funding, source of external authority.	I think different people, it might change the credibility. Because anytime you put a NASA stamp on something, I mean that's, that's pretty credible information. -T6, Temp
Social: References to social considerations reflected by or shaping the design of the visualizations.	CUR	Mention of decisions the data visualization authors made to present certain aspects/trends in a graph	I started looking at dates and wondered why they, those dates were selected. I can think 1944, okay World War II. But then, I was like oh, maybe the Gulf War but 98 wasn't really, well maybe there was some war there. And um, 1904. I guess 1904 was low, and then 2016 was the high. -T5, Temp
	PERS	Mention of multiple perspectives related to the data, situation, or its representation.	I would hope that, if the data was collected by different people, it will look pretty similar. Like, I would hope that people have access to the same information about global temperatures and there's a standard for like, how people turn that, like, data from weather stations all over the world into, like, hey here's the temperature. The average surface temperature for a year. I suppose different people, like I know there are different models that people use to, like, simplify such a large amount of data, it's like weather data from all around the world. -T4, Temp
	EMO	Mention of emotions related to the data visualization.	I think this will be something that a lot of people could connect with, or be concerned about at the very least. -T1, Temp
	INEQ	Mention of social inequalities that are related to, or evident within, the visualized data.	Cost, it doesn't talk all about costs. So I'd be really interested to know more about like, how available are oranges to people, even though they're the most healthy? How available is Coca Cola to people, even though it's the least healthy? -T2, Nutr
	CRIT	Mention of institutional structures or power in determining who or what is included in data.	But "what's healthy" that's, there's cultural biases in that. And there's, you know, industry kind of misdirection going on. So that, that might be an interesting way to discuss reframing or deciding when, when to frame it one way versus the other. -T3, Nutr
Student Difference: References to ways students may approach data visualizations	Comfort/Purpose of Discussion		If you really let it sit and marinate, I think students will say more and more about it. But sometimes I don't love being an English teacher and like waiting to hear other people's thoughts and doing the wait time. But I think that is really the key here on these types of graphs.-T5, Temp
	Experience w/ Topic		I think some of my students who have a lot of context or background information about rising global temperatures would say something similar to what I did. And then some who, who may not have as much background information might not

differently.		feel quite ready to say, hey like, I have a personal connection to this data. And I think that's totally okay. -T1, Temp
	Language	I don't currently have any students designated as English language learners who I know would benefit from that, but I can think of a lot of schools just around here where they would like they need that for it to be. An accessible resource for students. -T4, Temp
	Comfort or Facility w/ Graphs	The majority of students I've seen struggle, it's like fraction–understanding of fractions and rational numbers and knowing how to progress. I feel like students that have those things are far more likely to excel and students that don't, like, that is one of the specific barriers. -T3, Nutr

[i] Throughout this paper, we will use the term "framework" to refer to a set of general themes or structures used to organize the development of discussion questions about data visualizations. We use the term "guide" to refer to sets of generic discussion questions that can be applied to any visualization, and we use the terms "discussion task" or "task" to refer to questions designed or used in combination with a specific data visualization.