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Building Basic Statistical Literacy With U.S. Census Data

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The world is filled with information delivered through graphical representations—everything from voting trends to economic projections to health statistics. Whether comparing incomes of individuals by their level of education, tracking the rise and fall of state populations, or researching home ownership in different geographical areas, basic U.S. Census data can provide a starting point for children to pose a range of interesting questions.

As we learn about the 2010 Census, we can invite our students to ask questions about the information that is collected (See "Ten Census Questions," page 6): How were these data collected? What does it mean to have an average family size of 2.35 people? Why is the median used to summarize some data and the mean used to summarize other data?

The renowned author of books on effective graphs and other displays of data, Yale Professor Edward R. Tufte, describes "how seeing turns into showing, how empirical observations turn into explanations and evidence."[1] Children can manipulate information in graphs and charts to present evidence in meaningful ways. We can help them begin to analyze a visual display and make generalizations from the data it shows.

Charts and Graphs

Students in pre-K through grade 8 should have experiences with the basic concepts of statistics throughout their school years.[2] From pre-K through grade 2, children can learn how to sort objects by their attributes and display information that they have collected in a variety of graphic forms.

In grades 3-6, students should have experience asking their own questions and seeking answers within data. They should be able to represent data in forms such as frequency tables, bar graphs, circle graphs, and picture graphs.

We've summarized curriculum standards from statistics, mathematics, and geography in **TABLE 1,** page 8. We hope this "crosswalk comparison" suggests how teachers can integrate related disciplines in meaningful and creative ways.

Multiple Representations

The graph is a tool of communication. It can tell a story about the data, bringing important things to light that we might otherwise miss just looking at a list of numbers. Children can see how graphs (and charts) share information with the reader. We can help students recognize that different representations might tell different stories about the very same data.

Engaging students in construction of multiple representations of the same data is a way for them to discover how to share information in a variety of ways depending on the question. The true value of having children construct their own graphs is not so much in the technique, but rather in their experiencing first-hand how a graph contains information that can help us answer questions and make important decisions.

Taking Time to Ask

Some teachers might mistakenly end a lesson at the point when students complete a graph, and thus miss an interesting discussion. Ask the class, "What does this graph reveal that a collection of numbers might not?" A visual display can reveal a trend or a pattern that is not obvious from looking at numbers alone. (And a bad display can hide important facts!)

You might also ask your students, "What does the graph 'say' to you and to others?" This question naturally leads to an exploration of who would want to know this information, what it might be used for, and what is the best way to share it.

The activity described below goes beyond drawing a graph, as it requires students to interpret what the graph might be "telling" them. Building on educational standards, we have students use census data to formulate some questions about an authentic data set; analyze the data in multiple graphic

representations; and interpret the results. We've led this activity with students in the fourth and fifth grades in an urban setting.

The use of the multiple data representations should be explored with children over several days of investigations. This is a rich educational activity, so don't rush it.

Collecting and Depicting Data

Students first looked at a 1990 U.S. Census choropleth map on which different shades of a color indicate various population sizes[3] Then we asked students, working individually, to create their own choropleth maps of more recent (2000) Census data for each state,[4] using the same color key as the 1990 map.

Students observed that California, Florida, and Texas were among the most populated states, and therefore darkest in color on the map. Students suggested that a state's location, in addition to its physical size, could be a reason for its large population. The students identified severely cold temperatures as the reason why Alaska and Montana, while both large in land area, were sparsely populated. They had some initial difficulty reasoning why Kentucky and West Virginia, which are neighboring states, have drastically different populations. With some guiding questions, students finally determined that the mountainous terrain through much of West Virginia would affect that region's population.

This analysis of the colorful map piqued student interest in the nation's population distribution, setting the stage for the next portion of the activity.

Fifty Line Segments

On another day, we grouped students randomly into five teams and gave them a new task: to compile and organize population data for five geographical regions of the country (Northeast, Southeast, Midwest, Mountain, and Western/Pacific). These regions included all 50 states in the union.

Each team divided the states within its region among the team members, so that each student could focus on data for only one or two states. Each student then examined the Census table again to obtain data for his or her state(s).

Using a process developed by Charles Lovitt and Doug Clarke, the students marked paper strips to indicate a state's population, as summarized here.[5]

We gave each student a paper strip imprinted with a 20-centimeter ruler, on which he or she would draw a line segment representing the population of an assigned state. We asked that each state within a region be represented by a different color.

