Supporting Elementary Children as Critics of Data

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Introduction

We live in an age in which we are inundated with data of all kinds. There are data about the state of the economy, the nutrition of our food, the effectiveness of certain medical procedures or the success of sports teams. There are data from an array of opinion polls about myriad topics. And there are marketers who use data to tout their products and justify their claims. Given this ongoing statistical onslaught it is incumbent upon schools to include statistical literacy as a central theme in their curricula. Prominent national organizations have called for this kind of curricular emphasis. With the publication of its *Principles and Standards for School Mathematics* (2000) the National Council of Teachers of Mathematics included “Data Analysis and Probability” as one of its key mathematical standards for PreK-12 education. It calls for students to be competent in devising appropriate questions, selecting methods to analyze their data, and developing inferences and predictions to evaluate that data. In 2007 the American Statistical Association published its *Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report* (Franklin et al., 2007). It describes the permeation of statistical information in every facet of people’s lives and calls for a comprehensive PreK-12 statistical curriculum of increasing depth and sophistication.

However, there is more to statistical literacy than just learning the mathematical content. We argue here that it must also include the cultivation of a skeptical stance in which elementary school students can begin to learn to question “the legitimacy of reported results” (Franklin et al., 2007, p. 3) from scientific studies, opinion polls, or other data reports. A skeptical stance involves several important dispositions that include: raising questions, uncovering assumptions, interrogating conclusions, challenging authoritative sources, seeking out alternative interpretations, exposing decisions, and so on. The importance of this critical attitude is not new (Best, 2001, 2004; Huff, 1954; Schield, 2004). Some of the groundwork for this skeptical disposition harkens back to Dewey, who cites critical attitudes, such as posing questions, suspending judgment, weighing alternative viewpoints, and interrogating the complexities of problem situations, as an essential part of democratic living (1916/1966). Such habits of mind constitute an education for social responsibility and are an essential part of civic participation in a democracy. Building these dispositions can begin in the early grades.

Pedagogical Principles that Inform a Critical Stance toward Data-Related Texts

Fundamental constructivist principles for teaching and learning inform instruction that promotes a critical stance toward data-related texts. Such principles are also echoed in the two mathematics reports previously cited.

First, children learn by conducting their own investigations and constructing their own texts. For data-related texts, this principle means to actively involve children in the process of gathering, representing and interpreting their own data so they gain an insider's view of the messy complexities of these kinds of tasks. Children cannot be critics of texts unless they are first creators of texts themselves.

Children learn best through interdisciplinary experiences (Dewey, 1938). Therefore, it is important to integrate the construction of data texts across the curriculum so that children can acquire a broader understanding of how data texts are used in different contexts (Steen, 2007).

Children also learn by building on personal knowledge and experiences. For this reason it is essential to tie data investigations to personally relevant and meaningful contexts. Only in this way can children best understand the usefulness of mathematical skills and concepts (Schwartz & Whitin, 2006).

Children learn through social interactions (Wells, 2002). When children collect, represent, and analyze data, teachers can capitalize on the social nature of learning by inviting them to share their thinking, questions and findings with each other. In this way learners gain multiple perspectives on their own work and the work of their peers.

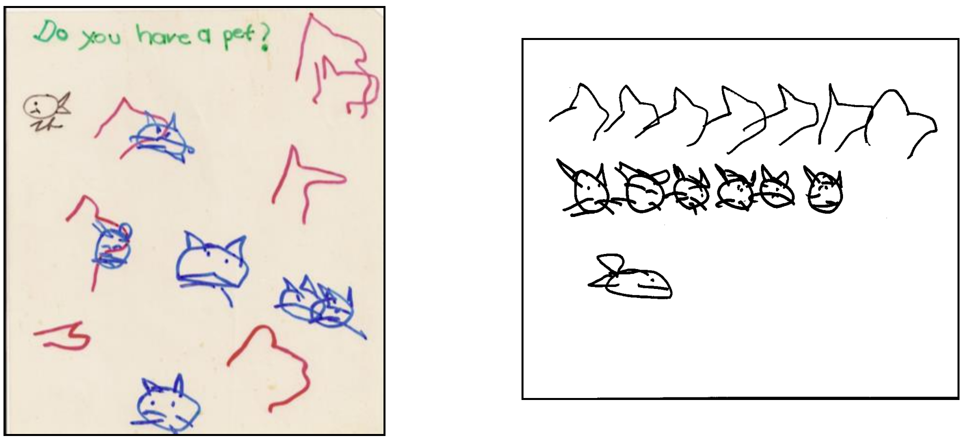
Finally, young children are active meaning-makers and problems solvers (Lindfors, 1999). Therefore, it is essential to begin to foster a skeptical stance in the early grades. Young children are quite capable of developing this discourse of critique if it grows from meaningful contexts (Vasquez, 2004).

