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Investigating Critical Numeracy

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If you think back on your reading over the past twenty-four hours, it's quite likely that you've encountered numerical data; the status of the housing market, a report on educational reform, or the results of a recent health study. It's also likely that in at least some of these texts, authors have used numerical information to make an argument or substantiate a claim. The numbers don't stand alone; as multimodal texts they work in concert with "the words framing the numbers" (Shield, 2004, p. 16) and most often with visual displays such as graphs and charts. From a critical literacy perspective, it is essential for readers to be able to interrogate all aspects of multimodal texts to expose the intentions, interests, and agendas of the authors (Janks, 2010). In this article we explore ways that teachers can include critique of numerical data within critical literacy practices. For our purposes here we use the terms "data" and "data-related texts" to mean numerical data and representational forms used to collect, categorize, display, or report numerical information. We will first consider perspectives from multimodal and critical literacy theories and then turn to instructional strategies for developing the skills and dispositions necessary for critiquing data-related texts.

Perspectives from Multimodal Theory

Multimodal theory helps explain some of the challenges involved in developing this critical orientation toward data, while critical literacy perspectives can guide ways to meet those challenges. One key underlying principle of multimodal theory is that through use, people shape all forms of communication, e.g. verbal, visual, gestural, and so forth, to serve social functions. Jerome Harste (2010) explains, "[T]here is nothing random in a multimodal text; what is there was done for a purpose" (p. 33). This notion may be apparent in the case of an editorial in a newspaper, but it's important to remember that it applies to all texts. For example, Janks (2010) shows how photographs convey implicit messages about gender, race or class. The important idea here is that as products of human activity, all forms of representation carry the cultural fingerprints of their makers and the social groups with whom they identify (Kress & Jewitt, 2003).

One of the challenges in applying these tenets of multimodal theory to data texts is the culturally acquired disposition not to question numerical information (Best, 2004), as evidenced by popular adages such as "numbers don't lie" or "the data speak for themselves." In the case of data texts, perspectives from multimodal theory remind us that people must decide what questions to ask, how to define what gets counted, how to categorize the data, and how to visually represent, describe and report the results. All of these points along the way involve choices and people (who in turn represent social groups with certain power) who make those decisions. A critical orientation toward data exposes those choices and asks questions about their implications. Critical literacy practices can suggest possible avenues for critiquing texts that involve numerical information.

Integrating Critical Numeracy within Critical Literacy Practices

Lewison, Flint and VanSluys (2002) describe several key dimensions of critical literacy that are particularly helpful in this regard. These include: developing a language of critique, interrogating how texts position readers, and examining texts to expose how certain voices are marginalized or silenced. The strategies and guiding questions found in Figure 1 reflect these dimensions. The guiding questions represent the language of critique because they attempt to uncover the decisions that authors made in constructing data texts as well as to interrogate the effects of those decisions on readers. These effects relate to how texts position readers (How might my audience respond if I use each of these questions?) and how they can marginalize or silence particular voices (Who might benefit from having the data described in these ways?).

Data texts are one example of a multimodal text that has infiltrated every part of our daily lives.

The strategies in Figure 1 relate to three aspects of the data-gathering process. They involve critique of how the wording of questions affects the data that are collected (Question Quest); examination of what is revealed and concealed by different visual forms of representation (Visual Re-View); and the relationship between the ways data are displayed and reported and the conclusions readers are likely to draw (Summary Scrutiny). We illustrate these strategies with classroom examples. The children's work as both readers and composers reflects another key principle of literacy instruction that strongly supports the development of a critical orientation toward data: that reading informs writing and vice versa (National Council of Teachers of English, 2004). When elementary school students have ample opportunities to collect, represent, and interpret data that are relevant and meaningful to their own experiences they gain a lived-through knowledge of the process (Whitin & Whitin, 2011). These experiences provide rich opportunities for them to examine their own data texts to see what is shown and what is hidden or lost. In this way they come to know that data-related texts are human constructions. It is this understanding that then supports them to examine the effects of the choices that other authors have made (Janks, 2010).

