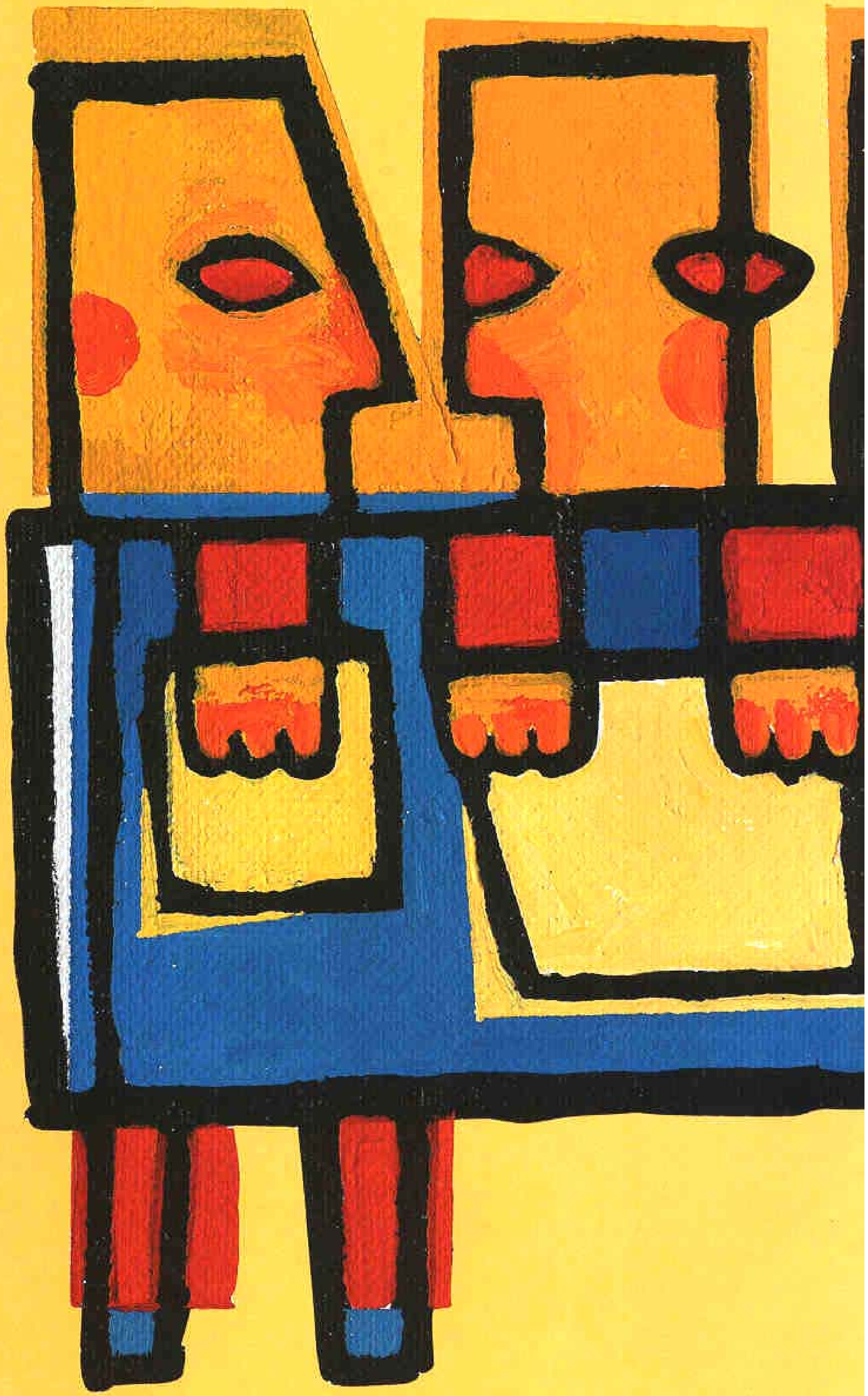
Engaging Students



Network science projects are one of the Internet's more interesting educational uses. Using inquiry approaches to learning science, these online projects link distant classrooms so they can pool locally collected data for analysis. In *Global Lab: An Integrated Science Course* (TERC, 2000), for example, students from all over the world collect and submit data on light intensity and sun angle they have collected at solar noon on the autumn equinox. Then they explore the complete data set for significant relationships. The hope is that, much like collaborating scientists, the students will share their data, hypotheses, and interpretations with one another.