The classroom examples below illustrate these principles in action. The first two stories each involve representing a set of data in different ways and then comparing/contrasting them. The third explores how collecting one's own data helps children learn that all data, even those in the field of science, are the result of choices that authors make. Therefore, critics have the right to interrogate those choices. These stories involve the following critical questions:

- *What does each representation reveal? What does each conceal?*
- *How might each form of representation influence an audience's thinking?*
- *How might people use each form of representation to promote a particular argument or point of view?*
- *What are the effects of posing questions in certain ways? How else might questions be posed? What might be the effects of these alternatives?*

Visually Representing Data in Two Different Ways: "Do You Have a Pet?"

A first grade teacher regularly invited her students to collect and represent data about topics of their own choice (Whitin & Whitin, 2011; Whitin, 1997). She provided blank paper for the task because she wanted the children to record their data in ways that made sense to them (Whitin, 1997). For instance, some children asked their friends to sign their names under labeled columns, others used tally marks, and some simply listed responses in the order they were received. When children completed their reports, they shared them with their classmates, and the children discussed the results as well as the recording method. On this particular day, a child asked her peers, "Do you have a pet?" She decided to record responses by drawing outlines of the pets' heads: red for dogs, blue for cats, black for fish. She soon encountered a problem when one child gave an unexpected response, "I have a dog and a cat." She solved the dilemma by inventing a way to signify this double ownership, i.e. overlapping the silhouettes (Figure 1a). Pleased with her results, she showed her teacher. After talking about her interesting findings, the teacher offered her a new piece of paper and posed an additional challenge: "Is there another way you could show your information? What might it look like? It would be interesting to show the class two different ways." After thinking for a moment, the girl redrew her pictures in another format that the class had used at other times, a more conventional pictograph (Figure 1b).



Figures 1a and 1b. A first grader represents data from her pet survey data in two different ways. **Copyright 2011 from *Learning to read the numbers: Integrating critical literacy and critical numeracy in K-8 classrooms* by David J. Whitin and Phyllis Whitin. Reproduced by permission of Taylor and Francis Group, LLC, a division of Informa plc.**

She shared her work with her classmates at circle time. Seeing the first display, one child noted how it captured multiple ownership, "You can see who has more than one animal to feed." Others counted the totals for each kind of animal. They also could see how many people had pets. The teacher then asked them to compare and contrast the two images. They remarked that it was easy to see that there were more dogs when the pets were in the rows. Other information was lost. No longer could they see that some people owned two pets, and if so, whether the pets were two dogs, two cats, or a dog and cat. The second visual also did not show the total number of respondents.

This example illustrates that when information is tied to familiar, personally meaningful contexts, and when teachers pose thoughtful questions to stretch thinking, young children can make sophisticated observations and thus lay an important foundation for developing a critical eye. This first grader and her classmates were learning that there is no one-to-one correspondence between a set of data and its representation. Authors have choices in how they visually display their findings. These choices have effects; some information is highlighted or revealed, while other information is minimized or concealed. No single representation can convey all possible relationships; not capturing some information is an inherent part of the process (Janks, 2010; Kress, 2000; Tufte, 1983).

However, as the next example shows, authors can and often do make intentional compositional decisions in order to promote a particular point of view. As children gain experience, they can learn to choose forms of representation to construct their own arguments and to interrogate the published texts of others.

Numerically Representing Data in Different Ways: How Much Sugar in Cereal?

We (David and Phyllis) had the opportunity to work with a team of fifth graders on a long-term study of cereals marketed to children on TV (Whitin & Whitin, 2011). At this point in the unit, the children knew well that consuming excessive sugar and/or sodium can have harmful health effects. Several of them had talked about relatives with diabetes or high blood pressure, as well as Michelle Obama's campaign to prevent childhood obesity. They had talked with adults about reading nutritional information on packages, but the data often made little sense to them. How much sugar is too much? 1 gram? 9 grams?