Students used a scale of one centimeter equals one million people, and indicated the population of the various states to

Table 1. Learning to Reason with Visual Displays of Data

We hope this "crosswalk comparison" suggests how teachers can integrate related disciplines in meaningful and creative ways, and meet multiple curriculum standards (in statistics, math, and geography) within a single rich teaching activity that uses Census data. The statements below are paraphrased from the various sources listed in the key, below.

I. Formulate Questions
- Clarify the problem at hand:
  - Formulate one (or more) questions that can be answered with data. (STAT)
- Ask geographic questions:
  - Use teacher-developed questions to collect data. Grade K. (GEO)

II. Collect Data
- Acquire geographic information:
  - Design a plan to collect appropriate data.
  - Employ the plan to collect the data. (GEO)
- Collect data and count to answer questions. Grade K.
- Organize geographic information:
  - Represent data in pictures and bar graphs. Grade 1.
  - Represent data in stem-and-leaf plots. Grade 4 (MATH)

III. Analyze Data
- Select appropriate graphical and numerical methods:
  - Use these methods to analyze the data. (STAT)
- Analyze Data:
  - Learn the foundation of data analysis by sorting or comparing by attributes. PreK.
  - Count and compare data. Grade 1.
- Construct and analyze frequency tables, bar graphs, picture graphs, line plots and stem and leaf plots (grade 4) to solve problems. Grades 3-4.
- Construct and analyze double-bar and line graphs. Grade 5. (MATH)

IV. Interpret Results
- Interpret the analysis:
  - Relate the interpretation to the original question. (STAT)
- Answer geographic questions. (GEO)
- Interpret the information collected (assumed through other statements). Grades K-8. (MATH)

KEY

STAT: Christine Franklin, G. Kader, D. Mewborn, J. Moreno, R. Peck, M. Perry, and R. Scheaffer, *Guidelines for Assessment and Instruction in Statistics Education* (GAISE) report, (Alexandria, VA: American Statistical Association, 2005). Statistical literacy is also supported by the Essential Skills for Social Studies as described on page 148–149 in National Council for the Social Studies, *Expectations of Excellence: Curriculum Standards for Social Studies* (Washington, DC: NCSS, 1994).

GEO: National Geographic Society, *Geography for Life: National Geography Standards* , (Washington, DC: National Geographic Society, 1994); National Council for the Social Studies, *Expectations of Excellence: Curriculum Standards for Social Studies* (Washington, DC: NCSS, 1994).

MATH: National Council of Teachers of Mathematics, *Curriculum Focal Points for PreK-8 Mathematics: A Quest for Coherence* (Reston, VA: National Council for the Teaching of Mathematics, 2006).

the nearest 100,000 people, that is, to the nearest millimeter. (**PHOTO 1**)

1. Students depicting state population data on centimeter strips.

In the space to the left of a line segment, we asked students to write the name of the state and the actual population number along side the line. Some larger states required students to tape two blank strips together to create space for their line segment.

Making a Bar Graph

On the next day, students used scissors to cut away extra paper beyond the end of any line segment. Students took these multi-colored strips and placed each end on a base line (representing zero population) to create a bar graph comparing the populations of five regions of the country (**PHOTO 2**).

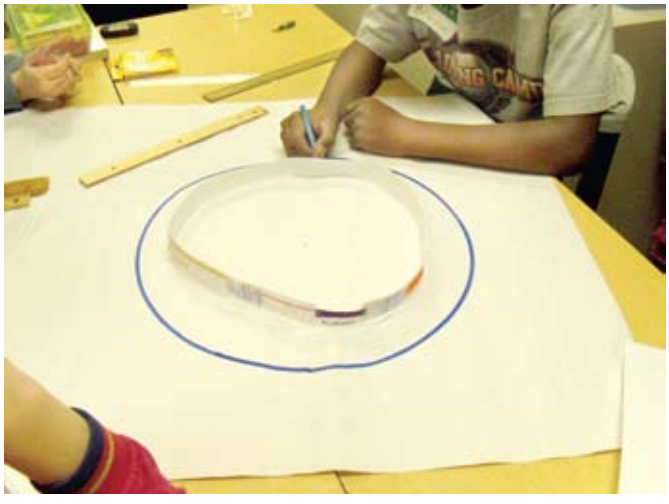
2. Representing regional data in a bar graph.