Figure 1: Strategies to Develop Critical Reading of Data-related Texts

Strategy	Questions to Pose
Question Quest	
	How might my audience respond if I use each of these questions?
	How is this text positioning my readers?
	What words or phrases might be influencing their thinking?
	How else might this question be asked?
Visual Re-View	
	What does each graph say or show us? What does it not say?
	Who might benefit from having the data displayed in each of these ways? How else might the data be displayed?
Summary Scrutiny	
	What might the audience think as they read these words?
	Who might benefit from having the data described in these ways?
	How are the results different from the conclusions?

How Questions are Posed Affects Data Collection

Opportunities abound for children to examine the format and wording of research questions and to analyze the effects of those decisions. The strategy we call Question Quest involves asking children to brainstorm alternative questions and to imagine the effects of each by considering, "How might my audience respond if I use each of these questions?" Actually trying out each question and comparing the results can be beneficial, such as posing a question in an open and closed format. Even preschool children can compare and contrast their classmates' responses when they are asked to choose their favorite color from a box of eight crayons (closed question) versus when they are simply asked, "What is your favorite color?" (open question). A follow-up discussion can highlight how a closed question restricts choices and can thereby silence the voices of some students. Interrogating the inevitable effects of each type of question format highlights the power that authors have in controlling the data they collect (Janks, 2010; Whitin & Whitin, 2011).

By including numeracy under the umbrella of critical literacy we can begin to break down the myth of data being both unquestioned truths as well as value-free creations.

A group of fifth graders similarly grappled with the different effects of open versus closed questions when their principal asked them to investigate possible improvements for the school lunch program (Whitin & Whitin, 2011). They decided to conduct a survey in several classes across grade levels. In order to give their respondents free choice, they asked open questions: What is your favorite fruit, vegetable, main dish, and dessert? When they received the completed surveys, they found that overwhelmingly students wrote "apple" in the space provided for fruit. Did these results reflect the actual popularity of apples, or, as one student hypothesized, might apples simply be the first fruit to come to mind? This student suggested, "If we didn't allow them to pick apples, then all those people would have to pick one of the other choices." The group then created a follow-up survey that offered a list of specific choices but omitted apples. This instrument did yield a greater range of popular choices. They included information from both surveys in their final report along with an account of the two question formats. This experience underscored for the children how asking about favorite fruits by using both open and closed questions can provide different numerical results.

We also guided these fifth graders to examine the affect and tone of another question on the survey. Since the intent of the investigation was to find ways to increase student participation and satisfaction in the school lunch program, the fifth graders wanted to identify areas for possible improvement. At the same time they did not want to encourage their respondents to complain unnecessarily. As one child pointed out, some students probably ate and enjoyed most cafeteria meals. Here was another opportunity for the Question Quest strategy. We asked the children to brainstorm several alternatives and imagine what respondents might think when they read the question. They thought that the question, "What bothers you about school lunches?" might suggest that everyone disliked all of the meals served. The children decided upon a question that deleted the word "bother" and suggested that only part of an occasional meal might be objectionable: "When you are not happy with something for lunch, what is usually your reason?" followed by several choices, such as "soggy" and "not cooked." They felt that this wording would be more likely to invite thoughtful consideration of their question. This experience demonstrates children's growing understanding of how word choice can position readers to think in particular ways, a significant aspect of critical literacy. The children were interrogating their own texts, and asking themselves, "How is this text positioning my readers?"

When children have the opportunity to explore the effects of their own alternative questions, they are better able to examine the questions of others. For example, a kindergarten class participated in Cornell Laboratory of Ornithology's Project FeederWatch, a program in which members of the public document the number and species of birds that come to feeding stations. The implied research question was, "How many birds of the same species do you see at one time at your feeder?" The students realized that the Lab did not ask them to indicate if the birds they saw were male or female. Although not all species have differentiated plumage, for these young birdwatchers, noting the difference when possible was important data. Several children enlarged the question to add this layer of information in the observational charts. The children's alteration demonstrated their emerging awareness as critical readers that the wording of a question can broaden or narrow what gets counted. This interrogation of word choice must pervade all subject areas, including the realm of science, which can often go unchallenged because of its socially-constructed aura of detachment and infallibility. It is this problematizing of texts across all content areas that is a noted hallmark of critical literacy instruction (Lewison, et al., 2002).

Visual Displays of Data: What is Revealed and Concealed?