Fortunately, Phyllis read a fact in an internet article that offered a way to put these data in perspective: Honey Smacks is about 50% sugar (Boyles, 2008). By building on this example children could explore how data can be represented as discrete numbers (e.g., 7 g of sugar) or as ratios (1:4, ¼, or 25%

of the total serving size weight). In addition to developing mathematical skills, the children could gain insight into how they, as well as marketers, can use these representations as tools for persuasion.

In order to explore these ideas with the children, we decided to ask them to choose cereals that interested them and then represent the amount of sugar by using three representations: 1) the content as grams (a numerical amount, such as 9 g); 2) a physical representation of the actual amount of sugar in a serving size (measured in a zip lock bag); and 3) as a ratio of the sugar weight to the serving size weight (Whitin & Whitin, 2011). They could then more easily compare the nutritional value of the various cereals. We also planned for the children to report their findings to their classmates.

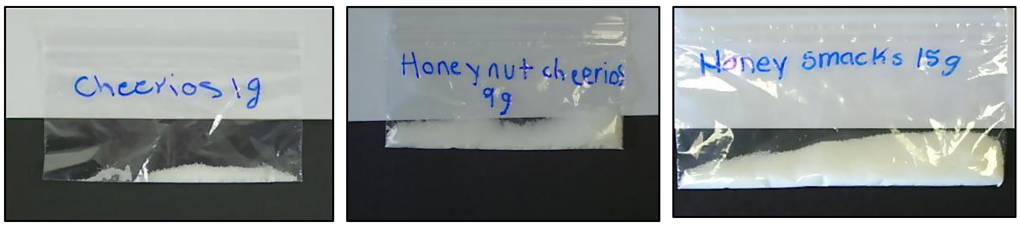
Name of Cereal	**Sugar**	**Sodium**	**Fiber**	**Serving Size**
Cheerios	**1 gram**	**210 mg.**	**2 grams**	**28 grams**
Honey Nut Cheerios	**9 grams**	**190 mg.**	**2 grams**	**28 grams**
Kellogg's Honey Smacks	**15 grams**	**50 mg**	**1 gram**	**27 grams**

Figure 2. Nutritional information for selected cereals.

Source: (Boyles, 2008).

The first representation (the number of grams) was shown in a chart that we compiled from information described in the Boyles (2008) article. Figure 2 shows some of these data. The children selected cereals that represented a range of sugar content. Next, they measured the appropriate amounts of sugar (Figure 3a, 3b, and 3c). Not only did the children gain some important experience using a weight measure that they were not familiar with, but they also were learning how a concrete representation could be a convincing way to show their classmates just how much sugar they were actually eating. The bags afforded their peers the opportunity to see, feel and compare the differing amounts of sugar in the cereals.

In hindsight we realized that we could have discussed with the children how marketers sometimes use a picture of a concrete measure in their advertising. For instance, advertisements for Kellogg's Raisin Bran featured a picture of two scoops overflowing with raisins, accompanied by the words "two scoops" (oral and/or written). This example would have reinforced to the children that even adults use pictures or physical embodiments of a measure to promote a particular point of view.



Figures 3a, 3b, and 3c: The children measured the sugar content of several cereals.

This display of the bags of sugar, such as those in Figure 3a, 3b, and 3c, served as a valuable referent for the children as they next created a representation for the sugar in the more abstract form of a ratio. Their interest in ratio grew out of their amazement in learning that a serving of Honey Smacks is about 50% sugar. A few children also wondered how this statistic could be true. This interest and questioning by the children provided us with an opportunity to discuss what ratios were, how they were created, and how people can use them to frame their claims.

Exploring Ratios as Representations

With David's scaffolded assistance, the children estimated the sugar/serving size ratio of Honey Smacks by using the data from the chart (15 g of sugar in a serving size of 27 g). He began, "Let's see if we can make one or more of these numbers into a number that is easier to work with. How about rounding 27?" The children agreed that "30" was a more convenient number than 27. "So what if we now compared the 15 grams to the 30 grams. What do you notice?" They quickly saw that the sugar weight was half of the serving weight. When David asked them if it was a little bit more or less than one half, one child reasoned, "It is even more than one half because we had to round up just to get to 30."