As we reported in part 2 of this series (Coulter, Konold, & Feldman, 2000), our study of classrooms participating in network science projects yielded little evidence of Internet use to engage in

By Cliff Konold, Bob Coulter, and Alan Feldman

Subject: Data analysis, science, math, social studies

Audience: Teachers, teacher educators

Grade Level: K–12 (Ages 5–18)

Technology: Internet/Web, e-mail, word processing software, data tools

Standards: *NETS•S* 3–6. *NETS•T* II–III. (Read more about the NETS Project at www.iste.org—select Standards Projects.)

with Data

substantive science discussions. Similarly, although we found students eagerly collect and upload data for others to analyze, they seldom downloaded data from other classrooms or attempted to analyze data they collected. Why is this? And what steps can a teacher take to move students beyond merely collecting and uploading data to actually working with data from many sites?

Shortages of Time, Skills, and Motivation

Goodman Research Group (1998) interviewed teachers participating in a range of network science projects. One reason these teachers gave for not getting to data analysis was time constraints. Another is that their students have little experience analyzing data and don't quite know where to begin. The teachers also were not shy about pointing out their own limitations: "Interpreting data is a problem area for me" (p. 31). Indeed, the majority of them, just as those described 10 years ago by Russell (1990), said they needed more help with teaching data analysis.

Lack of time and skills are certainly understandable reasons for not downloading and analyzing data. However, we believe these problems are symptoms of an even deeper one—a lack of appetite for data. People analyze data when they have a problem they need to solve or a question that begs to be answered, but the teachers and students we have observed typically lack a compelling reason to look at data. Without such motivations, analyzing data is simply a chore.

Here we offer several suggestions for how teachers can draw students into data analysis and keep them engaged. Because these ideas are rooted in our vision of investigative learning—what motivates it and how it proceeds—we must first look more closely at what is involved in a data-centered investigation. You can find more extensive discussions of technology-supported inquiry in the first two articles in this series (Coulter, Feldman, & Konold, 2000; Coulter, Konold, & Feldman, 2000).

Data Analysis as a Dialogue

Let's think of data analysis as a four-stage conversation:

1. ask a question,
2. collect data,
3. analyze the data, and
4. form and communicate conclusions.

It makes sense to list the stages in this order because this is more or less the sequence in which a research investigation proceeds. After all, it would be hard to analyze data before collecting them or to form conclusions before doing any analyses. Good research, however, seldom proceeds in this orderly fashion. Quite often, looking at data raises new questions that must be addressed before any conclusions can be drawn. So conscientious researchers often go back—to examine the data (while writing the report, they think of another analysis to do) and to the study site (while performing the additional analysis, they decide they need more data).

Ultimately, good research does not proceed linearly because these four phases (question formation, data collection, data analysis, and conclusions) are highly interdependent. Even before researchers collect data, they imagine how the analysis will proceed and make guesses (hypotheses) about what they will find. They refine their questions and collection procedures by thinking ahead to how they will analyze the data. Experienced researchers also look backwards. When it's time to analyze the data, they do so from the perspective of their original question, testing the intuitions they started with against what the data reveal. Their questions often evolve and change as they discover unanticipated results.

In these respects, data analysis becomes a give-and-take conversation between the hunches researchers have and what the data indicate about those hunches. What researchers find in the data changes their initial understanding, which changes how they look at data, which changes their understanding, and so on.

A data investigation by Zach and Paul, two fourth-grade students working collaboratively, shows how questions guide the exploration of data and how the questions are modified as a result of those explorations. Their teacher, Bob Coulter, wrote the account below. This investigation is one of several projects that grew out of the eagle studies discussed in October's article (Coulter, Konold, & Feldman, 2000).

In this example, we see how data analysis followed a question the students cared about ("Is there a difference between eastern and western eagles' migrations?") and how that question changed as a result of what they observed ("Why are the western eagles farther north?"). New questions prompted

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The students' first task was to generate a question they could pursue. After exploring a number of possibilities, Zach and Paul chose to investigate the migration of bald eagles in North America.

In the spring of 1998, Journey North (www.learner.org/jnorth) tracked three eastern and four western bald eagles. By accessing weekly updates of their positions online, and downloading this information into NGS Works, Zach and Paul were able to study the movement of individual eagles from late March through mid-May as they moved north from wintering grounds to their spring nesting sites. Because of time limitations, I encouraged the students to focus their attention on only two of the eagles. They selected eagles #5 on the West Coast and #F42 on the East Coast. With my assistance, they narrowed their question to see if there were any differences in the migration behavior of the eastern and western eagles.