At this point, we invited students to enjoy a "gallery walk" around the room, to view the other groups' data displays. In the class discussion which followed, students made some observations about the data.[6] For example, students noted the extreme cases, naming the region (and individual state) with the largest population, and with the smallest. They also remarked on how states with populations of less than one million were represented by stubby strips of paper on which the lowest number, "1" (representing 1 million people) was cut off! Students were interested to see that there were great differences in the "shape of the data."

Composing a Circle Graph

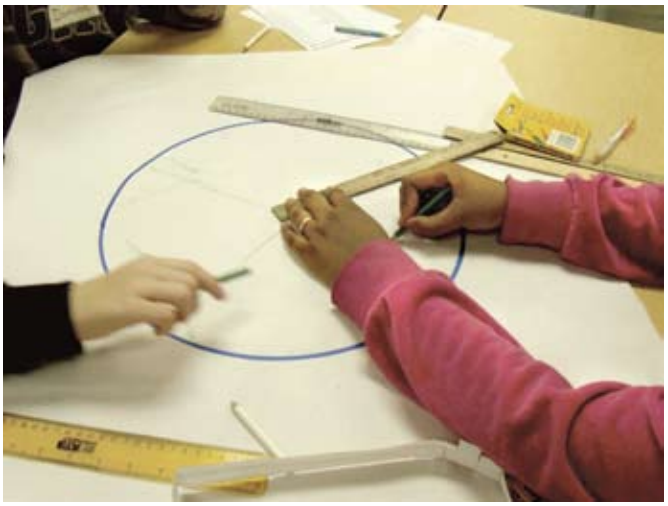
When students next arrived in the classroom, each team "lined up" its "state segments," end to end, and then taped the segments together. Now each team had a single long line that represented the population of one region of the country. The viewer could still distinguish the differently colored individual state data within each line. Adding the state populations together provided the numerical total for that region.

We had each group tape its colored line from beginning to end, thus making a paper loop. Students placed this loop on a large piece of paper, inside a pre-drawn circle. Then they transferred the end points of each line segment onto the circumference of the larger circle as tick marks. (**PHOTO 3**)



3. Transforming the population data from a collection of line segments into a single circle.

Using a straightedge, the students drew lines from the tick marks on the circumference to the circle's center point, (**PHOTO 4**) creating sectors representing each state in the region. Then students labeled each sector of their new circle graph with the name of the state in colored crayons.



4. Connecting lines and coloring sectors of the circle graph.

Students had now represented the same data in at least four different ways. They had created a choropleth map, written a number, created a bar graph, and transformed that bar graph into a circle graph. In doing so, students began to notice relationships in one format that had not been immediately evident in another. As one boy was coloring, he observed that the population of Texas was about half the population of the Midwest region, as represented by that sector of the circle.

Beads and Percentages

On another day, we gave a necklace made from 100 beads to each group. We demonstrated how to place the necklace onto the circle graph to make two concentric circles—one of beads and one drawn on paper (**PHOTO 5**).

5. Using a 100-bead necklace to estimate population percentages

If the circle made by the necklace had a circumference smaller than the paper circle, then it was ready to be used for the next step. If the necklace made a larger concentric circle, then we asked students to use the straight edge to continue each radius out to the larger circumference.

In either case, we used bits of masking tape to mark each bead that intersected with a radius of the circle. Then the beaded circle acted as a calculator of percent. For example, a sector with an arc of 12 beads constituted 12 percent of the circle's total area.

Counting beads on a necklace of 100 beads is a concrete visualization of the concept of "percent." You can have some fun with this idea. If 100 students hold hands in a circle on the playground, they might act as a "human percentage calculator!"

Interpreting the Data

To encourage students to communicate with each other about the data, we gave students blank paper "dialog bubbles" like those used in comic strips to capture the conversations of characters. We asked students to write in the bubble what a graph might be "saying." (**PHOTO 6**) Students worked with partners or individually to create statements about the data.

6. Analyzing a graph in order to complete a "dialog bubble."

Since this was an upper-grade class, we asked students to avoid repeating simple observations (such as which were the largest and smallest state populations). We asked them to compare, contrast, and combine information to learn more about the data.

We posted graphs at the front of the room, then read student-written bubbles aloud for the class and discussed some of them. Student responses follow. Percentages are approximate, and refer to regional populations.