Next, they used a circular sketch as a guide to convert the rounded fraction, ½, to its corresponding percentage, 50%. We then discussed how the claim of Honey Smacks being 50% sugar was actually an estimate, and that in fact it was more than 50%. The children found that this ratio, e.g. the comparison of the two quantities of serving weight and sugar weight, was a powerful way to represent the high sugar content of this cereal. They followed this same process of reasoning as they worked together to calculate ratios for other cereals (Figure 4).

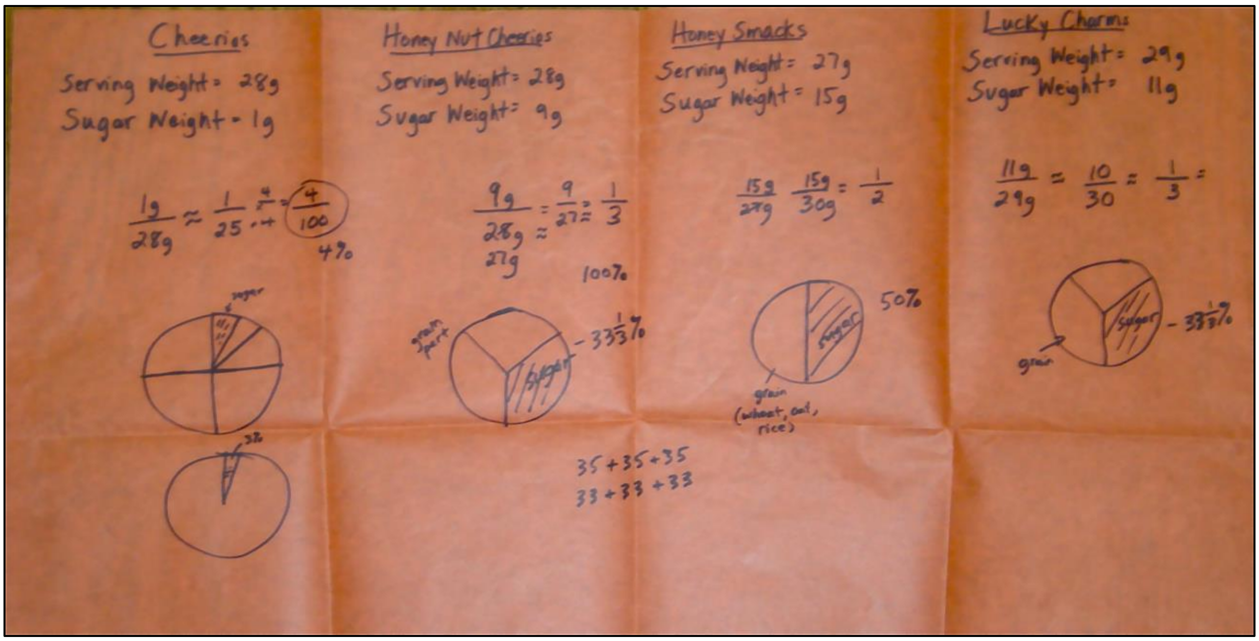


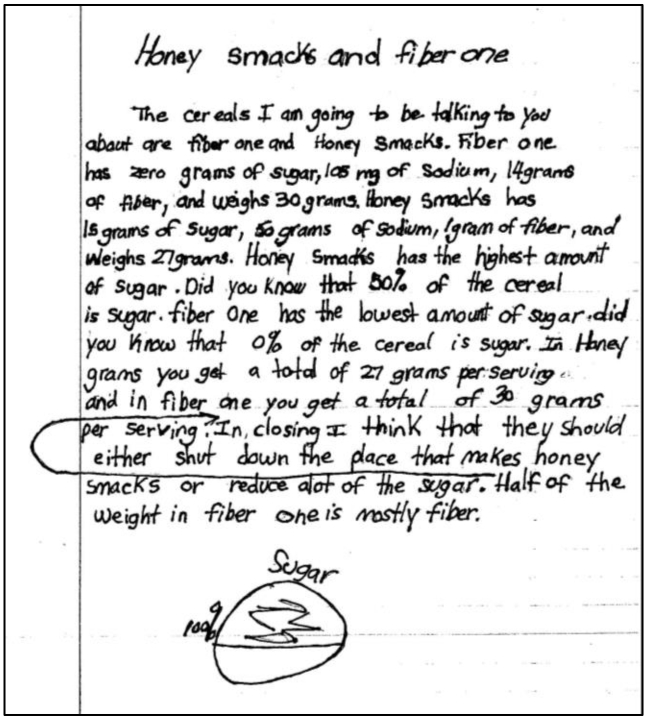
Figure 4. The children calculated the ratios of sugar to serving size for several cereals by estimating fractional parts and converting them to percentages.