Early in the project, Zach and Paul made weekly maps in NGS Works showing the location of each eagle. These locations shifted a bit from week to week but typically showed each eagle nesting in one general location. The students noticed a significant difference, however, by visually comparing latitudes on the map they had made—the western eagle seemed to be nesting farther north than the eastern eagle. To see whether this observation held for the other five eagles tracked by Journey North, I suggested they consult the data tables on that site, which listed the weekly latitude and longitude coordinates of each eagle. They confirmed by comparing the latitudes that all of the western eagles were wintering farther north than the eastern eagles.

I challenged the students to explain this observation. After some consideration, they mentioned possible differences in habitat and weather. Because information on habitat was not readily available, I encouraged them to explore possible differences in weather between the eastern and western coastlines. They quickly asserted that the West Coast was warmer than the East Coast. In making this argument, they referred to maps from Journey North of the past two years, tracking the blooming of red emperor tulip bulbs. Zach and Paul participated in this project last year, and students in other classes were continuing this study by comparing last year's results with this year's data. The maps showed the dates on which tulips bloomed in the spring for 1997 and 1998 for participating classrooms all over the United States. They chose a few sites on each coast and verified that tulips on the West Coast tended to bloom earlier than those at the same latitude on the East Coast.

I challenged them to verify that the temperatures differed along the two coasts. To pursue this question, I helped them locate climatological data in almanacs and online data through AccuWeather (www.accuweather.com). By comparing data for New York City and Seattle, the closest major cities to the eagle locations, they were able to verify that, at least in this case, the West Coast city was warmer during some winter months than its East Coast counterpart, despite its higher latitude (Table 1).

Zach and Paul continued tracking their two eagles. As the spring progressed, the western eagle left its wintering grounds earlier and travthem to look at the same data differently and to search out additional data. Left to their own devices, these students may have become overwhelmed or wandered off track. Offering effective assistance, however, requires walking a fine line. If the teacher gets too involved in telling students how to manipulate the data, the students can easily lose sight of the big picture and their motivation for looking at data. As one elementary teacher expressed it, the challenge for teachers is to "help students keep hold of the big picture as they explore the parts" (Russell, Schifter, & Bastable, in press).

To accomplish this, Coulter provides a structure for his students to take on a complex task that would otherwise be beyond their abilities. He does this by assisting them where they need help while allowing them to do what they are capable of doing. We see Coulter:

- helping his students select and refine appropriate questions but not giving them the questions,
- prompting them to generate explanations for what they observe but not explaining the data for them, and
- pointing them to other data sources to test their explanations but letting them analyze those data to draw their own conclusions.

Table 1. Average high and low temperatures for Seattle and New York City, January–April, 1998.

Month	*Seattle high/low*	*NYC high/low*
January	45/36	37/24
February	48/37	38/24
March	52/39	45/30
April	58/43	57/42

eled farther north than did the eastern eagle. This time without assistance, the students checked to see if this same pattern was true for the other eagles tracked by Journey North, and in general, it was.

Seeing from their data that these were general behavior trends and not just an aberration, Zach and Paul concluded that western eagles wintered farther north, left their wintering grounds a few weeks earlier, and that they headed farther north in the spring than eastern eagles. Based on their background reading about eagles, they speculated that this pattern was largely because of differences in weather, which they thought might affect food availability, especially if northern lakes were frozen.

Leading Data-Rich Investigations

Several other factors contributed to Zach and Paul's success. The project probably would have ground to a halt if the students needed data that were hard to get, if they had been using unfamiliar types of maps or graphs, or if they had not found recognizable patterns in the data. This project worked in part because, when the students needed them, the data were available, comprehensible, and contained some interesting trends. Let's look more closely at these and similar issues that teachers (and curriculum developers) should consider in the design and management of data-rich investigations.

Use Reliable Data. Many projects, unlike Zach and Paul's, make use of data collected locally by fellow students. One advantage of using these data is that the students know quite a bit about them from the collection process even before they begin analysis. The major drawback, however, is that such data can be riddled with errors, thereby undermining students' confidence in the data and their ability to make sense of them. Although having students search for and remove errant values can be valuable, the number of errors in student-collected data sets can be overwhelming. This can inhibit the investigation's flow and require considerable time and skill to detect.

When your class participates in a data-sharing activity, there should be an agreement that each class will carefully check for accuracy before submitting their data. Sponsoring organizations should conduct their own checks before making data widely available to classrooms.