- Florida is 15%, larger than Mississippi and bigger than Alabama.
- ME + DE + VT + DC + RI + NH = 9½ %, which is half a percent away from MD (9%).
- The largest state in the Midwest is Illinois but it is only 16% out of 100, so none of those states are that big.
- Florida is 25% of the Southern region and WV, MS, AR, LA and KY don't even add up to that. TN is 9% and VA is 9%!!
- I learned that California towers other states in the West Pacific Region.
- New York, with 35%, is larger than Pennsylvania and Massachusetts combined: 35% > 20% + 8%.
- Wyoming is the same as New Mexico.

These quotes reveal that some students can describe their mathematical reasoning quite well.

Asking about Causation

The next steps involved making broader generalizations. Students noticed that the geographic size of a state and the state's population did not always correspond. One student team wrote on their bubble, "Texas is bigger than Arizona, Wyoming, Oklahoma, Utah, Montana, Colorado, and more because Texas has a big wider place for people to live in." Another student wrote, "The populations of Montana and Wyoming are small because it is cold."

Students voiced new considerations. "I noticed that on my circle graph California was bigger than Washington, Oregon, Nevada, Hawaii, Idaho, and Alaska put together." This raised the question as to what might make California such a popular place to live.

Another student made a similar statement, "California has 33,900,000 and Alaska has 600,000. I think Alaska has the least [population] because it is cold."

This is an example of how the students were beginning to speculate about the reasons for variations in population distribution.

Conclusion

The integration of mathematics and social studies in lessons at the elementary level remains an important way to complement the two disciplines and develop broader life skills in young children.

In these activities, students generated multiple representations of the data. They created choropleth maps, bar graphs, numbers (actual population counts), circle graphs, and percentages. By looking at the same state data in each representation, they could experience the consistency of the data. By manipulating the data into different displays, they could begin to see some of the strengths and weaknesses of each form.

Creating, analyzing, and critiquing graphs and charts—these are all critical problem-solving skills. Citizens need the ability to make sense of numerical data. Especially when the numbers are about you and me.

Notes

1. Edward Tufte, *Beautiful Evidence*, (Cheshire, CT: Graphics Press, 2006), 9.
2. National Council of Teachers of Mathematics, *Curriculum Focal Points for PreK-8 Mathematics: A Quest for Coherence* (Reston, VA: NCTM, 2006); Christine Franklin, G. Kader, D. Mewborn, J. Moreno, R. Peck, M. Perry, and R. Scheaffer, *Guidelines for Assessment and Instruction in Statistics Education* (GAISE) report, (Alexandria, VA: American Statistical Association, 2005); National Geographic Society, *Geography for Life: National Geography Standards*, (Washington, D.C.: National Geographic Society, 1994); Statistical and geographic literacy are also supported by the Essential Skills for Social Studies as described on page 148–149 National Council for the Social Studies, *Expectations of Excellence: Curriculum Standards for Social Studies* (Washington, DC: NCSS, 1994).
3. A 1990 Census map is at www.census.gov/dmd/www/pdf/k4cmap.pdf. In a "choropleth map," areas are shaded or patterned in proportion to the measurement of a statistical variable, such as population density or per-capita income.
4. A 2000 Census chart, www.census.gov/population/ cen2000/tab05.txt.
5. Charles Lovitt and Douglas Clarke, *The Mathematics Curriculum and Teaching Program: Activity Bank Number One*, (Canberra, Australia: Curriculum Development Centre, 1988).
6. A gallery walk is a strategy that requires students to quietly walk around the room examining work by other groups.

Acknowledgement

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Related Resources

If America Were a Village, by David J. Smith and illustrated by Shelagh Armstrong. Towanda, NY: Kids Can Press, 2009.
Created by the same team who crafted *If the World Were a Village*, this book collapses the U.S population into proportionate village of 100 people, resulting in easily comprehended percentages, fractions, and circle graphs. The authors then provide an array of interesting U.S. Census data.

It's About Us: 2010 Census in Schools
www.scholastic.com/census/ and **www.census.gov/schools**.
These U.S. Census Bureau and Scholastic-sponsored websites link to geographic-specific information, a variety of teacher resources (including lesson plans), and interactive student activities.

Assessing and Investigating Population Data - NCTM Illuminations
illuminations.nctm.org/LessonDetail.aspx?ID=L239.
One of many lessons from the National Council of Teachers of Mathematics. In this examination of a U.S. Census website, data from 1995 is projected to the year 2025. A set of guided questions helps spark a discussion of how one might investigate demographic data from the 50 states.

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