The children felt that the ratios, as well as the bags of sugar, would be two convincing representations for emphasizing the sugar content of cereals to their classmates. The bags of sugar showed the actual amount that is consumed. The children also reasoned that just reporting the number of grams of sugar would not be meaningful to their peers. They felt that the discreet amount "was just a number." A ratio gave that number a context. As authors they were learning about the benefits of representing data in several different ways (Whitin & Whitin, 2012). Each representation had its own unique potential that together could help to intensify the children's message to their peers (Kress, 2000).

When they composed their reports to the class, we suggested that they include both a high sugar cereal and a healthier alternative. By using a contrast, they would be able to underscore how healthy or unhealthy some cereals were. In each of the contrasts that the children created they had specific reasons for their comparison. For instance, one child chose to contrast Cheerios (1 g of sugar, 4% sugar) with Honey Nut Cheerios (9 g, 33% sugar). This cereal research group thought that this contrast would benefit their peers who probably assumed that there was little difference between these two cereals. After all, the names of the cereals sounded almost the same.

One child used the contrast between Reese's Puffs (12 g, 40% sugar) and Kix (3 g, 10%). She chose this contrast because she was perturbed that the internet article had classified Reese's Puffs as a "good" cereal when she felt it should have been labeled as "fair" (Boyles, 2008). She wanted to be sure her peers knew about the high sugar content of this miscategorized cereal.

Another girl wanted to contrast Honey Smacks (15 g, 50% sugar) with Fiber One (0 grams, 0% sugar). Although Fiber One was not a cereal that the children had seen on TV or represented on the original chart we made, she had learned about its health benefits from an aunt who ate it regularly. The website dietfacts.com gave her the information she needed. In her report, she not only contrasted the sugar content using ratios but also took the initiative to create another ratio to emphasize the fiber content of Fiber One (Figure 5): "Honey Smacks has the highest amount of sugar. Did you know that 50% of the cereal is sugar? Fiber One has the lowest amount of sugar. Did you know that 0% of the cereal is sugar? …Half of the weight in Fiber One is mostly fiber. In closing I think they should either shut down the place that makes Honey Smacks or reduce a lot of the sugar." Representing her findings through these ratios helped to emphasize the unhealthy concentration of sugar, as well as the healthy fiber content, in a bowl of cereal.



Honey smacks and fiber one

The cereals I am going to be talking to you about are fiber one and Honey Smacks. Fiber one has zero grams of sugar, 105 mg of Sodium, 14grams of fiber, and weighs 30 grams. Honey Smacks has 15 grams of Sugar, 50 grams of sodium, 1gram of fiber, and weighs 27grams. Honey Smacks has the highest amount of Sugar. Did you know that 50% of the cereal is sugar. fiber One has the lowest amount of sugar. did you know that 0% of the cereal is sugar. In Honey grams you get a total of 27 grams per serving and in fiber one you get a total of 30 grams per serving. In closing I think that they should either shut down the place that makes honey smacks or reduce alot of the sugar. Half of the weight in fiber one is mostly fiber.

Sugar

100%

Figure 5. A cereal report using ratios to contrast the nutritional content of two cereals.

Examining How Marketers Represent Nutritional Information

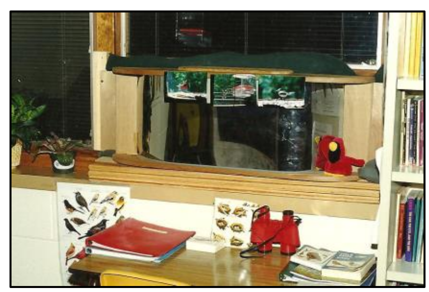
The children's interest in ratios as a form of representation led us to examine labels on dietfacts.com to see if marketers used any ratios themselves. We noticed that marketers listed separately the serving weight and the sugar weight. A comparison between the two was never made, as the children had done with their ratios. Marketers did use ratios (as percentages) for information such as vitamin content, e.g. 35% of recommended daily of Vitamin A. The children realized that cereal companies used a ratio that best emphasized a positive aspect of their cereal (vitamins) while omitting the unflattering ratio that the children had devised (sugar/serving).