Since developing technologies are giving rise to myriad new ways to represent data, it is crucial to develop children's ability to analyze the effects of the choices that composers make

to visually represent data. In the case of visual images it is the composer's use of the elements of design, e.g. perspective, spatial layout, size, and color, which work to capture viewers' attention and encourage them to notice particular details and relationships (Janks, 2010). These effects also extend to graphs and other displays of visual information (Kress, 2000). A strategy we call Visual Re-View can foster in children an ability to analyze what is revealed and what is concealed in graphs and other data displays. The strategy involves representing one data set in two different ways, such as a pie chart and a bar graph, and then comparing them.

There are many ways for teachers to incorporate contrasting visuals into nonfiction units in reading and writing workshop and across the content areas. For instance, during a science lesson that involves constructing a graph, teachers can ask half the class to represent the data using a different format. Another alternative when using software is to project several representational formats of the same data set and discuss them. Teachers can also ask students to re-represent data from a graph found in a textbook, the media, or a children's book. To guide discussion, ask: "What does each graph say or show us? What does it not say?"

Even young children can be encouraged to pose these questions. In the example of the Project FeederWatch described above, several of the kindergarten children varied the format that we had originally designed for data collection: a table with pictures of the most common feeder visitors, and spaces to enter only the number of birds seen at one time. One pair of children added "M" (male) or "F" (female) next to some of the marks, which recorded a second layer of information. Another pair designated "M" (mommy bird) and "D" (daddy bird). They also drew bird silhouettes to identify species by their specific physical features, e.g. showing the cardinal's pointed crest and sharp beak vs. a finch's rounded head and curved beak (See Figures 2 and 3). A class discussion highlighted that all three formats showed the numerical totals, but two revealed the additional information of sex and/or the bird's physical features. The children were learning to be critical readers of this data chart by changing it visually to represent other information that they felt was important to track.

Figure 2: Most of the kindergarten children represented data from Project FeederWatch based on directions from Cornell Lab of Ornithology. They recorded the total number of birds of each species seen at the same time.

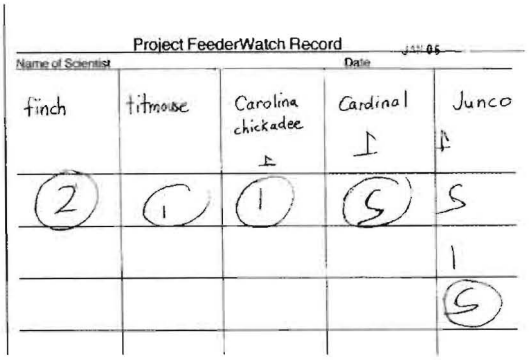
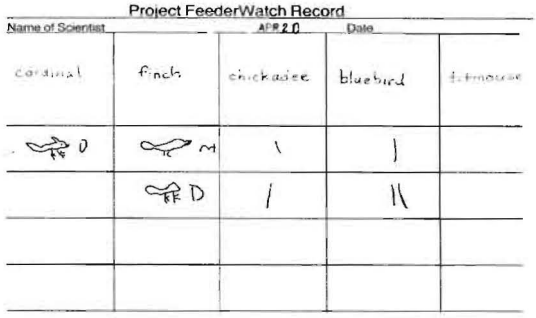


Figure 3: Some children invented ways to show additional layers of information, such as male and female birds ("M" for "mommy;" "D" for "daddy") and physical features such as a cardinal's crest.



This critique was particularly important because the children did not hesitate to question an authoritative source, the Cornell Lab of Ornithology. Although the children might have deferred their criticism in light of this perceived unequal power relationship they did not do so. We suspect a major reason that they challenged this scientific chart is that it was tied to a topic they were knowledgeable about. They had had discussions about beaks, plumage, identification by sex, and silhouette recognition and knew there were a range of attributes that could be tracked. Connecting this data table to the children's lifeworlds emboldened them to critique it. This disposition to critique authoritative sources is a significant stance for critical readers to take and it must be one that permeates all subject areas (Vasquez, 2004; Whitin & Whitin, 2011).