Begin with Familiar Contexts. If analysis is a dialogue between hunches and data, then analyzing data about novel phenomena is like conversing in a foreign language: The more remote the data are from our experience, the slower the conversation. In selecting data for educational use, we need to take into account how much students already know about a topic. The fourth graders easily handled the eagle data when it was presented as locations on a map. With the data in this form, students noticed that one eagle was farther north than the other. Had they been looking only at the latitude and longitude coordinates posted as a table on the Journey North site, or if the points represented locations in a foreign country, this difference and its significance may have escaped their notice.

Several elementary science curricula have students measure pH levels of local streams. If the idea of acidity was not itself a reach, then the logarithmic scale on which it is measured would certainly place it on a high shelf. Yet the curriculum instructs students to calculate arithmetic means of multiple water samples, an activity that takes them into yet a higher realm of abstraction. Data like these can prevent even highly motivated students from engaging in thoughtful analysis.

Use Data with Salient Trends. Real data analysis is a bit like prospecting for gold—for every nugget found there is a small mountain of sifted refuse. There-

More on Science and the Internet

This article is the third of four based on *Network Science, A Decade Later: The Internet and Classroom Learning* (Feldman, Konold, & Coulter, 2000). The authors' research focused on science curricula that use online communities and shared sets of data to support students learning science. Funded under grants from the National Science Foundation (RED-9454704, RED-9155743, and REC-9725228), their research examined the goals of these curricula and the actual experiences of teachers and students. Rather than seeing the Internet as a certain road to educational reform, the authors found that the Internet's greatest effects are felt in classes where teachers and students are already engaged in inquiry-based methods of teaching and learning. For more information about the book, see **http://teaparty.terc.edu/book**.

fore, we should not send students into unknown data-analysis terrain with the promise of rich returns. Data we provide or help them collect should include salient trends and differences. Coulter anticipated different migratory patterns of the western and eastern eagles when he encouraged his students to compare the two. Furthermore, it helps if students formulate expectations about what they might observe in their data analysis. Making predictions beforehand increases interest in seeing what the data really indicate and also serves to direct students' attention. During their investigation, Zach and Paul went to the Journey North Web site to compare the latitudes of the wintering sites of western and eastern eagles. These latitudes were only a few degrees different. Had they not expected to find higher latitudes for the western eagles, they may have never noticed the differences. When we look at data expecting to see nothing in particular, that's often just what we see.

Work with Representations Students Understand. Mapping and graphing data can be powerful ways to reveal patterns and trends. Ironically, the same properties that make many plots good for detecting patterns and trends make them difficult for novices to interpret. Roth and Bowen (1994) describe how, as we represent data with maps, lists, graphs, and finally equations, we move from more concrete to more abstract statistical representations. As we move along this "cascade of representations" (p. 300), individual data points disappear into larger aggregates. In a frequency histogram of height, for example, all individuals between 50 and 55 inches are represented in a single bar. This type of aggregation allows the expert to perceive more general features of the data, such as how the data are distributed and where they are centered. But this comes at the expense of being able to identify individual data values. Younger students have difficulty interpreting these plots, in large part because they can no longer locate individual observations in the graph (Bright & Friel, 1998).

In planning investigations for your students, keep in mind the sophistication required to interpret the more abstract statistical plots. Encourage your students to work with representations they already recognize. And, younger students can especially benefit from designing their own representations (Grant, 1999). Also, be sure that your students understand how the data are represented, and that they are thinking about the data as more than just numbers. For the eagle example, students will have difficulty interpreting the migration data if they can't read latitude and longitude grids.

More Support on the Way

Given the growing importance and widespread use of data in many fields and in everyday decision making, it's becoming more critical that our students learn how to reason with data. Fortunately, support is growing for doing data analysis in schools, much of it owing to the number of organizations now committed to getting data analysis into the precollege curriculum. The NCTM elevate data analysis to the same level as geometry and algebra in both their *Curriculum and Evaluation Standards* (1989) and their new *Principles and Standards for School Mathematics* (2000). Similarly, the *National Science Education Standards* (NRC, 1996) promote data analysis as an integral part of doing science. The *Geography for Life* standards (NGS, 1994) support the development of skills in analyzing geographic information. ISTE's *National Educational Technology Standards for Students* (ISTE NETS Project, 1998) call for students to "use technology to locate, evaluate, and collect information from a variety of sources" (p. 6). These recommendations are being repeated in state and local curriculum standards, and students' opportunities to work with real data are becoming more commonplace in many disciplines.

These and other developments suggest that in coming years there will be more support in curricula for doing data analysis, and most students we teach will already have some experience working with data. Yet teachers needn't wait to involve their students more with data. We have suggested a few things teachers should keep in mind as they support their students in data-rich activities. Two principles underscore these suggestions.