These observations and discussions helped the children to see how ratios are a human construct. People use them to build an argument and promote a particular point of view. The experience fed their skeptical disposition by revealing to them how ratios are not innocent representations but rather tools of persuasion. People make choices about how data get presented, and those choices can be interrogated. Thus, the experiences with ratios integrated children's growing understanding of the mathematics with the increased emergence of their skeptical stance.

In these first two stories involving the pet graph and the cereal investigation, the children were learning how authors of data texts have choices about how to represent their findings. Critics need to interrogate the reasons for those choices and analyze the potential benefits for each of those representations. The following story looks at the data gathering process itself. Here again the children learned to be skeptical, even of scientific conclusions, as they came to understand how decisions about what to count affect one's results.

The Effects of Making Choices in the Data-Gathering Process

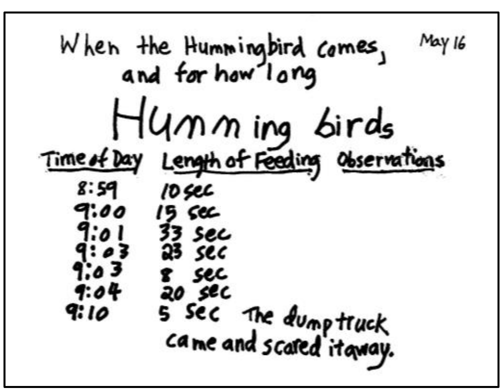
The fourth-grade children in Phyllis's class were fascinated by the birds that visited the feeders attached to their second-story window (see photos). Many of the children's questions became opportunities to gather real-life data. Through these experiences they gained a critical perspective on the data-gathering process --- that decisions made about what and how to count affect the results and ultimately the conclusions one can draw. Experience with an insider's view of the process also gave them confidence to critique scientific texts from published sources.



Several children raised questions about the hummingbirds at the nectar feeder, e.g. "How much nectar do they drink when they come to the feeder? Are they extra hungry after not eating all night?" David worked with a team of children to find out. The children took turns recording the time and length of stay for each hummingbird's visit. (They also measured the remaining nectar in the feeder every few days.)

In addition, David wanted the children who observed the birds to experience the many decisions scientists in the field have to make. To emphasize this idea he pointed out other factors that might be important to track. For instance, on one occasion he noted that a titmouse came to a nearby seed feeder, but the hummingbird at the nectar feeder continued to eat. Shortly thereafter the child who was observing noticed that after a hummingbird fed for only 5 seconds, a truck drove by and it flew off. She wrote: “The dump truck came and scared it away” (Figure 6a).

The children began to wonder if the interruptions affected the accuracy of their records. As other children continued to take turns at the viewing station, they also added observational notes about other birds’ activity to the record sheet. One girl even devised a notation for “birds” and “no birds.” Another boy wondered if keeping track of the species of birds that interrupted the hummingbirds might be important information. He wrote, “Maybe the hummingbird reacts in different ways to different birds” (Figure 6b). Yet another child, noting that hummingbirds drink in short spurts while hovering at the feeder, decided to record the number of times the hummingbird dipped its beak into the nectar (Figure 6c). It was becoming clear that there were countless aspects of data that might indicate an important relationship about feeding.