Published texts also offer opportunities for the Visual Review strategy. We used the children's book Tiger Math: Learning to Graph from a Baby Tiger (Nagda & Bickel, 2000) to investigate alternative representations with fifth-grade children. The book describes the efforts of veterinarians at the Denver Zoo to save an orphaned Siberian tiger cub. Graphs in a range of formats accompany the information in the narrative. Some of the same information is represented in two ways. For instance, a pictograph shows the estimated populations of several species of tigers in the wild, while a pie chart shows the percentage of each species in relation to the population of tigers as a whole. Interestingly, the pie chart has one additional species, the South China tiger, which represents only 1% of all tigers living in the wild. There are so few of this species (40 in 2000, when the book was first published) that it could not be represented on the pictograph, where one image of a tiger represented 500 tigers. What was revealed in the pie chart was lost on the pictograph. Discussing this distinction

This experience demonstrates children's growing understanding of how word choice can position readers to think in particular ways, a significant aspect of critical literacy.

helps to build critical readers who come to know that all representations, including graphs, are partial, and that authors have choices about what to show and what to omit.

Summary Scrutiny: How are Data Reported, Described, and Used?

The Summary Scrutiny strategy involves critiquing two aspects of how authors report their results and draw or imply conclusions. The first highlights the differences between the results (the data themselves) and conclusions (the interpretation of the results). The second underscores the power that authors have in framing their point of view when they can control how numerical information is represented. A discussion of a fourth-grade class graph of birthdays illustrates these ideas. The teacher first asked the children to make observations about the data. They offered a range of comments, such as, "September and October have the most," "The two 'J' months have 1 each," and then, "No one has a birthday in February." The teacher noted that these observations were the results, and then asked them to imagine someone looking at the data in order to draw conclusions. "What if someone said that no one is ever born in February?" Several children protested: "Our graph shows there are no February birthdays in here!" "My sister's birthday is February." "I had tons of kids in February at my old school." The graph, then, told a partial story about birthdays (i.e. birthdays in their class), but other graphs representing different samples could tell different stories.

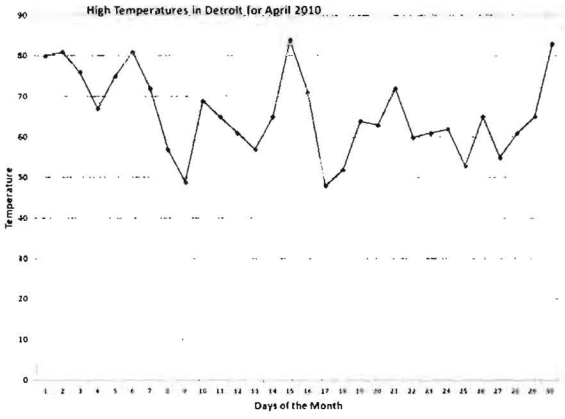
For homework the children tabulated the birthdays of family members so that they could compare data from a larger sample to the class sample of 25. When they examined the larger data set of 180 birthdays, they were surprised to find that February now had the second highest total, while April's rank changed from second to last. An entirely different set of conclusions could be drawn, but critics might question those conclusions as well. What if data were tabulated from an even larger sample, such as the entire school body? Raising questions such as these promotes a disposition of healthy skepticism toward the ways data are described and reported.

When children collect their own data about topics that interest them, they can use their experience of the process to consider questions such as "What does our graph not say?" or "What don't we know from our graph?" One second-grade child wanted to poll his classmates about their favorite sport. He designed his survey as a list of four choices: football, hockey, basketball, or soccer. However, as he surveyed various children, a few objected to this restricted list because they liked gymnastics or skating best. He decided to group these responses in a category of "other." Later, when he shared his graph with the class, children objected to this "other" category because it concealed the specifics of these other choices. For example they knew that the graph "didn't say" that everyone in the class favored team sports. The discussion highlighted the power that authors have in shaping their results and in implying their conclusions by the way they categorize and represent their data.

The second application of the Summary Scrutiny strategy entails examining how authors can choose visual displays to promote particular points of view. A discussion about the pictograph and pie chart of tiger species in Tiger Math provides an example. As described above, the pictograph, where one picture represented 500 tigers, did not show the South China tiger because there are so few of them in the wild. However, representing the data as percentages on a pie chart made it possible to include a small sliver representing this species. David asked the children to consider how people with different points of view might use these graphs to promote their causes, e.g. an environmentalist who wanted to convince lawmakers to protect South China tigers vs. loggers who wanted the habitat's resources to make a living. The loggers would probably choose the pictograph in order to avoid discussion about the South China's low population, while an environmentalist could use the pie chart to emphasize it. Imagining how different representations from the same set of data can provide alternative arguments helps to underscore the idea that any single representation is only a partial account.