First, students should have a good reason to collect and analyze data: They should have a question *they* want to answer. Second, as the class proceeds through the phases of data collection, representation, and conclusion formation, the teacher should help students keep sight of what the data are and why they collected them. Nearly every problem we've observed with fostering data analysis and keeping students engaged ultimately stems from students losing the connection between the data they have and a real-world question they care about. Teachers can solve many of these problems by helping students make and maintain these connections.

Editor's note: In part 4 of this series, the authors will describe how schools and districts can support teachers as they integrate technology into teaching and learning practices.

Resources

NGS Works is available from the National Geographic Society. To receive a catalog, call 800.368.2728; or submit a request at http://ngsstore.nationalgeographic.com. Select "Free Educational Catalogs."

References

Bright, G. W., & Friel, S. N. (1998). Graphical representations: Helping students interpret data. In S. P. Lajoie (Ed.), *Reflections on statistics: Learning, teaching, and assessment in grades K–12* (pp. 63–88) Mahwah, NJ: Lawrence Erlbaum Associates.

Coulter, B., Feldman, A., & Konold, C. (2000). Rethinking online adventures. *Learning & Leading with Technology, 28*(1), 42–47.

Coulter, B., Konold, C., & Feldman, A. (2000). Promoting reflective discussions. *Learning & Leading with Technology, 28*(2), 44–49, 61.

Feldman, A., Konold, C., & Coulter, R., with Conroy, B., Hutchison, C., & London, N. (2000). *Network science, a decade later: The Internet and classroom learning.* Mahwah, NJ: Lawrence Erlbaum Associates.

Goodman Research Group, Inc. (1998). *An evaluation of the Testbed for Telecollaboration.* Cambridge, MA: Author.

Grant, C. M. (1999). Beyond tool training: Professional development for elementary math teachers. *Learning & Leading with Technology, 27*(3), 42–47.

ISTE NETS Project. (1998). *National educational technology standards for students.* Eugene, OR: ISTE.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

National Geographic Society. (1994). *Geography for life.* Washington, DC: Author.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

Roth, W. M., & Bowen, G. M. (1994). Mathematization of experience in a grade 8 open-inquiry environment: An introduction to the representational practices of science. *Journal of Research in Science Teaching, 31,* 293–318.

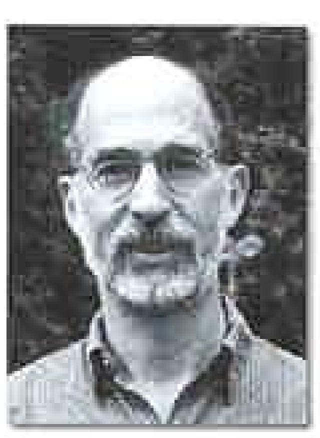
Russell, S. J. (1990). Issues in training teachers to teach statistics in the elementary school: A world of uncertainty. In A. Hawkins (Ed.), *Training teachers to teach statistics.* Proceedings of the International Statistical Institute Round Table Conference (pp. 59–71). Voorburg, The Netherlands: International Statistical Institute.

Russell, S. J., Schifter, D., & Bastable, V. (in press). *Developing mathematical ideas: Collecting, representing, and analyzing data.* Parsippany, NJ: Dale Seymour Publications.

TERC. (2000). *Global lab curriculum: An integrated science course.* Dubuque, IA: Kendall/Hunt Publishing.

Cliff Konold (konold@srri.umass.edu) is a research associate professor at the Scientific Reasoning Research Institute, University of Massachusetts, Amherst. His current research focuses on understanding and improving students' abilities to reason about data. With funding from the National Science Foundation, he is heading a team building data-analysis software for middle school students. The tool, Tinkerplots, is structured like a construction set, permitting students to create their own types of plots and analyses.

Bob Coulter (bob.coulter@mobot.org) is director of Mapping the Environment, a program at the Missouri Botanical Garden's Litzsinger Road Ecology Center that supports teachers' efforts to enhance their science curriculum through use of the Internet and geographic information systems (GIS) software. He is also president-elect of the Math Educators of Greater St. Louis. Previously, Bob taught elementary grades for 12 years.



Alan Feldman (Alan_Feldman@terc.edu), PhD, is a principal scientist and cluster leader at TERC. His work focuses on technology integration in K–12 schools and classrooms and exemplary teaching and learning practices. He has worked in schools with teachers and instructional technology specialists and led workshops for district and school leaders throughout the Northeast.