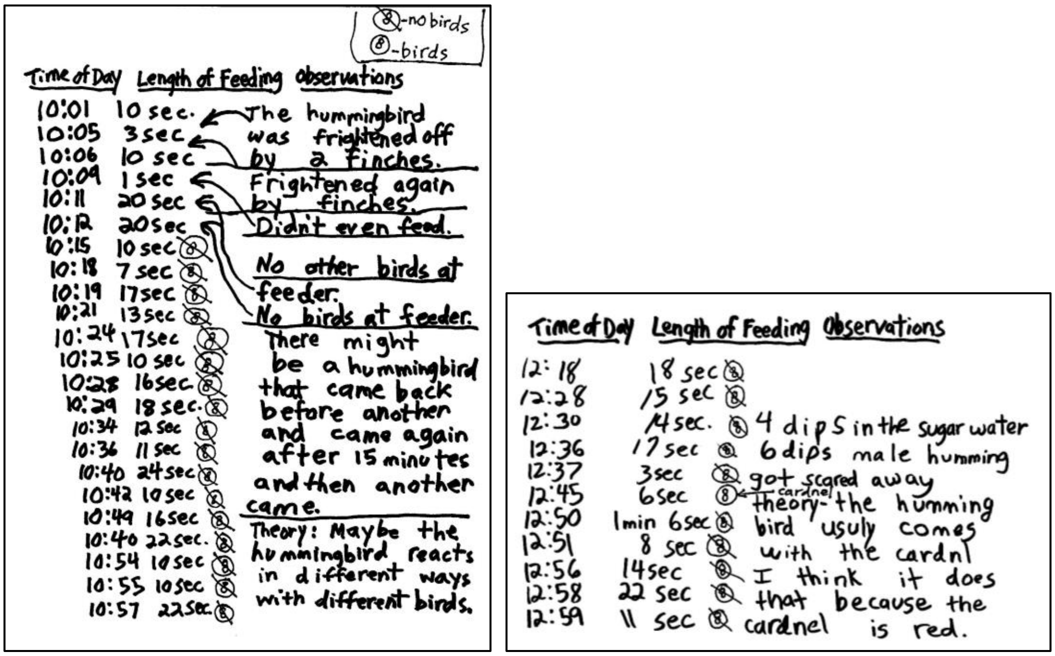


Figure 6a, 6b, and 6c. Tracking the times and lengths of hummingbird feeding. The children decided to add other observational details that they thought might affect the data.

In the end, although their results did show the times and duration of feedings (not counting breaks), and the daily consumption of nectar, their data only told a partial story. If the children had kept complete records of the hummingbird dips of the nectar, the interruptions to their feeding, the presence and behavior of other birds in the area, or other possible factors, then they might have been able to draw other important conclusions about the hummingbird's feeding habits.

However, from a critical perspective, this continuous generation of observations and questions taught the children some important lessons. They were learning that one of the benefits of collecting data is reflecting upon all the data that is not tracked. Best (2004) argues, "Something is, in short, always missing. In evaluating statistics, we should not forget what is lost, if only because this only helps us understand what we still have" (p. 25). Even in science, a field that is often perceived as a body of unquestionable facts and infallible truths, data are always partial and incomplete. This understanding helps children recognize the limits of their findings, an important part of a skeptical stance.

Concluding Thoughts

If children are to take an active role in the civic discourses of the 21st century they must develop a competent and confident voice in challenging the conclusions of data texts that permeate their lives. Maintaining a skeptical stance toward "facts," claims and assertions of all kinds is a democratic right and responsibility (Dewey, 1916/1966). However, too often people defer to conclusions that contain numerical information because they believe "numbers don't lie." The stories in this article help to show that data are not unassailable truths but rather constructions made by people for particular reasons. It is the role of critics to raise questions about data by exposing the decisions that authors made in creating them.

The cultivation of this skeptical stance is best nurtured when it is tied to key tenets of constructivist teaching and learning. For instance, when data arises out of familiar contexts and for authentic purposes, children can more easily challenge the results. The fourth graders were aware of the limits to their data on hummingbirds partly because it was connected to a collaborative, ongoing classroom experience. Furthermore, when data is tied to a topic that has a deep, emotional connection for the children, a critical stance is more successfully developed. The children wanted to know about their classmates' pets and had a vested interest in analyzing the data from two representations. They cared about nutrition because they knew family members with diet-related ailments. This integration of affect and content is an essential principle of learning that undergirds a skeptical stance (Dockter, Haug & Lewis, 2010).

Being a skeptic is more likely to become a habit of mind when it cuts across all subject fields. The stories described here include social studies (family life and pet ownership), economics (advertising of cereals), health and nutrition (cereal content), and science (bird studies). This emphasis on interdisciplinary learning also demonstrates how the learning of mathematical skills/concepts and the cultivation of a skeptical attitude can be acquired simultaneously. In fact, both skills/concepts and dispositions are necessary for each to develop in a meaningful and lasting way. As children gain an insider's knowledge of the many decisions that people in all fields must make in creating data, they become well equipped to raise critical questions about their own texts, as well as those of others

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