After reading the entire book to the children, we asked them to re-represent the information in different ways (Visual Re-View). One girl used additional information she had researched on the Internet about the South China tiger's changes in population over time. The visual impact of this new graph helped her to make an even stronger case about that species' perilous condition. She drew on her graph a line that plummeted from an estimated 200 tigers in 1980, to 40 in 2000, and to 30 in 2008. In her narrative report she noted these statistics, as well as further information from the 1950's when the population was roughly 4,000. (The range of 30 – 4,000 was too difficult to represent on one graph). Her additional research, narrative summary, and graph showed how the element of time can impact how data get interpreted. By representing data as far back as 1950 she was able to render a longitudinal perspective and thereby emphasize more dramatically the precipitous decline in the population of South China tigers. In this way she was able to present an even stronger environmental argument for the tiger's preservation.

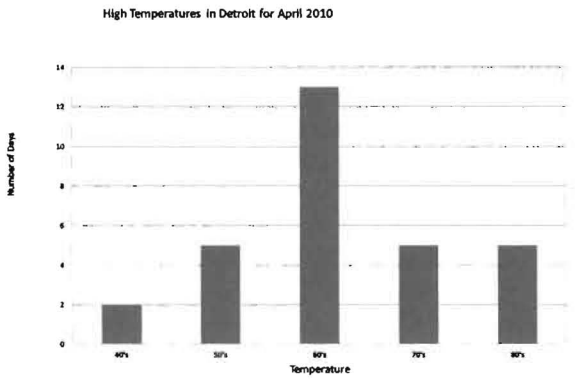
Figure 4: Line Graph of Temperatures



A third way to practice the Summary Scrutiny strategy is to ask children to create contrasting headlines to accompany two different graphs for the same data set (Visual Re-View). Since headlines are condensed to capture the essence of a text,

they highlight language choices. Pairing Summary Scrutiny and Visual Re-View is a particularly beneficial way to highlight how modes of representation work together to intensify meaning (Janks, 2010), e.g. visual displays of data and the language that describes them.

Figure 5: Bar Graph of Temperatures



The common practice in elementary classrooms to record the daily temperature provides an example to illustrate these paired strategies in use. Data from one month can be represented as both line graph and bar graphs, as illustrated by temperatures in Detroit for April 2010 (Figures 4 and 5). The line graph shows data over time; in this case conveying the temperature fluctuations throughout the month. On the other hand, by grouping together categories of data, the bar graph draws attention to the high number of days in the 60's. This 60's bar suggests words such as "spring-like" or "moderate." A Michigan tourism bureau might therefore choose the bar graph to entice visitors to the state by exclaiming, "Moderate April Weather in Michigan Beckons Visitors." In contrast a competing agency from another state might discourage Michigan travel by focusing on the fluctuations of the line graph. In this way they could choose words such as "unpredictable", or "fickle" e.g., "Unpredictable Weather in Michigan Limits Tourists' Activities." Exercises such as these help readers to understand how authors can make choices about multimodal representations that enable them to position audiences to think in certain ways.

Final Thoughts

Critical literacy involves critiquing texts in all their multi modal aspects. Data texts are one example of a multimodal text that has infiltrated every part of our dally lives. We have argued that principles of critical literacy practice can inform this critique of data texts. At the same time the stories and strategies presented in this article underscore the potential power that critical numeracy has within the dimensions of critical literacy practice. By including numeracy under the umbrella of critical literacy we can begin to break down the myth of data being both unquestioned truths as well as value-free creations. This relationship between numeracy and critical literacy broadens our perspective so that we see numerical information as a human construct, just like verbal, visual and other forms of expression. Furthermore, the construction of numerical data is motivated from the very beginning. This understanding helps to highlight the importance of supporting children to critique their own data texts as well as the texts of others. In this way they begin to assume the role of critics who are both readers and composers.

Finally, another key benefit of making this link between numeracy and critical literacy is the recognition that its application cuts across all content areas, such as science, social studies and health. By sanctioning numeracy's rightful place in critical literacy practice we broaden the spotlight for our critical gaze and more fully recognize that the interrogation of data texts is everyone's business.

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